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Batteries & Energy Storage Technology

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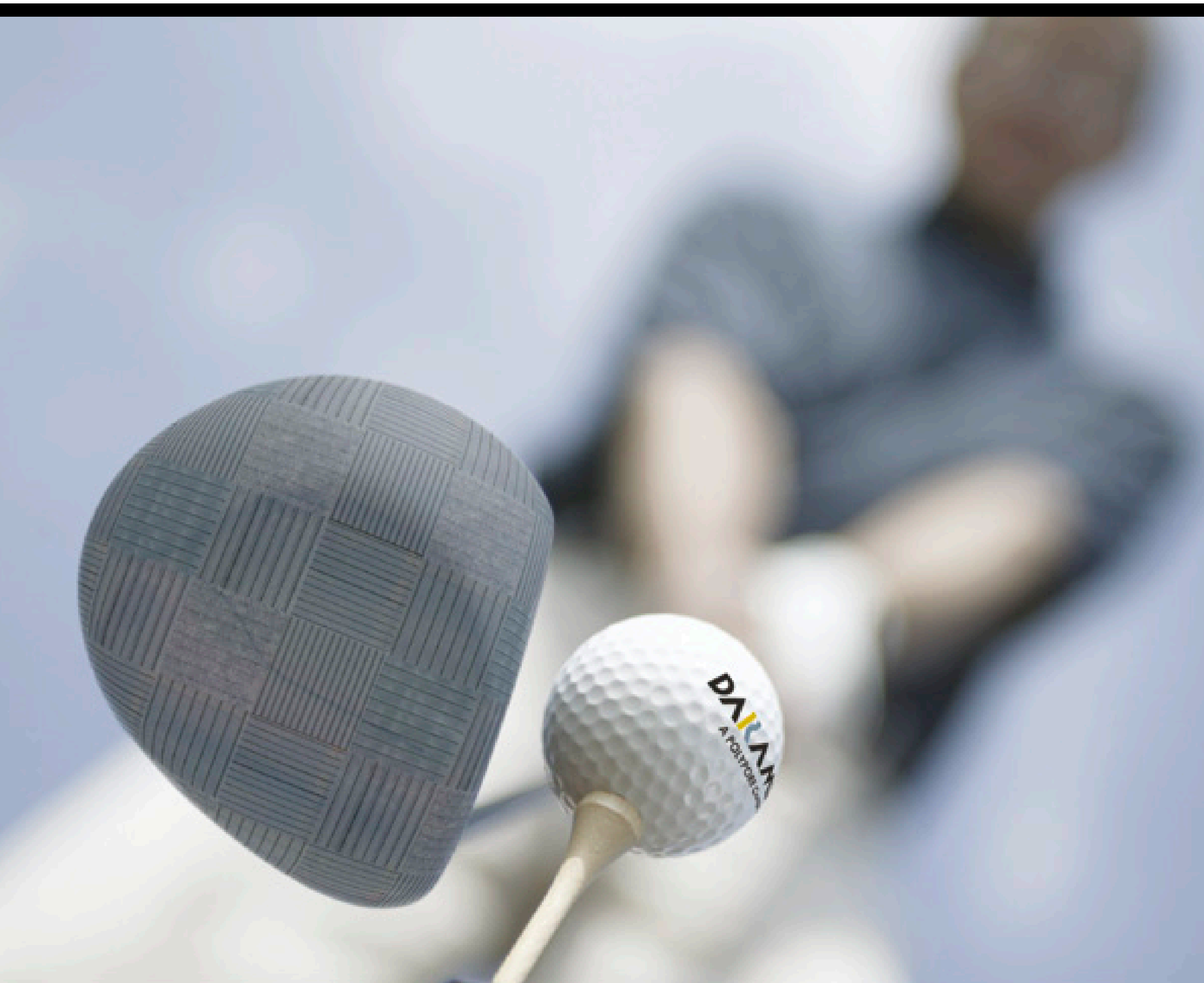

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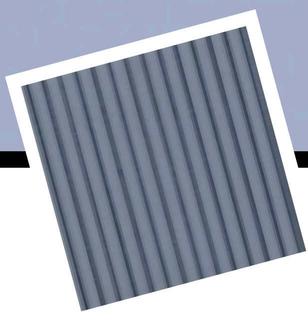

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Tim Probert
Editor

Time to give lead-acid a leg up?

In my first six months as Editor of Batteries & Energy Storage Technology magazine it has become abundantly clear that, in the lead-acid industry at least, conservatism is the watchword.

Given lead-acid batteries remain competent, consistent and cheap, who can blame them? Companies the world over are making a decent living from supplying equipment and components for the production and sale of, mostly, the good old SLI lead-acid battery.

Yet the relatively comfortable position of the lead-acid battery industry and the ‘lead is best, forget the rest’ type of refrains heard and read at certain conferences and publications has created an environment whereby companies have become extremely risk-averse.

The shedding of R&D teams and relentless cost-cutting to compete in the ‘down and dirty’ commodity market that is the lead-acid battery may be good for the bottom line, but, as we cover in this edition of BEST, has undermined the long-term future of the industry. Something needs to change.

Italian battery machinery maker Sovema knows this damn well. In many ways, Sovema personifies this dilemma. As my article (pg. 81) explains, here is a successful lead-acid battery company run by a guy soon to retire.

His forty-something successor knows the share of the battery pie for the humble 12V SLI battery will slowly shrink. But he also knows the size of battery pie overall will grow.

And most of all he knows it falls to him to transform his firm from an equipment maker for mostly SLI batteries to one that also supplies equipment for a different type of lead-acid battery, perhaps for energy storage and automotive, not to mention more lithium-ion.

But, as is repeated several times in this issue, no-one wants a battery alone. It has to be part of an integrated system, which places additional challenges on equipment makers.

Being able to adapt to future demands does require, as Sovema is doing, a beefing up of its R&D capability. And thankfully, due to schemes like the colossal, €80bn ($110bn) EU Horizon 2020 programme, there is funding help, even for lead-acid.

Of course, there are many pitfalls in trying to bring a ‘game-changing’ technology to market and I’d like to draw your attention to a barnstorming article (pg. 71) by Applied Intellectual Capital’s Steve Clarke on his ultimately unsuccessful efforts at Atraverda with Ebonex.

Elsewhere in this issue, we feature an exclusive interview with Enersys head honcho John Craig. While not keen on lithium-ion much beyond medical/aerospace applications, Craig knows there are great opportunities for other chemistries than lead-acid, and Enersys is working on nickel-zinc, which had even the great Thomas Edison flummoxed.

Whether it’s automotive or electrical energy storage, the opportunities (and sales) are plain for all to see.

Enjoy the issue.

Tim

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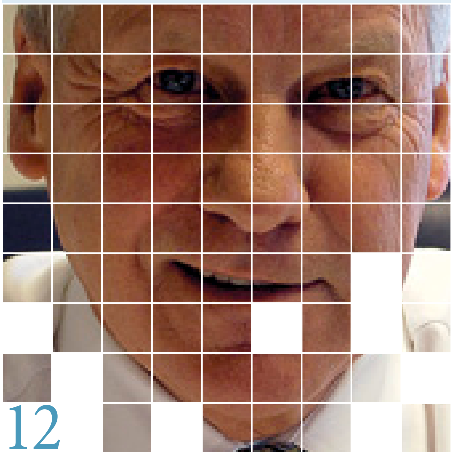

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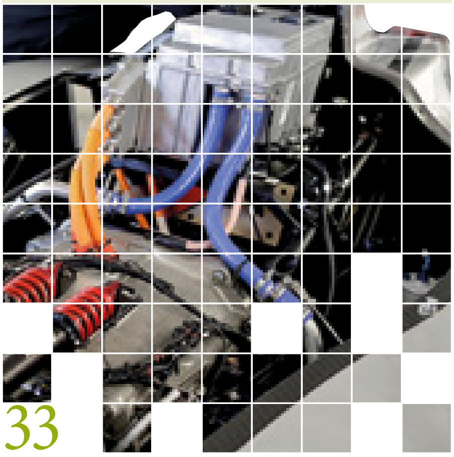

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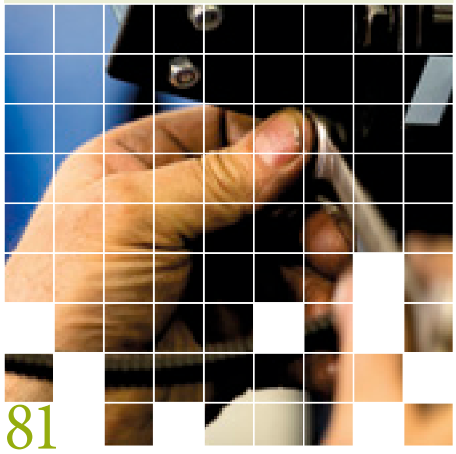

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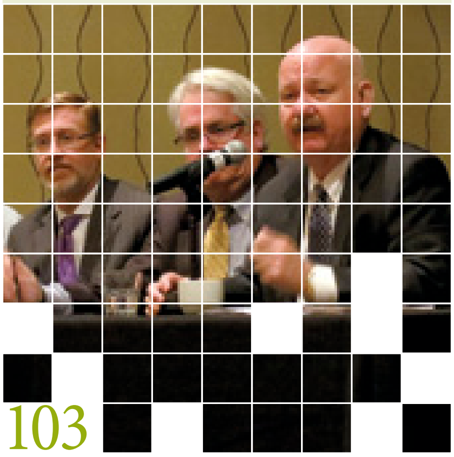

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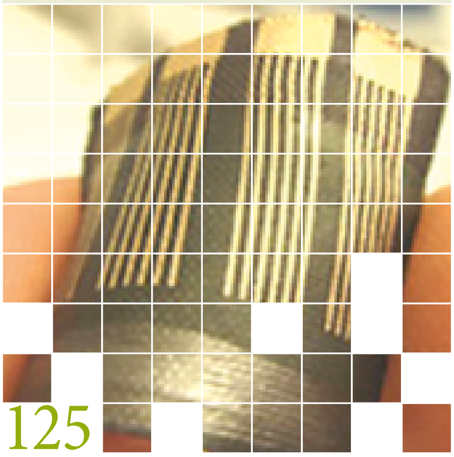

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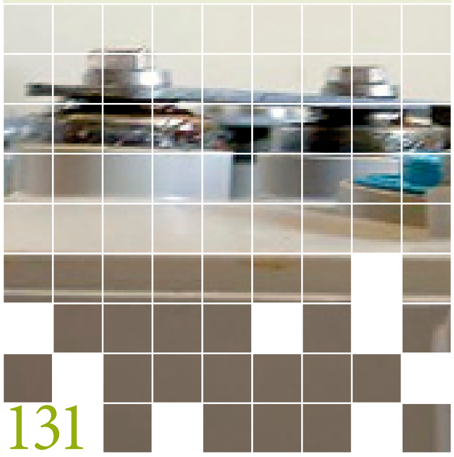

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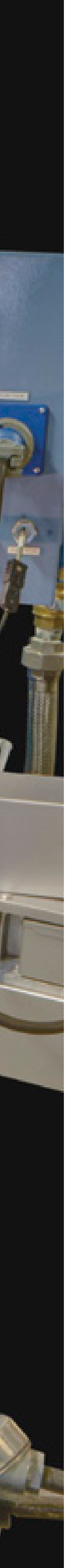

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Winning isn't everything

It seems a little odd that motorsport should move centre stage in public education about hybrid electric vehicles and energy storage, but this year, that's exactly what has happened in Formula One.

A little like soccer, or football to non-Americans, Formula One doesn't command the same interest or following in the USA as that of, say, Nascar. But maybe that will change.

As Ruth Williams explains in her article on page 43, motorsport has changed— roaring V12 engines have steadily shrunk to V10, V8 and now V6, with complicated rules for the vehicle design and race parameters to boot.

No longer mere 'engines', Formula One cars now officially feature a 'power unit', which combine a 1.6-litre turbo engine with two separate electric motors. The three engine manufacturers Ferrari, Mercedes and Renault have worked very hard to get these engines, batteries and motors working in unison together with the view that they will ultimately produce a similar amount of power.

This is all supposed to make Formula One more relevant to the mass-market vehicle industry and the cars that you drive on the road. But, at least in the short term, it has made the cars quite unreliable.

The cars are also now fitted with a 'brake-by-wire' system, which means the brake balance between the front and the rear is controlled electronically. This is because under deceleration, the electric motors become generators and this energy is then used when accelerating for more power. Getting the brake balance right is proving very tricky for the drivers and software engineers.

The other big change for 2014 is a fuel limit of 100kg (~130Litres, 35US or 29UK gallons) for the race from the start to the chequered flag. This represents a reduction of about 40% from what the teams used in the past, a huge amount. Race outcomes are going to be surprising.

Inaccurate fuel metering caused feathers to fly at the first of the season's races in Australia and this writer wonders whether the events really will do very much to improve the public's appreciation of battery and energy storage technology.

Probably not. If Silverstone is anything to go by, by the time you've reached the public car parks and started to make your way home, the battery in your cellphone will be too discharged for you to tell your family and friends that you're on you way home. Something that's likely to increase one's disdain for electrochemistry even more.

Gerry Woolf - Publisher

Let's hear from you

Got an opinion on the above or anything else? Then share it. If it's battery standards or the answer to the ultimate question in the universe, BEST's readers would like to know.

Contact: tim@energystoragepublishing.com

Exide in grid-tied multi-tech battery energy storage system

A consortium consisting of Exide, Beta-Motion, RWTH Aachen University, E.ON and SMA Solar have joined forces to create the world's first modular large-scale 5MW battery storage system in Germany.

The Modular Multimegawatt, Multitechnology Medium-Voltage Battery Storage System (M5BAT), is being co-ordinated by the E.ON Energy Research Center at RWTH Aachen University in Germany.

M5BAT uses a combination of five battery types: two Beta-Motion lithium-ion batteries (1.25MW/0.75MWh, 1.25MW/0.7MW), a 1.25MW/1.25MWh Exide VRLA and 1.25MW/1.25MWh Exide CSM flooded battery; and a 0.5MW/1MWh sodium nickel chloride.

The project has received €6.5m ($9m) in funding from the German Federal Ministry for Economic Affairs and Energy. Planning begins in July, with construction a year later. The project will then run for two years until June 2017.

The system will be connected to the local medium voltage grid via SMA Solar inverters. The consortium will test operations in different applications and E.ON will participate in energy trading.

Leonhard Birnbaum, member of the E.ON Board of Management, said: "Due to the conversion to renewable energy sources in Germany, smart grids and large-scale energy storage technologies are getting ever more important. Battery storage systems are particularly interesting because, unlike compressed-air or pump storage power stations, they neither require special geographical conditions nor long planning cycles."

NEC acquires A123 Energy Solutions

Just when you thought all the acquisitions and buyouts of A123 were old news, Japan's NEC Corporation has acquired A123 Energy Solutions from Wanxiang Group for around $100m.

The acquisition relates to the portion of former A123 Systems that supplies grid-level lithium-ion energy storage systems based on A123's lithium iron nanophospate technology.

A123 Energy Solutions will be integrated into the NEC Group of companies and, under the working name NEC Energy Solutions, will begin operation in June 2014 under the direction of NEC. The company will continue to work in the grid-connected energy storage space with plans to also look into behind-the-meter energy storage.

The day to day running of the company has not changed and there are no plans to relocate away from the existing office and headquarters in Westboro, Massachusetts.

The company said as the deal works towards finalisation in June, more information on NEC Energy Solutions will become available. The new company will continue to supply A123 systems and provide service and support for existing systems. NEC intends to combine its wealth of experience in the IT field with energy storage to create energy efficient infrastructure as part of its Solutions for Society programme.

A123 Energy Solutions is an independent business unit within A123 Systems LLC, which is owned by Wanxiang America Corporation.

Tesla to build $6bn cell/pack plant

EV maker Tesla is to invest up to $6 billion in a US 'Gigafactory' to produce 35GWh/50GWh of lithium-ion cells/packs a year.

Tesla wants to manufacture its own cells and battery packs to lower costs by achieving greater economies of scale and minimising costs via reduced overheads, guarantee of supply, reducing the supply chain and co-locating processes.

In a statement, Tesla said construction of the plant would begin this year, with production beginning in 2017.

The location of the plant is still to be decided, although California has been ruled out as a location; Tesla said it will choose from one of four states: Nevada, New Mexico, Arizona and Texas.

The EV maker believes it can drive down the cost per kWh by more than 30% by the end of the factory's first year of full capacity production. When the location has been decided, construction will be completed by the end of 2015 with equipment being installed in 2016 and production to begin from 2017, reaching full capacity - enough cells for 500,000 cars a year - by 2020.

Tesla said its 'manufacturing partners' will help build and finance the factory, assumed to be Panasonic, which currently supplies 18650 cells for the Model S. Rumoured potential partners in the venture include Samsung and Apple.

Panasonic is inviting other Japanese material suppliers to invest in Tesla's battery plant. Investment is expected to be in the region of $979m.

To help finance the investment, Tesla also announced a $1.6 billion convertible debt offering.

Entek invests $17m in novel lead-acid separators

Battery separator manufacturer Entek is investing £10m ($17m) to develop its next generation lead-acid separator materials for automotive batteries at its UK manufacturing plant.

The company is keeping the new separator, which will be formally unveiled at the 14th European Lead Battery Conference in Edinburgh this September, under wraps. The first phase of the investment includes £2.5m of new machinery installed at its site near the city of Newcastle, with more to follow in the coming 18 months.

Two new production lines were installed at the plant four years ago to continually mix and extrude materials into continuous polyethylene sheets, which are then subjected to specialised process treatments to become separators.

The US-owned company has manufacturing sites around the globe including the plant in Killingworth in the north of England.

Meanwhile, Entek has rebranded, bringing all three of its operating divisions under a common-look logo-wise and with a single Web presence.

David Trueba, Entek's VP for sales & marketing, told BEST the rebranding brings together the Oregon firm's manufacturing of membrane battery separator materials for lead-acid and lithium-ion batteries; design and manufacture of extrusion machinery; as well as its own proprietary product units under one umbrella. "Even our business cards looked like we were from different organisations— this is a big, welcome change," said Trueba.

FIAMM to launch lithium-ion battery pack in 2015

Italian battery maker FIAMM is to launch a lithium-ion battery pack in 2015 aimed at the hybrid/micro-hybrid electric vehicle market, BEST understands.

FIAMM CEO Nicola Cosciani said it is currently in deep negotiations with a lithium-ion cell manufacturer with the aim of launching a battery pack next year. Due to non-disclosure agreements, Cosciani would not be drawn on either the lithium chemistry it was pursuing or the name of the cell manufacturer.

Cosciani told BEST: "We are exploring a range of chemistries, including lithium NMC and lithium iron phosphate, to develop an alternative battery for hybrid automotive applications. It could be a European cell maker or it could be Asian; we will reveal full details in due course."

FIAMM currently manufactures lead-acid and sodium nickel chloride batteries. Its 'SoNick' battery is used in Iveco's electric van; Cosciani did not rule out the Vicenza-based company providing lithium-ion battery packs for hybrid vehicles made by Iveco's owner Fiat.

Cosciani added FIAMM is actively exploring dual architecture solutions for stop-start and 'micro-hybrid' cars featuring a 12V lead-acid starter battery and a 48V lithium-ion pack to provide 'eboosting' and allow for higher loads.

Siemens and M+W collaborate for large format cell making

Siemens and fellow German engineering and construction firm M+W are collaborating to develop battery manufacturing technology and to mass produce large format ltihium-ion batteries.

The intention is to raise manufacturing standards to achieve consistently high quality results that can be repeated. The cooperation agreement will develop automation, monitoring and control of technical processes based on Siemens' existing stringent manufacturing processes.

As part of the joint venture all processes will be automated to develop the energy storage technology using M+W's technical expertise in optimisation and verticle integration of production processes. M+W has supplied lithium-ion manufacturing plants for automotve batteries since 2008.

The two companies hope that achieving these processes will reduce costs and ensure stability to customers of large format lithium-ion batteries.

Siemens currently develop its own products and equipment for battery manufacturers and suppliers from cell to pack level.

Highview Power Storage signs deal with GE

GE Oil & Gas has entered a global licensing agreement with the UK's Highview Power Storage to integrate liquid air energy storage (LAES) with peaking power plants.

The giant of the energy world will work with Highview to undertake feasibility studies before implementing a liquid air energy storage system at a GE peaking plant where GE gas turbines and engines will be installed. The system will increase plant efficiency, grid reliability and the distribution of renewable energy.

"There is a lot of engineering needed on both sides to make the equipment fit together. Working closely with GE Oil & Gas to engineer our technology into their peaker plant products is an excellent opportunity to accelerate the commercialisation of liquid air energy storage." said Matthew Barnett, Highview's head of business development.

"Considering that, it is realistic to see an operational liquid air energy storage peaking plant by 2016." Highview sees its LAES technology as providing a medium to long-term energy storage option from 5MW to more than 50MW on a compact footprint.

The news comes a month after winning £8m ($13.3m) in funding from the UK Department of Energy and Climate Change (DECC) to build a utility-scale demonstration site. Since 2011 Highview Power has run a 350kW/2.5MWh pilot plant to demonstrate the liquid air technology in the UK and DECC funding will be used to build a 5MW demonstration site adjacent to a Viridor waste management site in Canterbury, Kent.

A GE turbine will be used at the Viridor site demonstration plant, which will be operational from Spring 2015.

"Highview's readily available LAES technology, with its ease of implementation and access to an operational pilot plant, makes it an ideal partner for GE Oil & Gas to provide fully integrated energy solutions to our customers," said Luca Maria Rossi, product management general manager for GE Oil & Gas' Turbomachinery Solutions business.

The system takes ambient air and compresses it before storing it in a cryogenic cold store where it is progressively cooled using a liquefaction cycle. It is then stored at low pressure until power is required. The liquid air is then pumped to high pressure and put through an evaporation and cold recycle unit. Waste energy from gas turbines or engines then heats the air that expands to drive a generator that produces electricity.

In the Winter 2014 issue of BEST we asked if Highview Power could run the gauntlet from pilot plant to commercial venture and it seems to have had a successful quarter since that visit.


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Laurie Gardiner moves up at TBS

Laurie Gardiner, the self-styled salesman of ever faster lead-acid battery assembly systems, is stepping down as managing director of TBS Engineering to become chairman.

Gardiner, who turned 65 on 17 March, has worked with the company for 41 years having worked his way up from hand-finishing moulds to closing multi-million pound deals on assembly machine sales to the world's biggest lead-acid battery makers.

Many in the battery industry assumed Gardiner was the owner-manager but the company is in fact part of the famous Berkshire Hathaway conglomerate led by Warren Buffet. Stepping into the role as managing director at TBS is David Longney. Son Mark Gardiner takes over as head of sales.

Gardiner says his success has been about whetting the appetites of his customers to believe TBS "could always build a bigger, faster cast-on system", than the previous generation of machines.

"I had to tell them that because our machines don't wear out— they just demand replacement parts."

Today 20% of the company's business is supplying spares, while the majority of sales are machine and tooling, increasingly in Asia. "We've just renewed out joint venture agreements with Digatron in China and from this year we will doing some limited assembly of our products there."

After years of international sales Gardiner isn't applying the brakes to a lifetime in battery making. "I shall still be involved in bringing new technology to market — we have great hopes for new ideas in the pipeline which will revolutionise the cast-on process and save manufacturers money."

JCI in European battery technology collaboration

Johnson Controls and Fraunhofer Institute have entered into an agreement for developing lithium-ion batteries for vehicles.

R&D staff from JCI will work with the Fraunhofer's Institute for Environmental, Safety and Energy Technology (UMSICHT) and its Institute for Manufacturing Technology and Advanced Materials (IFAM). Under the agreement the group will investigate technologies and thermal management strategies for lithium-ion battery packs.

"Optimising the energy storage solution within the broader vehicle environment will enable Johnson Controls to design, develop and commercialise systems which not only meet our customers' requirements, but also lead to improvements in function, package and cost," said MaryAnn Wright, vice president of Engineering and Product Development for Johnson Controls Power Solutions.

The work will initially be focused on developing a 48V battery for micro hybrid cars. The battery technology will need to achieve fuel efficiency and lower carbon emissions while managing the additional loads placed upon the battery over and above SLI batteries.

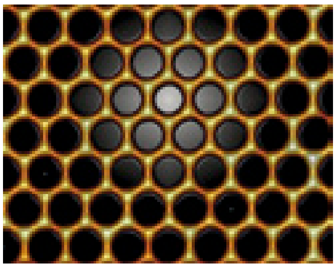
The work will build upon

JCI's existing advanced battery technology for the micro hybrid market that reduce fuel consumption by 15%.

48V micro hybrid technology is anticipated to follow the trend of mild hybrids by experiencing earlier adoption in Europe than elsewhere in the world as European emissions targets force the hand of industry. Global adoption will begin from 2020.

Samsung invests in graphene manufacturer XG Sciences

Samsung Ventures Investment Corporation has invested in the Michigan, US, based graphene engineering company XG Sciences.



The lithium-ion giant is providing XG Sciences with investment as part of a funding round to further the company's R&D efforts. The terms of the investment have not been disclosed.

The CEO of XG Sciences, Philip Rose, said the investment "represents another significant milestone in our progress toward commercialisation of large-scale graphene applications."

There are a number of demonstrations projects using XG Sciences advanced graphene and battery materials already in place in the electronics industry. Rose said having Samsung as a partner will accelerate demo projects to a commercial stage.

This investement follows $1m in funding from the US Department of Energy for continued development of its XG SiG high-energy anode materials for lithium-ion batteries. Rose added XG Sciences and Samsung SDI will work on a joint development programme aimed at next-generation batteries for consumer electronics and other devices.

Sinopoly Battery acquires Hong Kong EV maker

Sinopoly Battery, a Chinese lithium-ion battery maker, has acquired EV charger supplier Hong Kong Southwest Electric Vehicles from Giant Industry Holdings for HKD190m ($22.8m) in shares.

The transaction will allow Sinopoly to expand its electric vehicle manufacturing capability. This will be enabled by Hong Kong Southwest Electric Vehicles holding a 50% interest in EV manufacturing company Yunnan Meidi Coach Manufacturing.

Haldor Topsoe invests in sodium-ion developer Faradion

UK-based Faradion Limited has secured investment from a group comprising Haldor Topsoe, a catalysis technologies developer, and Finance Yorkshire's Seedcorn and Rising Stars Growth Fund.

Haldor Topsoe acquired an 18% equity interest in the Sheffield sodium-ion battery developer and will collaborate to co-develop and scale up the technology. The Danish engineering firm will also hold a license to manufacture and sell cathode materials using Faradion's technology.

While interest in sodium-ion batteries has been high in recent years, there has been relatively little R&D in this area. Faradion hopes to increase R&D and bring advanced battery materials to market.

Faradion is working to replacing the lithium in a lithium-ion battery with metal sodium for large-scale batteries that Faradion claims will have the same performance level at a much lower cost.

"The relationship with Haldor Topsoe provides us with a fast-track route to bring our proprietary materials to market in commercial quantities.

Haldor Topsoe's experience of large-scale manufacturing of highly similar materials will enable the future users of our technology to secure high quality materials in commercial volumes at competitive prices," said Chris Wright CEO of Faradion.

The technology is being aimed at the automotive and stationary storage markets.

Is Europe finally turning on to EVs?

The Nissan Leaf was the best-selling EV in Europe in 2013 with 11,120 vehicles sold.

Sales increased 204% compared to 2012 and are 25% greater than the next best-selling EV, which was the Renault Zoe.

Norway accounted for a large portion of the Leaf's overall sales. The government of Norway has invested heavily in charging infrastructures for EVs and offer substantial incentives for purchasing an electric car. In October 2013 the Leaf was the best selling car in the country – including non-electrified vehicles.

France has seen a 240% year-on-year growth in Leaf sales and the UK saw sales increase by more than 1000%. Worldwide over 100,000 Leafs have been sold.

The growth of electrified cars has not been as rapid as forecasters would have hoped, however the growing infrastructure of charging points has helped.

Europe's 1000th rapid charger has been installed in the UK. Rapid chargers have sprung up as rapidly as they charge, in 2010 there were on 16 in the UK and now there are around 200. The rapid charger can take recharge a battery to 80% in under 30 minutes.

Redflow and Flextronics to manufacture flow batteries

Redflow, the Australian developer of zinc-bromine flow batteries, has named Flextronics as its manufacturing partner.

US-based Flextronics will be responsible for increasing production of the flow battery to get it to a commercial level for use in stationary storage markets.

Redflow's battery will be the first flow battery to be produced on a large scale and several are already deployed in demonstration projects. Stuart Smith, Redflow CEO, said: "The corresponding improvements in manufacturing quality, consistency, scalability and reliability are all important attributes for customers in addition to cost efficiencies."

Flextronics was selected because of its extensive production capabilities in the energy industry and has manufacturing facilities in the US and worldwide.

Germany-Ghana lead recycling programme

Ghana and Germany have begun an agreement for Germany to recycle lead-acid batteries from the West African nation as part of an initiative for sustainable interdependence between Europe and Africa.

The first shipment of 20 tons of used batteries has successfully been processed in Germany, by Johnson Controls at its Krautscheid plant. A local recycling firm collected and packaged the used SLI batteries from passenger vehicles and trucks for export.

Transportation was arranged by the German Federal Ministry of Education and Research to be recycled in an environmentally sound way under the “Global Circular Economy of Strategic Metals: Best of Two Worlds (Bo2W) approach”.

Johann-Friedrich Dempwolff, managing director of JCI’s Power Solutions EMEA, confirmed the shipped batteries fulfill Johnson Controls’ requirements: “We can recycle up to 99% of a used battery at our recycling center in Germany. Part of this process is to ensure that batteries are shipped to us intact and that the acid isn’t drained into the ground in Ghana, as it has often been the case before, causing environmental damage.”

The project seeks to find a feasible way and affordable way for countries to work together to recycle batteries, end-of-life vehicles and electronic waste for which there is no local recycling facilities available.

The initiative has been implemented in response to an increase in the number of lead-acid batteries being used combined with the lack of proper recycling facilities in many African countries.

The project will run until May 2015 and is sponsored by the German Federal Ministry of Education and Research (BMBF) r3 programme and will involve recycling collections from Ghana and Egypt.

Battery Watering Technologies enters European distribution deal with Wetac

Battery Watering Technologies has entered a partnership with Wetac Motive Power to distribute battery watering systems and accessories throughout Europe.

Wetac is an importer and distributor of batteries headquartered in the Netherlands with distribution locations throughout Europe. Battery Watering Technologies is based in North Carolina, US, designs, develops and manufactures components for motive power batteries.

“Wetac is known for providing quality products and service and we are very excited to partner with them”, said Scott Elliott, President of Battery Watering Technologies. “Our clients are accustomed to a high level of quality and Wetac has a professional staff that is very knowledgeable and reliable”.

Sovema to launch improved enveloping machine

Italian battery manufacturing machinery firm Sovema is to launch an updated enveloper machine for enveloping lead-acid battery plates in mid-2014.

After two to three years of testing and trials in various locations around the world, in the next quarter Sovema will launch an improved version of its enveloping machine, General Manager Massimiliano Ianniello told BEST.

"We have solved the reliability and other issues," said Ianniello. "Some of the parts were unreliable meaning we were unsure how long the machine would last. We like to put our machines in the 'worst' places where the customer is effectively abusing the machine.

"We cannot pretend that the first or second machines we make of each model will be perfect. Some of the small parts like cylinders and belts we had issues with; we immediately solve the belt problem and now we have solved the cylinder issues."

Sovema is imminently launching an improved drum paster, as well as a 30 tonnes ball mill, a significant increase on its previous model of 24 tonnes.

The Verona-based firm is also developing a new punching machine, one which Ianniello claims is unlike any other on the market.

"We want to have a 'smart' punching machine which allows the operator to know exactly what is going on with each phase of the process."

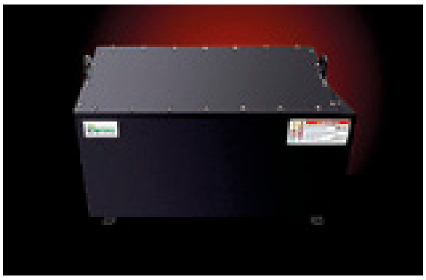
Navitas Systems secures forklift truck contract for drop-in lithium battery

Drop-in lithium-ion battery supplier Navitas Systems has secured a contract to supply one of the world's largest forklift truck OEMs, BEST understands.

Michigan-based Navitas said the forklift truck batteries would be rolled out in Europe first. Due to a non-disclosure agreement, no further details are forthcoming.

"Within this calendar year there will be a major announcement," said Mil Ovan, chief marketing officer at Navitas.

Lithium-ion batteries for forklift truck batteries are expected to be a growth sector. Lithium's fast charging capability and higher energy density versus lead-acid means forklift truck operators can mitigate battery handling and maintenance.



Ovan said Navitas is registering strong interest in its 6T battery for military applications, particularly in Scandinavia. However, the 6T needs prior approval from the US State Department before it can be exported.

Navitas recently moved in to a 50,000 square meters facility in Ann Arbor, Michigan. Employees were relocated before Christmas 2013 and manufacturing/R&D equipment is expected to be fully online by the end of Q1 2014.

Xtreme Power files for bankruptcy

Grid-scale battery startup, Xtreme Power, has filed for bankruptcy after failing to raise sufficient capital through selling its manufacturing site.

The company, which makes advanced lead-acid batteries for large stationary projects, has been struggling to maintain its business for some time. In April 2013 the company put its Oklahoma factory on the market. It has not yet been sold and will form part of the bankruptcy arrangements.

Creditors are financing the continued operations and maintaining a core staff.

A takeover by a creditor could keep the company afloat as it enters Chapter 11 protection at the bankruptcy court in Texas.

In the court papers the company outlined its intention to "continue its operations at all locations as it begins the process to identify an acquirer".

CEO Alan Gotcher said the bankruptcy filing is "structured to allow one of the company's creditors to file a stalking-horse bid" in case a bid has not been made by the end of February.

According to the CEO the business is set to break-even this year after interest, taxes, depreciation and amortisation have been taken into account.

Xtreme has around 60MW of advanced lead-acid batteries deployed in stationary energy storage sites around the world. It also has significant deployments in the emerging grid-scale energy storage including a 36MW system at Duke Energy's Texas wind farm – the largest battery project in the US.

Xtreme has raised more than $55m from investors since 2004. It hopes finding a creditor to buy the company will save Xtreme from bankruptcy.

Timcal renames as Imerys Graphite & Carbon

Battery additives manufacturers Timcal Graphite & Carbon changed its name to Imerys Graphite & Carbon on 1 April.

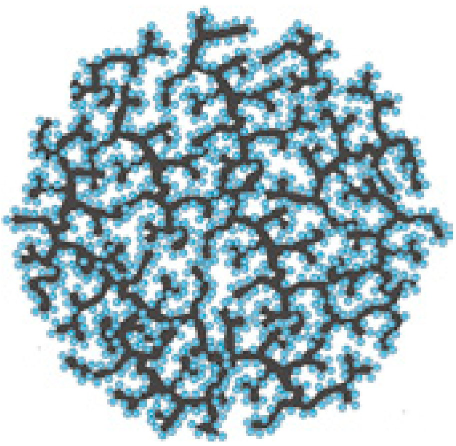
In a statement, the Swiss company said the name change was part of the creation of a common Imerys brand, which would increase the visibility of Imerys and will also improve the co-operation within the group.

EnerG2 boosts Li-ion capacity with carbon-silicon composite

EnerG2 Technologies, an engineering company working to improve energy storage technologies with the use of carbon, has introduced a line of carbon materials to increase capacity and boost performance of lithium-ion batteries.

The US-based company has blended carbon and silicon to replace graphite materials in lithium-ion batteries. The resulting silicon blend utilises EnerG2's polymer chemistry-based approach to engineering energy storage materials. It has been scaled-up for commercial manufacturing for use in electric vehicles and consumer electronics.

The company claims the silicon-carbon composite could extend the driving range of an EV to 300 miles on a single charge thanks to the increased capacity. While the energy density of the composite compared to silicon only anode is dramatic with a claimed 500% cycle life improvement.



Using silicon can cause problems when manufacturing at scale- due to expansion and contraction during charging and discharging. However EnerG2 claims making a composite with carbon overcomes this issue.

EnerG2 has kept the costs down because it has labs and production sites ready to output the material using its propriety carbons so the new product can be integrated quickly and at low cost.

The company has a manufacturing facility in Oregon dedicated to commercial-scale production of nano-engineered carbon materials. The site has been upgraded to produce the new carbon-silicon material.

Bolivia opens lithium-ion battery plant

Bolivia's first lithium-ion battery manufacturing plant has opened in La Placa, a town near the Uyuni Salt Flat— the world's largest lithium reserve.

The factory has been built by Chinese battery manufacturing company LinYi Dake from Shandong. A small team from LinYi Dake will oversee the plant that will employ 21 Bolivian operators.

The factory was expected to reach full capacity in April when output is expected to be 1000 cellphone batteries and 40 EV batteries a month.

The dried up seabed contains more than 100m tons of lithium, according to the Bolivian government, in an area that covers 10,000 square kilometres. The area is already home to a lithium carbonate processing plant to process raw lithium.

In 2013 the Bolivian government announced it is investing $900m in the development of lithium mining and processing operations.

Flowgroup supplies compressed air batteries to Canadian telecom Co

Flowgroup, a UK energy technology developer, has received an order for two compressed air batteries totaling 150kW capacity from Trane Canada for a telecoms company.

Flowgroup's air battery business, ambiguously named Flow Battery, will supply one 100kW and one 50kW compressed air battery units for a telephone exchange in Toronto which is part of a national network.

The compressed air battery was selected for resistance to a range of temperatures. While the larger unit will be housed inside, the smaller battery will be outside where it will be exposed to temperatures between -40°C to 40°C.

The compressed air battery can produce power on demand using a store of ordinary compressed air from cylinders to drive a scroll generator, which can spin up and decelerate rapidly to match output to load.

Flow Battery has an agreement with UK national grid to supply 200 compressed air batteries per year to replace existing lead-acid back up batteries at substations across England and Wales.

Battery giants enter joint venture

GS Yuasa, Mitsubishi and Bosch have set up Lithium Energy and Power GmbH & Co– a joint venture to develop next generation automotive lithium-ion batteries.

The group has ambitious plans to double the energy capacity of batteries within the next decade for the electric vehicle market.

"In setting up this joint venture, we want to achieve nothing less than a giant leap forward in the development of battery technology. Our aim is to make lithium-ion batteries twice as efficient," said Volkmar Denner, chairman of the board at Robert Bosch.

The intention to set up the group was announced in June 2013, it is headquartered in Stuttgart, Germany, where Robert Bosch– which holds a 50% stake in the JV– is also based.

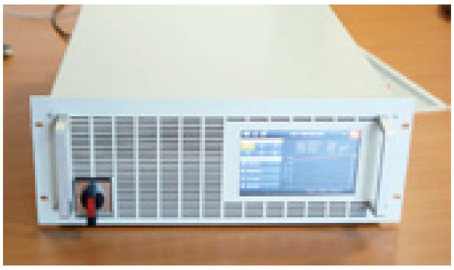
Digatron flashes Six Pack

Digatron Power Electronics has unveiled a new multiple cell tester for its regenerative series called The Six Pack, so named because it contains six individual circuits.

The Six Pack is designed to test cells and batteries up to six volts with a 300A charge/discharge rating for each of the six test circuits.

The system can perform high current tests and allows for flexible configuration and paralleling of circuits. It utilises energy efficiency improvements to reduce the need for fans and cooling equipment.

The system is fully scalable to enable high packing density of up to 48 circuits per battery cabinet.



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Källström agrees Chinese representation deal with Digatron

Källström Engineering, the Swedish supplier of acid filling and dilution equipment, has entered into an agreement for Digatron Firing Circuits to represent the battery equipment manufacturer in China.

The agreement, in place since late 2013, will see Digatron represent and sell Källström equipment in China to increase sales and improve aftersales service.

Bo Johansson, sales manager at Källström Engineering, explained why it is an important move for the company: "Globally we have seen an increasing demand for our equipment over the years. China is a big market with many battery companies and there is great potential for us in this market."

Källström filling and dilution equipment will be available across the whole of China and shipped from the production site in Sweden.

"From Källström's point of view it is great to have Digatron as a representative in China because they have many years experience working in the country as well as having a Chinese office and staff," Johansson added.

This agreement strengthens the two companies long-standing relationship; Källström has represented Digatron in Scandinavia for many years. Johansson said the opportunity to work together again was an easy choice.

Daimler to buy out Evonik stake in Li-Tec

Daimler is to acquire Evonik Industries' 50.1% stake in their Li-Tec joint venture, making it the sole owner of the lithium-ion cell manufacturer.

Daimler will also buy Evonik's 10% share in their Deutsche Accumotive battery partnership to take full control of that business. The parties have agreed not to divulge the details of the agreement.

Li-Tec, based in Kamenz, near the eastern German city of Dresden, and has about 380 employees. It produces lithium cells for Daimler's Smart Fortwo electric-drive city car. Deutsche Accumotive had about 230 workers as of the end of last year and is based near Stuttgart.

Harald Kröger, Head of Development at Mercedes-Benz Cars Electrics/Electronics, said: "Along the value chain for drive-system batteries with lithium-ion technology, we now have the two most important components: the production of battery cells and the related development and production of highly complex drive-system batteries as a combination of cells and battery electronics."

Münstermann oven cures plates in four hours

German machinery maker Münstermann has developed a plate-curing oven that cures battery plates in less than four hours using the Concure process rather than the conventional 30 hours.

The Concure process is a patented rapid curing process, which Münstermann claim that including the loading and unloading time the total process time is approximately five hours. The short turnaround time allows manufacturers to switch between batches of product types quickly with no need to intermediary storage of plates.

The patented process is based on the combination of using higher temperatures than conventional curing ovens with highly pressured steam.

The company has supplied curing chambers to Willard Batteries and an unnamed Asian battery manufacturer. The capacity of the ovens is 37,000 plates per curing session; Münstermann said, based on their internal calculations, investment costs could be halved for a company to ramp up plate curing using the Concure curing ovens.

AES to build 100MW battery storage plant in Northern Ireland

US energy storage firm AES is to build a 100MW battery energy storage plant at Northern Ireland's biggest power station.

AES plans to build the facility at the Kilroot 660MW coal/oil power plant in Carrickfegus. The company has submitted a connection application to System Operator Northern Ireland (SONI), which operates the electricity grid in Northern Ireland.

Depending on "a suitable commercial agreement", AES could have the facility operational early in 2015.

Racing ahead of the battery pack

This year sees the start of an all-electric racing series to rival Formula One. Ruth Williams reports how Formula E aims to propel electric vehicle technology into the spotlight both in terms of worldwide audiences and competitive engineering.

Many things can be said about electric cars: they are better for the environment, driving range is improving, and the cost is just about coming down. But the cars themselves have not been seen as impressive or powerful compared to a big gas-guzzling engine.

If motorsport can raise that image and show the world how fast these cars are then just maybe punters will be persuaded to buy them. The Fédération Internationale de l'Automobile's (FIA) Formula E series may do just that.

Formula E is a carbon-zero all-electric race series conceived to act as a research and development framework for electric vehicles to challenge battery pack makers and car manufacturers to raise the bar for performance and get more electric cars on the road. The series kicks off in September in Beijing, China as the first of ten rounds that take in each continent before finishing in London in June 2015.

During the first season the teams will each drive the same car; although the cars are identical, modifications will be permitted to the engine, torque mapping, suspension and ride height depending on the circuit and driving style.

The cars and all the components have been designed and supplied by a consortium of seasoned racing engineers. Renault is building the car, the carbon fibre and aluminium chassis comes from Italian firm Dallara; McLaren has designed the powertrain and electronics; and Williams Advanced Engineering is supplying the 200kW battery.

Okan Tur is the chief technical specialist of hybrid systems at Williams Advanced Engineering. Tur has been instrumental in designing the battery pack for the inaugural race season. To keep a competitive edge for future race seasons Williams is keeping schtum on the battery pack and cells.

Williams is only revealing it uses lithium-polymer cells. The battery pack being delivered by Williams is engineered to FIA specifications.

The voltage is limited to 1,000V, which is more than double that of the Tesla Model S. It has a capacity of 30kWh, which combined with the power capacity of 200kW gives a discharge rate of 7C — far greater than any on-road EV.

It may seem strange that teams will not be engineering competitive advantages into their cars in this first year. Yet getting the race off the ground with a single car design was problematic enough, let alone inviting teams to develop their own car in such a short timeframe. Tur explains the challenges Williams Advanced Engineering encountered in reaching the finished battery design.

"There was a massive timing constraint around choosing the battery," he says. "We won the contract back in June (2013) and began running prototype batteries from January."

This means Williams has designed the architecture and selected the cells, designed a prototype and started testing in about seven months. "Anyone who has designed a battery will understand and appreciate the challenge of this task. It would be nearly impossible for a company that doesn't have Williams' experience."

Few companies have the technical backing to speak so assuredly. But Williams has been building cars for its own Formula One team since 1978 so understands the demands of racing as well as designing cars and components.

"We didn't have all the luxury of going ahead and playing with different chemistries and cells, instead we had to come up with what kind of architecture we could put forward such as how many cells and how we could connect them."

Designing for a pre-designed team car meant Williams had to work with the dimensions and volumes set by the FIA. The maximum weight limit is 200kg within the overall weight limit of 800kg for the car including the driver.

The short lead-time leaves no leeway for Williams to make amendments to fit the car. Had Williams designed the entire car there would have been the flexibility to incorporate the battery pack into the design of the car.

The rules also state the capacity of the battery is limited to 28kW per hour. However unlimited power regeneration is available via thermal recovery from braking. "Regenerated energy is calculated by a fixed efficiency value defined by the FIA," says Tur. All energy ratings are taken from the output of the battery so when you regenerate energy goes back into the battery and all power used by the car comes out of the battery. So there has to be fixed efficiency ratings by FIA."

Another important parameter is the power limits. The FIA has fixed the maximum power at 200kW- equivalent to 270hp. This power will be divided between 'race mode' and 'push-to-pass'; race mode is a power saving option for use throughout the races and will provide 133kW- equivalent to 180hp on the throttle.

The push to pass is essentially a booster button that drivers can use for a short sharp burst of 67kW of extra power - equivalent to an extra 90hp. Here is where Formula E may become reminiscent of a video game.

> **"Anyone who has designed a battery will understand and appreciate the challenge of this task. It would be nearly impossible for a company that doesn't have Williams' experience.** Okan Tur

The maximum power can be used throughout qualification sessions but during the races its use will be limited to give teams the opportunity to bring tactics into play when driving identical vehicles. Drivers will have to make two compulsory pit stops during the 60-minute race to change the car, which must be worked into the teams' race strategy.

To keep the race relevant to road cars it was decreed more beneficial for drivers to switch between two cars rather than teams developing rapid battery swapping systems with little relevance outside of Formula E.

Okan Tur is the chief technical specialist of hybrid systems at Williams Advanced Engineering

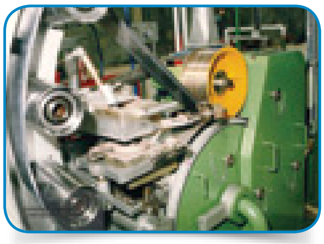
Tactics aside, the challenge for Williams was to work within the design specifications for weight and dimensions and the limited time to get a pack together so they chose a familiar chemistry. "We have been using a specific cell technology for some time that we are comfortable with and understand very well. We had to be confident on that so we went ahead and ordered a number of different versions from the same supplier."

Cell selection process

Williams began the cell selection process in May 2013 and immediately began thinking about cell configuration. "We came up with the number of cells, undertook simulation and thermal analysis of different architectures and for each architecture simulated a different number of cells in series and physically how they are packaged and what kind of cooling systems to use. We did thermal analysis and performance analysis in a simulation environment and then, when we received the cells, we went through complete characterisation."

Williams works with many cell providers of multiple chemistries across its range of applications besides racing technology. The department designs electric drive

PUNCHED GRIDS FROM WIDE LEAD STRIP FOR BATTERIES PRODUCTION



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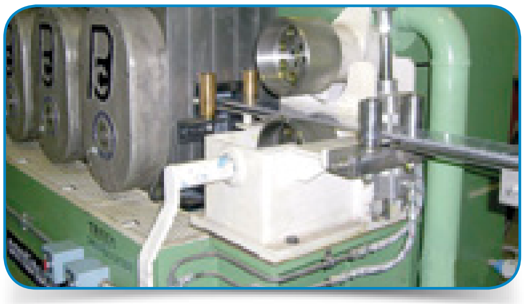

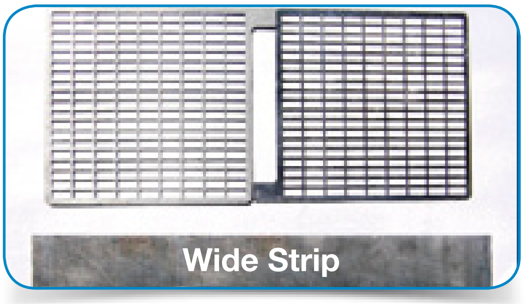

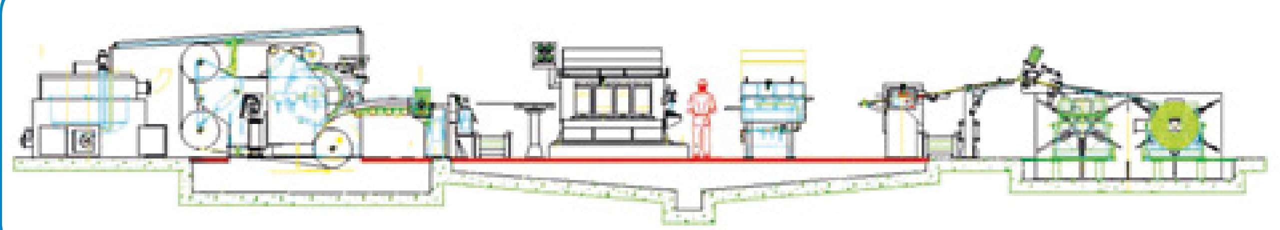

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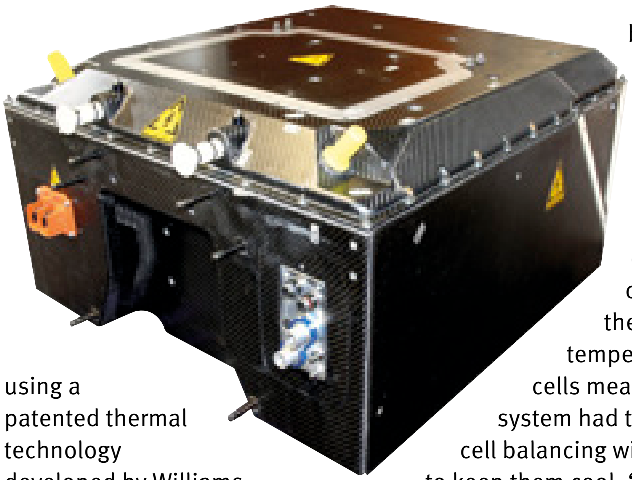
trains for e-bicycles from which a wealth of experience can be drawn that clearly helped with the time constraints of the battery design.

"For this project we had one cell type that we targeted," says Tur. "We didn't compare this cell to other manufacturers but we had enough time to extract all the specific parameters of that specific cell before definitely going ahead."

Testing included internal resistance, impedance characterisation, power levels and capacity testing. Williams has in-house test facilities to run race simulations, life analysis, complete life testing at cell level and characterisation at single cell level. The advantage of designing a race car battery instead of a road car is lifecycle ability: this is not designed to last ten years so life can be traded in for improved performance in the cell selection process.

The team at Williams is coy about the details of the battery with good reason: from 2015 onwards teams will be invited to design and race their own cars and propulsion systems, so Williams does not want to dish out its secrets. This even extends as far as teams not having access to the battery within the car; during races trackside engineers from Williams will be on-hand to perform maintenance on the battery pack.

The battery is liquid-cooled using a patented thermal technology developed by Williams for Formula One and used in the Jaguar CX75 hybrid supercar. The requirements on the battery pack for Formula E differ: "We did not follow the same rules as Formula One fundamentally because if you look at the specification of the battery the peak is about 7C, so it's not very powerful."



Right:
Formula E battery

Below:
Spark BMS screen

Source:
Williams Advanced Engineering

The pack required for Formula E has a greater balance between power and energy requirements which means cooling was less of a challenge compared to Formula One. The thermal liquid cooling system helps with the pre-conditioning of the battery prior to the race just as an internal combustion engine would need to be warmed up on the track to reach optimised race standards.

"Compared to road cars the racing car battery has to operate at higher temperatures because the cell's internal resistance starts dropping at higher temperatures." The lifetime expectancy is traded off against lower internal resistance but for such short race sessions this is not a problem.

The lifetime of the packs is two seasons, but this is measured in hours not years as each car and battery pack is used for just 30 minutes per race session. This made lifecycle testing more straightforward as Williams has in-house testing facilities for batteries and propulsion systems from cell-level upward. Delivering sufficient energy while controlling the maximum temperature of the cells meant the cooling system had to optimise the cell balancing within the pack to keep them cool. "We have very sophisticated electronics, which Williams is well known for.

"Our battery electronics and in-house software are good enough to control the entire racing car. Architecturally our electronics are based on many years of controlling Formula One racing cars. We used our control platform for our KERS application from 2011 and have developed local monitoring units for the voltages and temperatures for all the cells."

The monitoring system is adapted from a system Williams developed while working with Jaguar on the high performance CX75. The system monitors the temperature and voltage of the cells individually and as a pack.

Another key design criterion, in addition to the weight and volume requirements, is transportation. With the races taking place across several continents the battery packs must adhere to the UN Transportation of Dangerous Goods guidelines.

Williams' design is modular that will remain assembled at all times, utilising a "clever way of partitioning the battery into modules so they can travel in-situ without taking it apart." This suggests a lot of metal or walling between cells, but not enough to impact the 200kg weight restriction as the overall electronics do not significantly change the battery weight.

Safety is at the forefront of all racing technology, which has led to crashes that the driver can walk away from, even if the car is destroyed. When it comes to electric cars the battery has the potential to be a hazard. Williams has taken every precaution for safety because the image of a car engulfed in flames would cause serious damage to the reputation of electric vehicles.

With the races being watched globally any problems with the battery pack will resonate loudly but Tur is unphased at the thought and compares the number of petrol-engine cars that crash and burn each year compared to electric vehicles.

"It's only perception; it's a new technology that's only just coming out. Transmission system, brakes and engines are catching fire in road cars that have undergone years of testing. So yes, it is challenging and in a racing environment it is even more challenging but at the same time we are aware of it and we are using state of the art safety features and taking precautions."

As an all-electric race showcasing a low carbon future, the elephant in the room is how to charge 20 supercars in city centres without damaging the zero-carbon message? The exact details are still being finalised for each city but the goal is to use sustainable power wherever possible.

"We will most likely use a combination of environmentally-friendly generators and the city grid with the latter drawing on renewable energy where possible." The host cities and local utility providers are working with Formula E to minimise grid disruption.

Real world applications?

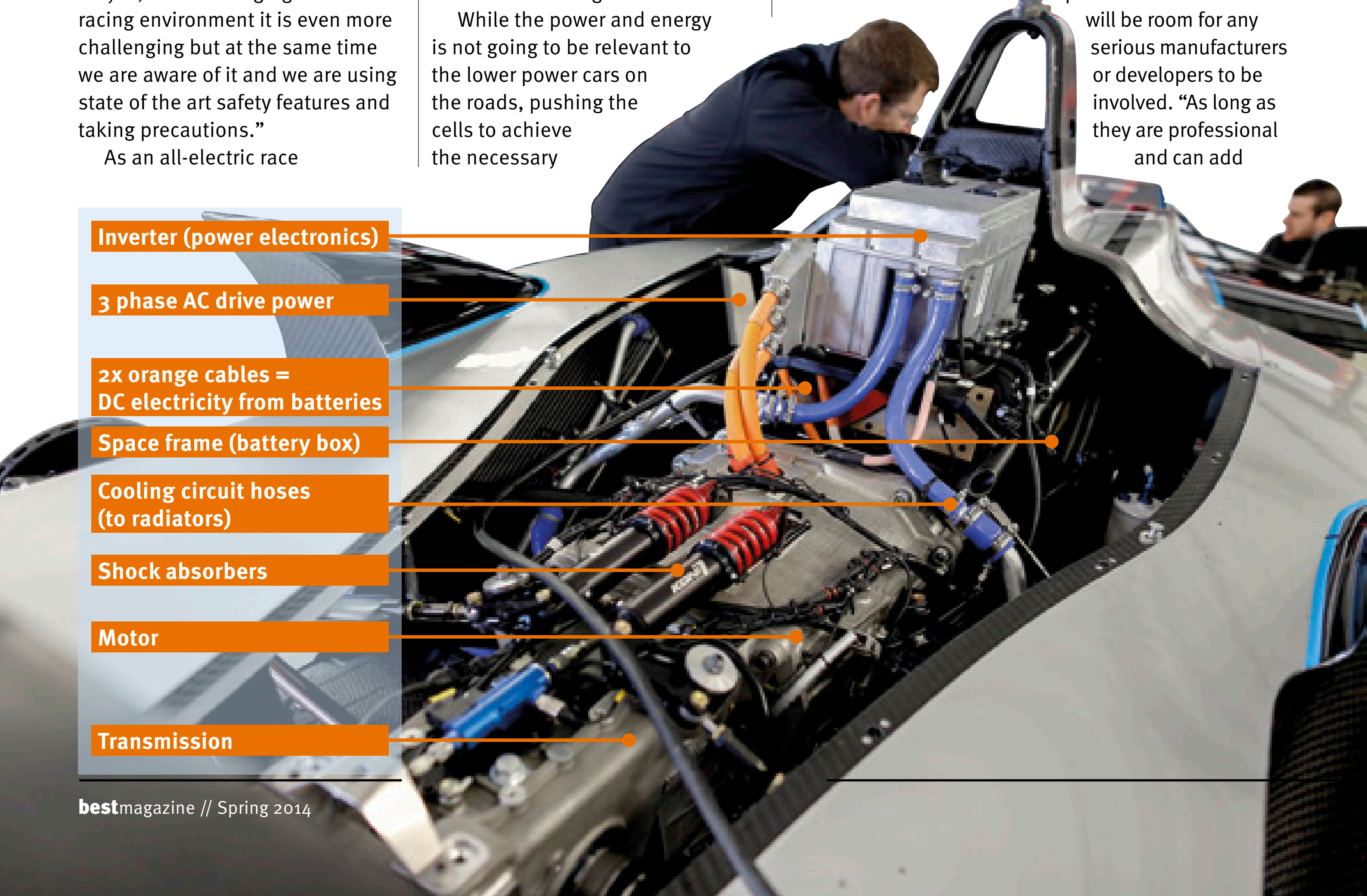
So how can the technology developed for racing be useful to road cars of tomorrow? Following the first season, teams will be invited to develop their own car designs including the motor and battery system. This will create opportunities for battery manufacturers to get involved.

While the power and energy is not going to be relevant to the lower power cars on the roads, pushing the cells to achieve the necessary capacities will enhance the performance for the future. The process is a two-way street for a company like Williams that has its fingers in so many pies.

The developments made for the Jaguar CX75 uses the same electronics and a similar cooling concept and cell chemistry. Tur says: "There is plenty to learn including investigating the life of the cells throughout the series under road conditions and at increased temperatures."

From the second racing season there will be opportunities for other manufacturers to get a look in although the regulations will restrict what can be used in terms of novel or cutting edge chemistries, according to Dirk Spiers, director of ATC Technologies and Formula E consultant.

Spiers believes safety and the professionalism of the teams will prevent anything radical being permitted but there will be room for any serious manufacturers or developers to be involved. "As long as they are professional and can add



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value they could add an option. These cars are so new compared to the cars in other long established racing series so there is a lot of development work to do. If you add value on a technical level you will have a chance."

The cars and batteries will be able to push the limit in terms of performance without being restricted by cost and lifetime and this is where innovation can happen. Removing the constraints will let the electronic engineers get to the best technical solution for the racing environment and then adapt it for road cars.

From the second series onwards as teams begin to develop battery packs and electronics systems, they will learn a lot about the batteries and as gains are made the trade-offs in terms of durability and cost versus performance will level out to an acceptable level for everyday cars.

The cars are still so new and, while some companies have dedicated much time and money to developing electric cars and batteries to power them, there simply has not been sufficient time for EVs to enjoy the budgets that combustion engine cars have. This should not be looked on as a failing on the part of manufacturers—more a matter of timing: When EVs have been around as long as their fore-bearers then the budget and development will be there but fast-tracking development to make EVs affordable and with the performance of diesel or gas-powered cars needs a force of momentum like this.

The ultimate aim of Formula E is to share experiences and build upon them for a framework to increase electric vehicle usage for the future as well as showcasing the technology and changing perceptions. It does not mean electric supercars will be on the roads imminently but it is pushing the batteries, chargers and electrics in the right direction.

There is a lot riding on the success of this. Electric cars need an image change and a boost in sales, which Formula E could bring if it can go off without any major hitches. But will that be enough to change perceptions and sell cars?

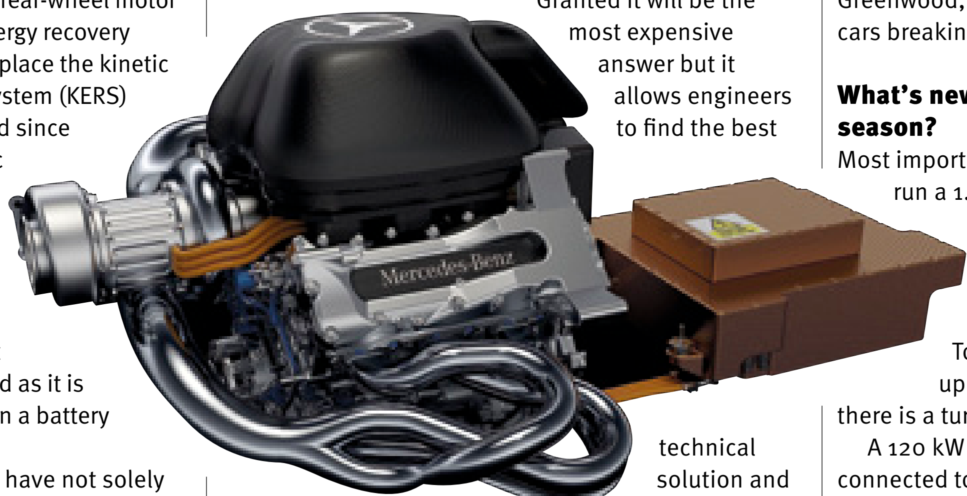
F1: Re-writing the rules of the road

This season sees greater levels of electrification in the world's best-known and well-loved motor sport. Formula One is going green(ish). Ruth Williams visited engineers Ricardo to talk to the experts in hybrid engineering for motor sport to hear how incorporating energy storage and reducing fuel will filter down to the real world.

Motorsport has traditionally been ahead of road car technology development but there are more hybrids on roads than on circuits. Hybridisation and electrification has been embraced as a way to lower emissions but hitherto has not been seen as high performance.

The Federation Internationale de l'Automobile's (FIA) inclusion of more energy recovery and storage will show audiences around the world that hybridisation brings not only fuel efficiency but more powerful performance. And that it is sexier.

This season's cars have a smaller engine with a turbocharger to boost power, an electric rear-wheel motor and a complex energy recovery system (ERS) to replace the kinetic energy recovery system (KERS) that has been used since 2009. Both kinetic and thermal energy recovery will be used to increase the power available to the car and that energy can be used as it is created or stored in a battery for tactical use.



These changes have not solely been made for fuel efficiency but to win back spectators. Falling viewing figures are blamed on a combination of dull, processional races and young people simply being less interested in cars and driving. The generation who spent all their spare cash fixing up their first car now have grown-up children of their own and much of the sentimentality has been lost.

The FIA has recognised this disconnect and wants the implementation of ERS to bring excitement back to F1, with more overtaking and greater use of team tactics rather than the team with the biggest budget building the best car and winning races.

The relationship between road and racing cars is crucial because the technology developed for motorsports, with motorsport's budget, gives a leg-up to road cars. This means motorsport can reach the best technical answer quicker. Granted it will be the most expensive answer but it allows engineers to find the best technical solution and then work on reducing costs.

That's where Ricardo comes in. Ricardo is a world-renowned engineering consultancy firm with 18 locations around the world; its head office is in Shoreham, on the south coast of England. Ricardo works alongside most major automakers, including F1 teams.

Dave Greenwood is currently the head of hybrid and electric systems but will shortly be taking up a Chair in Advanced Propulsion Systems at the University of Warwick, while Steve Sapsford is Ricardo's director of high performance vehicles & motorsports. They have developed systems for teams and understand how the components of the car will interplay.

"It's going to be exciting this season – there have been many technical changes all at once – it could be Wacky Races one way or another but it'll be exciting," says Greenwood, "there could be lots of cars breaking down to start with."

What's new for the 2014 season?

Most importantly, all cars will run a 1.6-litre V6 internal combustion engine, which is more fuel efficient than the old 2.4-litre V8 engines. To boost the power level up to its predecessor there is a turbocharger.

A 120 kW electric motor connected to the rear wheels and a 4MJ (usable energy) battery and power electronics between the two. The kinetic energy recovery system it replaces harnessed the waste energy from braking alone and transformed that into electrical energy to provide the car with an

Steve Sapsford, Ricardo's global market sector director high performance vehicles & motorsport and Dave Greenwood, head of product group hybrid & electric systems

additional 60kW of power up to a maximum of 400kJ per lap.

This is the equivalent to 80HP that can be used each lap for about 6.67 seconds. Compared to KERS there is now twice the power and ten times the energy storage available.

On top of this is another form of energy recovery and delivery. The energy recovery system (ERS) is made up of two components: a motor generation unit heat (MGUH) and the motor generation unit kinetic (MGUK).

The MGUH is a high-speed electric motor of around 100-150kW, which is connected to the shaft of the turbocharger. This system uses a turbine in the exhaust system to generate electricity from exhaust gas heat, either to store up to 2MJ per lap in the battery, or to provide power to drive the wheels through the MGUK. The MGUH can also be used to spin-up the turbocharger faster, allowing the engine to build up power more quickly.

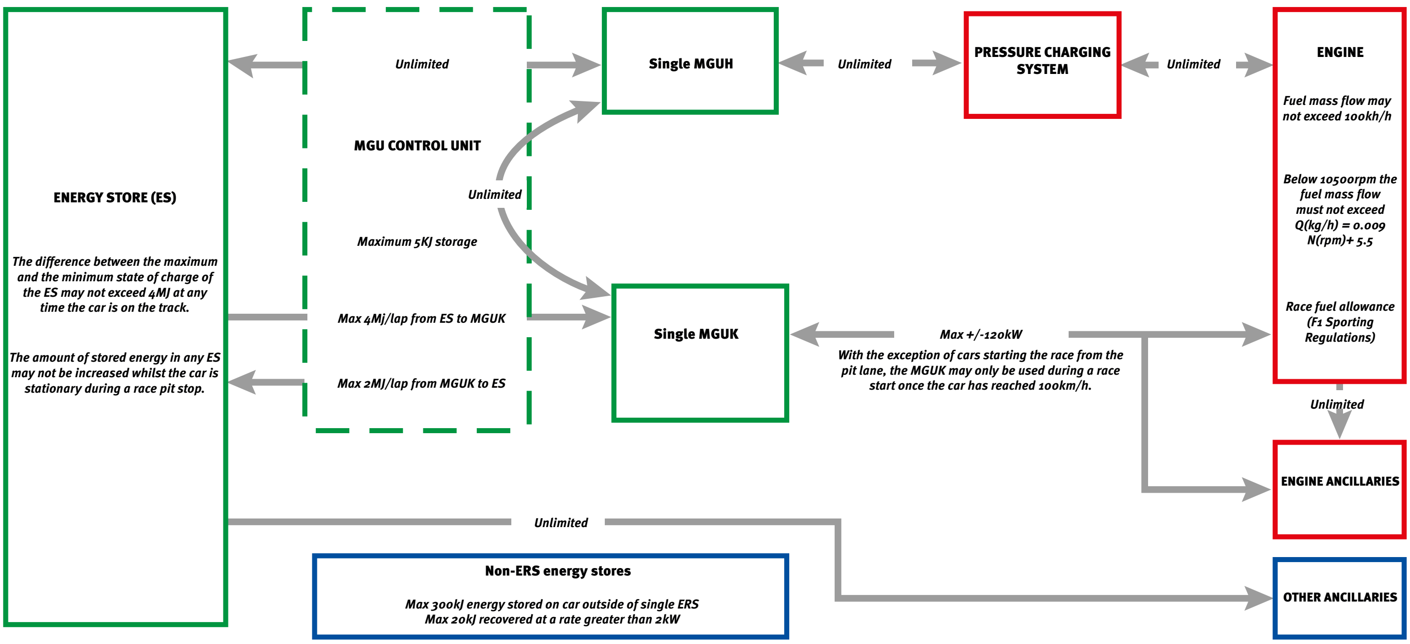
The MGUK is a 120kW motor connected to the rear wheels. This can be used as a generator under braking, storing up to 2MJ per lap in the battery. It can also be used to take energy from the battery and MGUH to power the rear wheels.

The capacity of the battery is unlimited, but it is only allowed to provide 4MJ per lap to the MGUK. In addition to this, there is no limit to the amount of energy which can be supplied directly (not via the battery) from the MGUH to the MGUK. Since the MGUH can generate 100-150kW, this is a very significant source of power for the car.

To ensure teams embrace fuel efficiency, cars can carry a maximum of 100kg of fuel for the race – about 130 litres. This is a third less than teams carried in 2013 when there was no limit and a bigger engine. The fuel is limited not just to the total amount for the race but also the instantaneous rate it can be used.

"They're effectively saying 'Get the best performance out of smallest amount of fuel'", explains Sapsford. "That's where all of the

POWER UNIT ENERGY FLOW
Legend: Engine - ERS - Other



rest of the power comes from: recovering it and using it in the system all essentially comes from burning fuel."

Renault was the first team to unveil its race engine. Called the Energy F1-2014, the unit provides the car with 760hp — 600hp from the engine and 160hp from the ERS.

FIA rules dictate where and how much energy can flow through the car during a race. This requires serious engineering to adhere to the rules while ensuring reliability for the duration of the race because no team wants to run out of fuel or finish the race with excess weight of unused fuel.

All of this means the powertrain can be run in many different ways in order to prioritise for fuel consumption, lap time or overtaking power. This is where team strategies can really come into play. Teams will have to decide how and when to use the energy sources in different scenarios.

At the same time, teams will have to second-guess the strategies of their opponents. The challenge for the teams therefore will be to get to know how the cars work and how to push them to win.

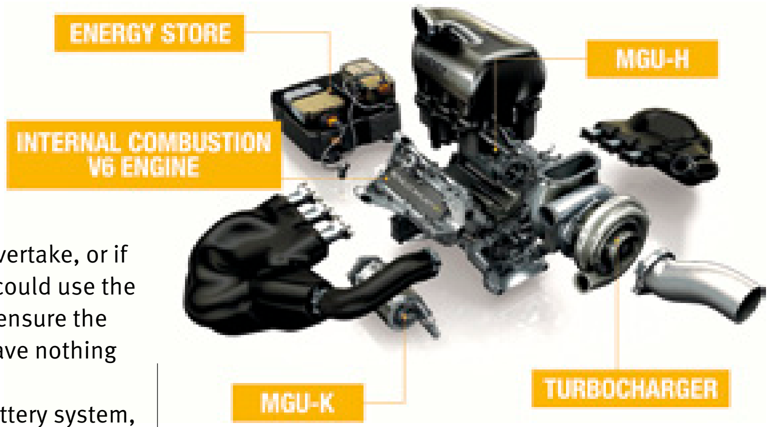
Understanding how the energy flows will be crucial to this, as Greenwood explains: "Teams could store the energy to prepare to overtake, or if the track is clear they could use the power on every lap to ensure the fastest lap time and have nothing stored."

For the choice of battery system, teams can choose any chemistry, any cooling system, and any management system. A minimum weight and maximum amount of energy used per lap is dictated by the rules but, besides that, anything goes. So does that mean we will see some novel chemistries powering these high performance cars?

"There's a lot of interest in bringing new chemistries into it," says Greenwood. "Bringing a new chemistry from the lab to the track is a quicker process than for a road car."

A battery used in motorsport needs a lifetime of hours, not years; durability can be traded off to push boundaries of performance. When developing a lithium-ion system with one team, Ricardo worked with the (unnamed) cell maker to alter the structure of the cells to keep the pack cool and achieve the energy density required.

Greenwood says Ricardo looked at the cells differently to the cell manufacturers, who focused on electrochemistry, but Ricardo examined the mechanical structure and thermal management. "The cell makers we worked with didn't think it was physically possible. We changed the internal structure to get heat out because, at the rates we use the cells, if you don't the core overheats before the outside has a chance to cool it down."



The battery packs need to withstand a discharge rate of 100-C, which creates immense heat that needs managing so as not to overheat and kill the pack. Thermal management allows sufficiently dense energy to be packed into cells structured in a way to let the heat dissipate.

Ricardo has engineering experience from a wealth of industries to call upon to find solutions for racing.

The company's knowledge of how cells not only work but die means it can engineer a battery pack to last exactly four hours running flat out.

This is the trade off in F1 that road car manufacturers could not afford to make.

So with this greater freedom, what batteries could be seen?

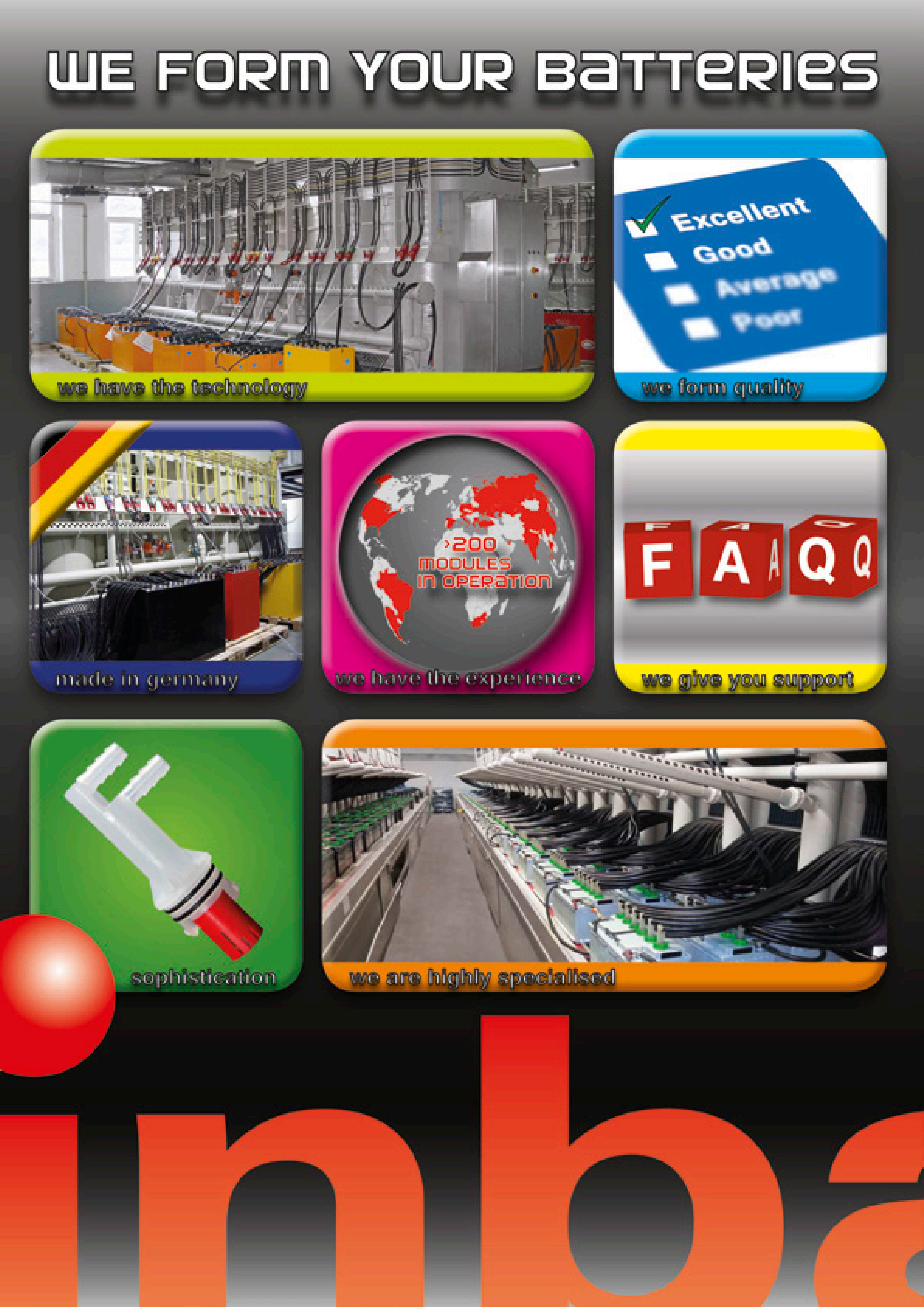
"There is great interest in anode and cathode development", says Greenwood. "We want to know how much chemistry can you pack into each cubic millimetre of cell and how fast can you get the electricity and heat out."

Getting the best combination of chemistries will be essential to a winning battery system. So which looks the most promising?

Ricardo is cautious not to reveal any team's secrets but explains lithium iron phosphate and nickel cobalt-manganese are good for power density. Motorsports need power over energy, for which cobalt chemistries would be the ultimate, but fears of thermal runaway and safety problems have meant they have not yet been selected for development.

The carmakers want to reach out to a marketing audience and it will kill a technology— or a marketing message— instantly if a battery goes into thermal runaway in a very public way. The bottom line is high profile accidents will kill the industry.

With this in mind, the battery is packaged in the vehicle to survive an impact from any angle— in accordance with F1 crash regulations. Crashes can be the most exciting part of watching F1 and watching a driver walk away from a wreck of a car shows just how well the cars are engineered.


WE FORM YOUR BATTERIES
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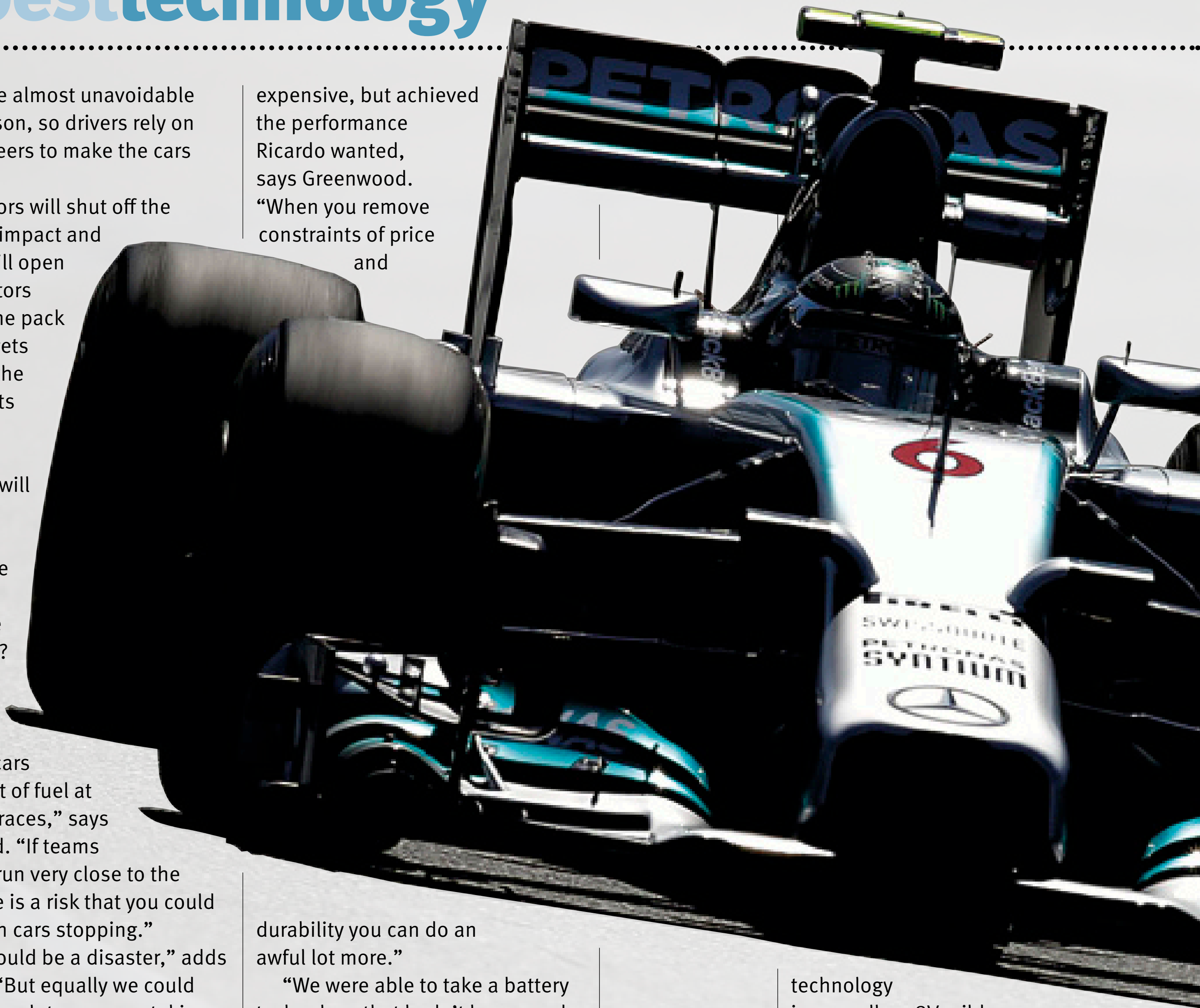
Good
Average
Poor
we form quality
made in germany
>200
MODULES
IN OPERATION
we have the experience
F A Q
we give you support
sophistication
we are highly specialised



Impacts are almost unavoidable over a season, so drivers rely on race engineers to make the cars safe.

Contactors will shut off the battery on impact and the BMS will open the contactors and shut the pack down if it gets too hot or the BMS detects anything unusual.

So how will the energy recovery and storage systems change the race series? "I would not be surprised if you see cars running out of fuel at the end of races," says Greenwood. "If teams choose to run very close to the limits there is a risk that you could end up with cars stopping."

"That would be a disaster," adds Sapsford. "But equally we could end up with a lot more overtaking because of the strategy choices. Teams can use the energy store and turbocharger strategically to overtake more and gain quick advantages."

This comes back to why F1 wants to bring in the changes: To make the races more exciting with more overtaking and lead the way with energy efficiency.

This technical know-how will filter down into road cars, says Sapsford. "The advances made by F1 show things that even cell manufacturers had no idea they could achieve. From this position they can look at reducing costs and improving durability."

The first custom-made batteries used in F1 were astronomically expensive, but achieved the performance Ricardo wanted, says Greenwood. "When you remove constraints of price and durability you can do an awful lot more."

"We were able to take a battery technology that hadn't been used in F1 before and remove constraints of lifetime and cost to see what the cells can do. When it doesn't have to last ten years it can be worked a lot harder."

These lessons can be used in road cars of the future. Ricardo has adapted a lithium-ion system that had been developed for F1 to be used in a high-performance hybrid car.

By downscaling from 100-C rate that lasts four hours to a 30-C charge/discharge rate with an eight-year life. The car is in production now and will be the leading on-road battery pack.

"These are in premium supercar vehicles, not everyday cars yet, but we are looking to use similar technology in a smaller 48V mild hybrid system with the same kinds of power densities," says Greenwood. "These will be at a cost point and durability suitable for mass-market cars."

Ricardo is well versed in engineering cars to reduce carbon using greater levels of electrification. The engineering consultancy has been involved in several projects for passenger vehicles to achieve that ends.

In 2012 it led the HyBoost project that saw the micro-hybridisation of a Ford Focus to produce a power train that emitted under 100g/km of CO_2. The consortium involved the ALABC, Ford, Control Power Technologies and Valeo.

The car was retrofitted with a 1-litre, three-cylinder engine—this was downsized from a 2 litre, standard Focus engine. An electric supercharger, energy capture and storage were all engineered into the powertrain to recoup the power levels needed to match driveability of the original vehicle.

The Focus was heavily modified, to achieve the reduced emission target it had to use fuel more

efficiently. The car gained micro-hybridisation capabilities from the incorporation of an adapted belt starter generator and 200-farad supercapacitor unit that uses double layer capacitor technology. Recaptured energy from braking is stored in lead-acid batteries.

The prototype has been demonstrated around the world and achieved 39% reduction in CO2 emissions; with an engine half the size it lowered CO_2 emissions to just 90g/km. This car was developed for the mass car market not high-end performance vehicles or niche hybrids.

On the back of the success of HyBoost the Advanced Diesel Electric Powertrain (ADEPT) programme was launched in September 2013. It brings together the previous working party and again used a Ford Focus as the demonstrator model. It had similar aims of significantly lowering CO2 emissions without impacting performance, but at lower cost.

Having demonstrated the theory with the HyBoost car, the ADEPT aims to bring emissions to under 70g/km in a diesel car.

The programme will find out the advantages of using a 48V system to cost-effectively harness kinetic energy and waste heat using available, market-ready technologies.

The ALABC involvement brings lead-carbon battery manufacturers into the arena. It has several members including East Penn, Exide and FIAMM who are developing 48V automotive advanced lead-acid batteries and collaborate with the ALABC to enhance their position in the 48V market.

The very expensive high performing batteries developed for motorsports will be downsized to be affordable and relevant until, in a few generations, they will be seen on the roads – all enabled by F1.

Other technologies have been developed for racing that did not make it as far as the track but will re-emerge in other formats, for instance Ricardo developed flywheel technology for Formula One teams when the KERS regulation came into play.

Acting as consulting engineers, Ricardo analysed available technologies for recovering and storing energy then designed the system and architecture and how to control it etc. The team looked at batteries, hydraulics systems, pneumatic systems and flywheel systems.

Greenwood explains the final choice: “The flywheel looked really promising but the lack of maturity meant it wouldn’t be at a feasible point of use in 18 months so the battery was chosen.” The risk of the flywheel not lasting the race season was too great so it was never brought to track.

Flywheels are limited by the amount of energy it can store but are excellent at getting power in and out, so are an ideal solution for applications involving frequent stop-start events.

Having been developed for Formula 1, the flywheel technology is now being used in buses and a prototype digger trialled at Ricardo’s technical centre.

The cost of a flywheel is one-third that of an equivalent battery, which means the technology is generating great interest.

In the 2013 FIA World Endurance Championship Audi raced flywheel technology in its R18 e-tron Quattro. It won its class at the Le Mans 24 Hours race and became the first hybrid sports car to win the FIA World Endurance Championship.

The FIA introduced the rule changes to level the playing field for smaller teams to get ahead by strategising but the teams with the biggest budget can still throw the most resources at building the cars so how far can tactics take them?

The big idea is hybridisation will make the cars better and the race more exciting. With greater power available and more chances for overtaking, audiences will witness energy storage enhances fuel economy and results in a better racing car.

AABC: Running out of road?

The Editor brings a fresh pair of ears and eyes to the 14th Advanced Automotive Battery Conference. Is the industry sticking to the roadmap or has it taken a detour?

This author recently saw a presentation by brand marketing guru Peter Economides, who worked on Apple's relaunch following the return of Steve Jobs in 1997. Economides' key message was that to succeed, you have to get your customers to do your work for you.

In other words, word of mouth. The early adopters and influential types buy something, like it, and tell their friends. The friends buy it, who tell their friends and so it goes on. Granny will never buy it, by the way, no matter what it is.

Economides cites Better Place, which hired him in its dying days in late 2012, as a classic example of how not to do it. He showed a Better Place commercial featuring a young man telling us why he drives an electric car. In a word, it boiled down to domestitude.

He drives his EV because "She" is for people who want to save the polar bear. The visuals of a similarly aged woman makes it clear that "She" also refers to his lover, the woman who he hopes wants to marry him and have his babies.

Ultimately, the advert (and Better Place) was, in effect, trying to sell electric vehicles as a concept—a Herculean task and probably doomed to failure.

Trying to convince someone to spend upwards of $50,000 on a car in an effort to settle down to domestic bliss with their sexy, tree-hugging partner was a bum steer, said Economides. It wasn't cool enough to influence the influencers; it was trying too hard to be cool while simultaneously trying to appeal to everyman.

Tesla is different. Flying in the face of the mainstream, Elon Musk's outfit has switched its marketing focus on to the sexiness of the car rather than the driver. The message is rapid acceleration = sexy. Saving polar bears = not sexy.

Tesla was conspicuous by its abscence at AABC 2014

A rootin' tootin' cowboy enjoys hospitality at AABC. Note the 1930s non-electric Ford

The drawback, of course, is the cost. And what is the main cost? The batteries!

Tesla, which did not attend AABC, was something of an elephant of the room. It remains an outlier. Who could have predicted when AABC started in 1999 that a nerdy billionaire would cram 7,000 laptop cells into a supercar and thus turn the concept of away from environmental masturbation to a penis-extension supercar?

Most of the presentations were by mass-market OEMs, but it would have been very interesting if Tesla had been there too, 18650s or not. Will Tesla's 'cheap' EV be able to weigh in at circa $40,000 as publicised? Besides, what will $40,000 get you? 40 miles range? 60 miles? 100 miles? Seats included? Doors too? We'll have to wait and see.

Detour from the roadmap

AABC is quite a glitzy show, sleekly managed in an impossible-to-get-lost kind of way. There are concerns that AABC is not quite the force it once was. Perhaps this is true. But if it is, it's more due to the industry taking a detour from the EV roadmap.

All the projections for EV take-up are well short of expectations. When AABC first came into being in 1999, peak oil was a real concern and future decisions about auto electrics and the contribution it could make to vehicle performance and emissions reductions were up in the air. Shale oil and gas has seen that off for the time being.

In Europe, emissions reduction targets have been delayed and/or watered down. Will the US follow suit? The final decision to adopt the federally mandated fleet average of 54.5 mpg by 2025 will be taken by Congress in 2017.

If the Republicans get in again, this ambitious target could also be seen off as an 'attack on personal liberty' or some such. Perhaps the answer to the car industry's emissions headaches lay in paying off Jeb Bush, Chris Christie or whichever character ends up winning the Republican nomination?

Even if the EV industry hasn't quite taken off as hoped, AABC remains a conference with clout on the cultural calendar, attracting C-level speakers and most of the right companies. But it is noteworthy AABC will hold its first conference in Asia – in Japan's Kyoto - in May.

The Japanese may have already won the battery war. Toyota, Panasonic, NEDC et al are years ahead in both lithium batteries and EVs, while South Korea's Samsung and LG Chem have caught them up in terms of lithium battery sales. Asia, perhaps more than ever, seems the natural place for an advanced automotive battery show.

To this end, the author was struck by a presentation by ARPA-E's Ilan Gur, who spoke about an AMPED (Advanced Management and Protection of Energy Storage Devices) project for the US DoE.

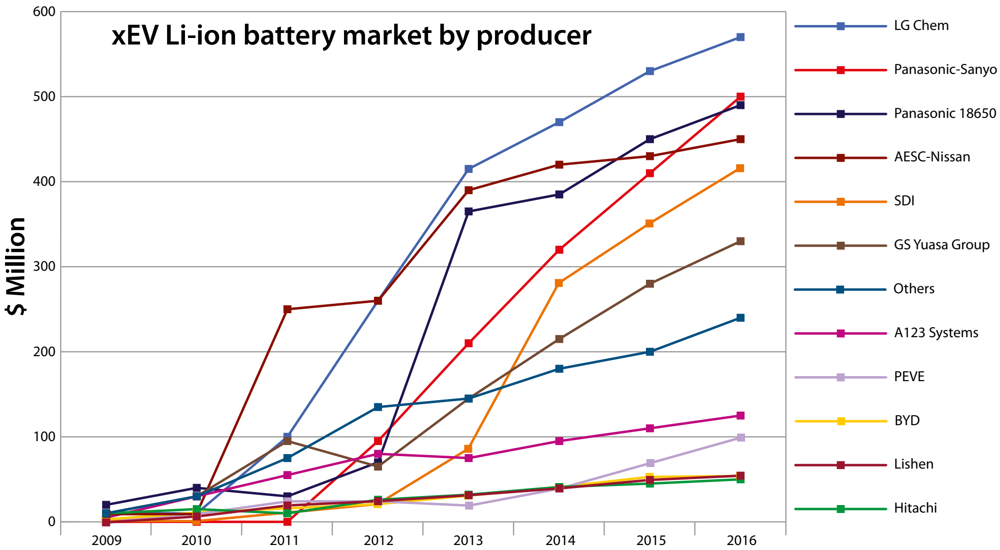
Gur repeatedly boasted about how ARPA-E was the "skunkworks" of the US battery industry, but this particular project seemed pretty conservative. Gur started off by saying next-generation technologies typically took 50-70 years to become standard issue, the implication being they shouldn't bother.

But surely the job of ARPA-E, so often compared to the Pentagon's DARPA, is to reduce this (extremely lengthy) timeline? Instead, AMPED is dedicated to getting more out of existing technology: what it calls "removing the blinkers" from lithium-ion.

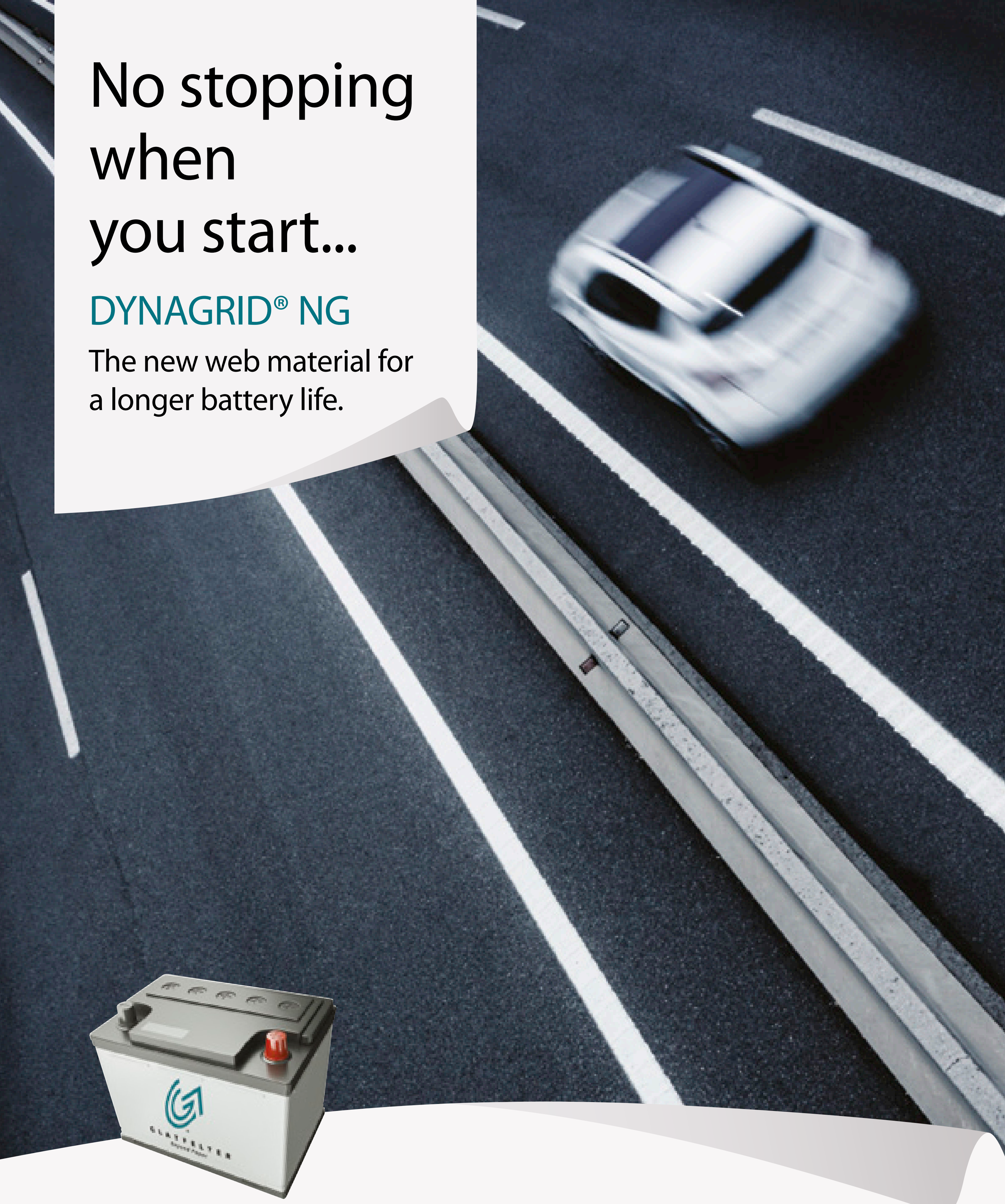
This, it is envisaged, would achieved by developing 'smart cell' battery packs, with individual cell-level active monitoring and control via sensors. A 'smart cell' system would reduce the physical capacity of battery packs by 20-30% by mitigating the need for other power electronics in the vehicle.

As this is a system-level approach, the development of 'smart cell' EV battery packs requires the input of 10-15 different development teams, so there is little chance of manufacturers developing such a system. Which is a big reason why ARPA-E is funding it.

But is this really something which should concern ARPA-E? Is this going to have the Japanese quivering in their boots?



xEV Li-ion battery market by producer- source Dr Anderman, AABC



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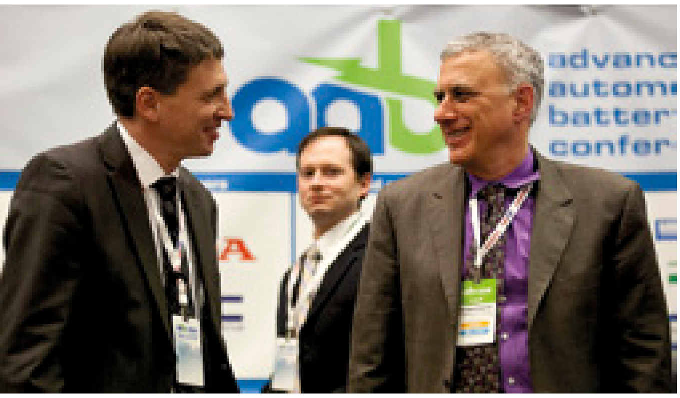
It is also highly noteworthy that both AABC Europe and AABC 2015 will both include “two to three sessions” concerning stationary battery applications. This seems a sign AABC is either running out of automotive ideas or delegates, or both.



AABC 2014 Juergen Hofmann, Andy Leutheuser and Menahem Anderman

Attendees were down roughly 100 on 2013. Is this merely due to being held in Atlanta rather than Florida, as initially planned? Next year’s AABC will be in Grand Rapids, Michigan, which may well be picturesque but is not exactly a metropolis.

Commerical breaks

AABC seemed rather like US television: commercials punctuated by the actual programmes you tuned in to see.

William ‘Freedom’ Wallace of General Motors kicked things off with a commercial for the Chevy Volt, aka the Opel Ampera in Europe. It remains the United States’ best-selling PHEV (40% of sales were in California) at 23,000 units, although sales dropped by c.350 in 2013.

GM draws encouragement from the widening socio-economic profile of buyers of the Volt. The average income of a Volt owner has fallen from $150,000 in 2011 to $75,000.

GM’s sample of 500 Volt users found they drive an average 27 all-electric miles per day, leading to an 81% reduction in gas. A concern for GM is that US power utilities are looking to recoup the cost of EV charging infrastructure – the days of freebies are coming to an end.

GM said ‘fun to drive’ was the main reason to buy a Volt. It was only when your author brought up the question of how much longer will Volts be eligible to drive in California’s car pool lanes – its days are numbered - were reasons other than the Volt’s ‘greatness’ proffered.

Michael Lord of Toyota wasted no time in saying the Prius is better than the Volt and the Leaf, but served up a few useful nuggets, such as EV sales total 10,000 a month in the US, with an 84% jump in 2013 overall. xEV sales have risen 900% since 2005 and with BMW, Daimler, Hyundai, Kia, Mazda and Volkswagen coming to the party before 2018, sales are only going one way, if not as quickly as anticipated.

As usual, Avicenne Energy’s Christophe Pillot won the ‘Most Beautiful Slides’ award at AABC 15. Even if EV sales are not spectacular, a very small EV market in the automotive world will still represent a huge market for batteries.

The ubiquitous Boris Monahov celebrates winning an iPad Mini at the AABC 2014 Networking Mixer

The respected Frenchman forecasts 10% annual growth of lithium sales until 2025, with 15% annual growth for ‘new’ lithium applications such as UPS, telecoms, forklift, medical, residential and grid energy storage.

As an aside, Pillot mentioned the cost of 18650s falling from $1.50/Wh in 2000 to just $0.17/Wh now. Expect further substantial price decreases in the coming years.

The great 48V debate

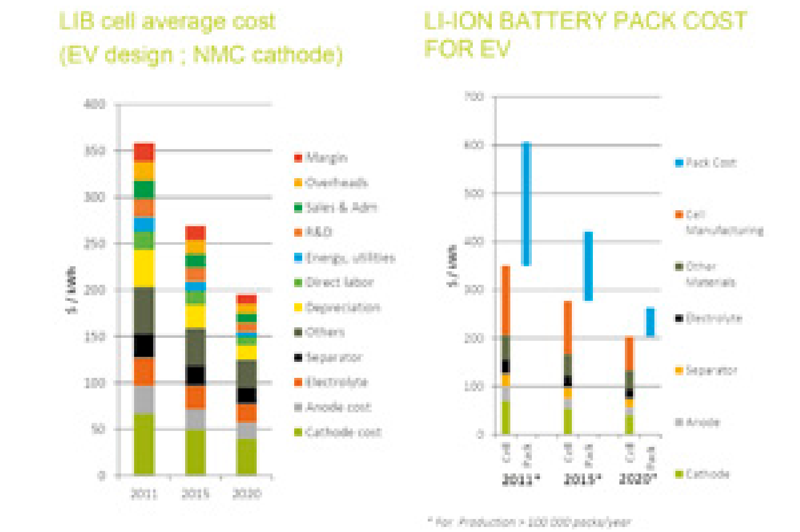
The debate about whether the auto industry should introduce 48V vehicles to cope with the growing power demands of cars continues apace. Stephen Kim of SK Continental gave the by now obligatory ‘48V is inevitable, it’s happening, please buy our kit’ spiel.

Having developed a 48V NMC pack, SK Continental is in a slightly smug position if it does take off but overall this author was not particularly convinced about its apparent low cost/inevitability.

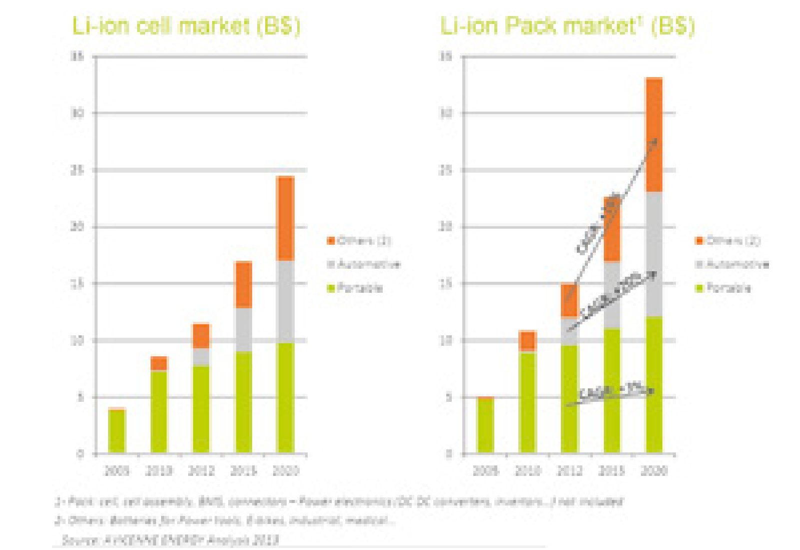
Real-world 48V driving conditions may see a 25% in CO_2 reductions against only 10% for test cycles, but real-world conditions do not matter when this is driven by regulation. Unless, of course, the regulations change…

SK Continental expects 9% of the global market will comprise mild hybrids, of which 21% will be sold in the EU, 15% in the US and just 1% in Asia. Hmmmm.

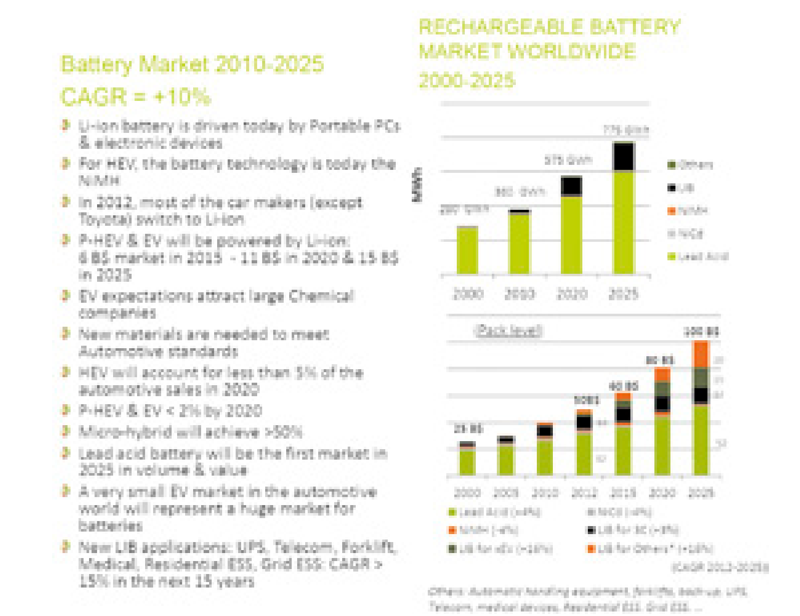
Dr Anderman then went about obliterating the arguments for 48V, starting off with a reminder of just what a flop 42V was ten years ago, with more or less only the 42V versions of the Ford Escape and GM



Li-ion battery cost 2011-2020. Source: Avicenne Energy



Li-ion cell and pack market details. Source: Avicenne Energy



Takeaways- and above. Source: Avicenne Energy

Silverado seeing the light of day. The implication was clear: 48V is the new 42V.

Dr A raised more questions than he answered. The costs of lithium 48V were a predicted $1,000/kW, more than a full hybrid EV. Can OEMs deliver a cost-effective 48V system while keeping within the 60V safe over-voltage limits? Will mass production of 48V bring down costs enough before 2020?

Is 12-15 kW at 48V really much less expensive than at 110V for a plug-in hybrid? And, that being the case, why would anyone buy a mild hybrid and not a plug-in hybrid?

The plain truth is mild hybrids are not sexy enough and even if it costs $1 500 for a 15% fuel efficiency gain, the stats show customers are more willing to pay $3 500 for 35% fuel efficiency improvement as it offers the prospect of a purer hybrid experience. Indeed, mild hybrid sales are expected to fall over the next three years.

Looking to what's happening in Japan, Dr A notes Honda has replaced its Fit mild hybrid and is offering two new powertrains: the P2 strong hybrid and the Micro-2 hybrid with ultracap pack.

While Honda and GM are likely to continue shrinking their moderate/mild hybrid offerings, European car makers are developing 48V mild hybrids for Model Year 2016 and beyond.

But at current cost levels, these can only be justified for high-end cars. Automakers have to absorb much of the extra cost and a positive business case is probably still beyond 2020.

The debate was taken on by the car manufacturers, which are looking to 12V stop-start as far as possible to meet emissions regulations in the mid-2020s. Ford's Daniel Kok said the business case for 48V was a challenge and may well not bother with it.

Compared to Europe with 25% of new sales, stop-start cars are a relatively small phenomenon in the US. But if there is one projection on which you may wish to bet your house, it is that the adoption of good old lead-acid 12V stop-start in the US will soar.

Unlike hybrids, there are common standards for almost all stop-start processes, and it is cheap, low-hanging fruit for emissions reductions. The question is: will 12V lead-acid stop-start be enough in the US?

Probably not; Ford, for example, needs to reduce emissions by 4% a year. Chrysler, meanwhile, was sweating cups about its gas-guzzling pick-up trucks ruining their future average fleet emissions.

Besides, lead-acid stop-start doesn't always functon as it should and this makes customers uncomfortable; Ford says 30% of its customers deselect stop-start. So, Ford is looking at 12V lithium-ion stop-start not only as a fix to the increased energy demands of cars, whose cabins are rapidly becoming entertainment centres, but also to harness regen power.

Kok says 12V lithium-ion is a very feasible option but the costs need to drop 30-50% to get there. LG Chem agreed, seeing 12V lithium coming down the track before 48V.

Jeff Kessen of A123 Systems says the 11.5kg weight reduction and 3-5% fuel economy saving due to increased charge acceptance puts the value of a 12V li-ion battery system at the $200 mark compared to $78 for 70Ah AGM lead-acid system.

In cash terms, the pack costs of a VRLA lead-acid battery are roughly $115 versus $600 for an equivalent lithium iron phosphate pack. This $500 cost premium could drop to $300 by the end of the decade. Although even then it will still be more than twice as expensive as VRLA, this does seem as a relatively cheap way to, potentially, meet emissions reduction targets.

A123 says there is a positive business case for 12V lithium now, but where are the sales? The cost of lithium remains the biggest hurdle, while there is also the 'hot button' issue of cold cranking temperatures.

12V lithium-ion could potentially offer 4 kW compared to 10-15 kW for 48V. In effect this would be a micro-mini hybrid; not quite up to 48V levels, but offering significant fuel economy and emissions reductions on existing 12V stop-start.

Bright lights, big city

The final day was a little PR heavy and only 90 brave soldiers managed to stay the course for the full five days of AABC. Yet one of the most interesting sessions was saved for last – on charging infrastructure.

The key messages was using the public purse won't be enough to pay for chargers – it needs capitalism – and, like the Kevin Costner movie 'Field of Dreams', build it and they will come.

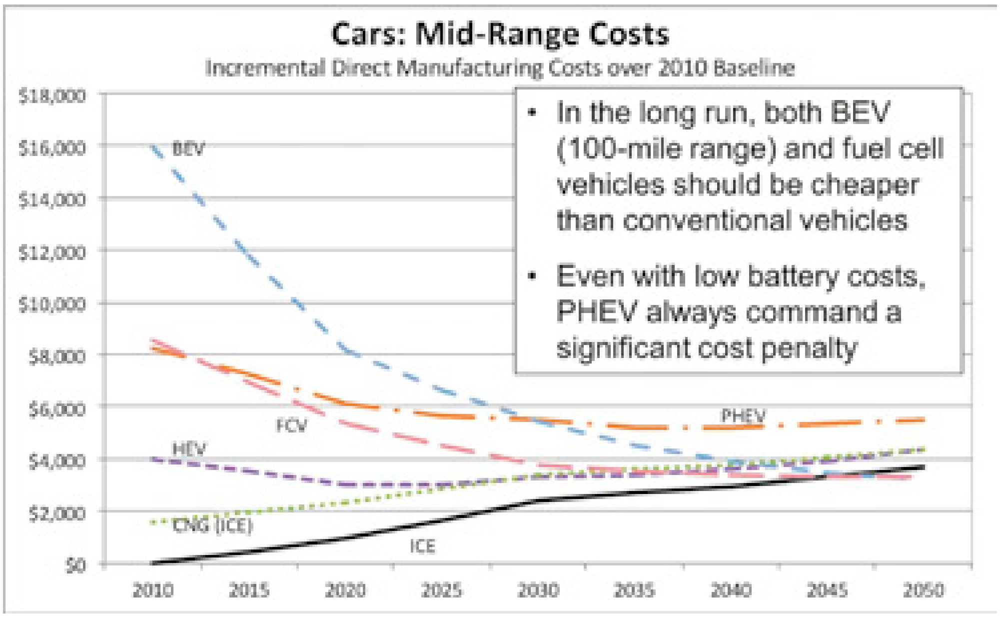
For Chargepoint, which is doing a roaring trade in installing EV equipment for private parking lots in the US, capitalism is working. So much so, in fact, that the wife of Chargepoint's CEO Richard Lowenthal has a housekeeping allowance which stretches to buying him a Tesla S for Christmas.

Lowenthal explained how free electricity for EV charging is worth $550 per employee per year to Google as a tool to retain employees. In contrast, Microsoft makes a profit from employee charging.

The 'build it and they will come' model may well work in the US, where many businesses have their own parking lots in which to offer subsidised charging. In countries where there is not a mall on every corner and citizens make use of their legs to get around, however, public charging may be needed for EVs to take off as hoped.

This remains a very tough nut to crack. EVs are being sold as city cars, but many city dwellers live in apartments without practical access to charging. Furthermore, with space in cities at a premium, installing charging infrastructure may mean retrofits.

Mark Duvall of EPRI put the cost of retrofitting car parks at $100,000 for a DC charger. Who is going to pay for that? In this case, capitalism



Car incremental cost over baseline-High-Production midrange estimates. Source: John German of the International Council for Clean Transportation won't be enough; it'll need grants, subsidies, mandates etc.

An elephant in the room

One of the main takeaways of the 14th Advanced Automotive Battery Conference was the future cost of electric vehicles versus their ever more efficient internal combustion engine rivals over the coming decades.

Next-generation ICEs, which may feature turbo-charged dedicated EGR (exhaust gas recirculation) engines, will match or even exceed the fuel economy of hybrid cars. For a Toyota Camry, an engine efficiency rise from 36.3% to 38.4% in 2030 and 42% in 2050 would translate into a fuel economy rate of 32.2 mpg today rising to 65.6 mpg to 88.5 mpg respectively.

The message is that one of the strongest arguments to go electric– fuel savings – may not always be so.

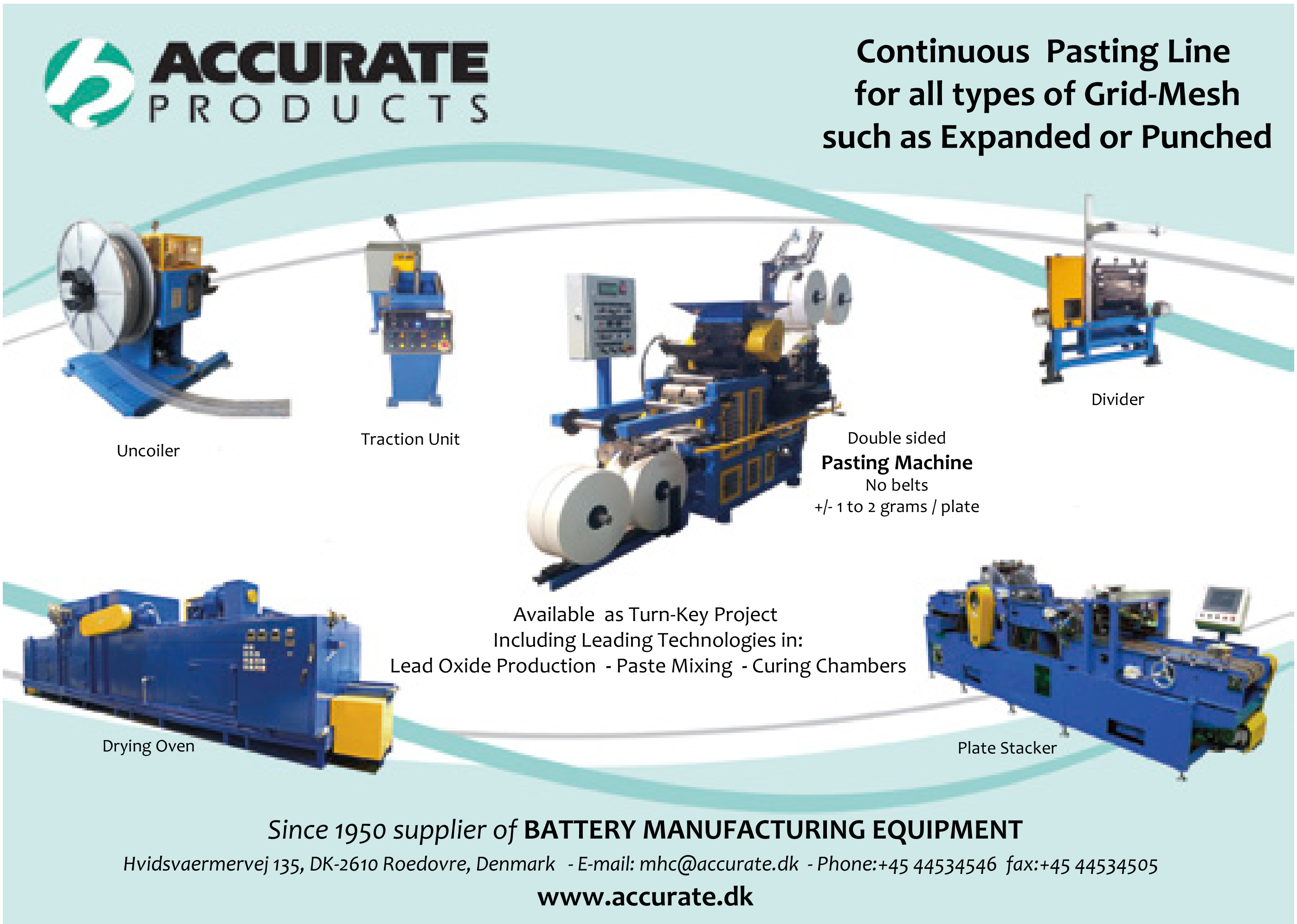
Yet for most of the advanced powertrain technologies there is a single point in the future where the costs start to get very similar. John German of the International Council for Clean Transportation had a number of interesting slides that showed the manufacturing costs of ICE, plug-in hybrids, pure EV, and fuel cell cars would converge in the 2040s.

Eventually, the manufacturing costs of ICE cars will exceed battery EVs, hybrid EVs, fuel cell cars (if not plug-in hybrids) and the cost of ownership issue will have disappeared. But this may not be for decades.

At the moment the industry is at 80 real-world miles range for a mass-market electric vehicle, but what happens when we get to 120 miles? The greater range will simplify charging infrastructure.

A lot of the need for convenience charging goes away and the need for public charging infrastructure comes from PHEVs, and they'll be lots of them. Domestic charging will be sufficient for metropolitan day-to-day charging. Fast charging will take care of the rest.

Dr A sees 120-150 miles real-world range needed for mass-market appeal of EVs. This is someway off at a realistic price point with lithium. Or will Tesla prove everyone wrong?



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John Craig— Life, lead and lithium

The Editor caught up with Enersys President and CEO John Craig for an exclusive interview about lead, lithium, new battery technology and applications, as well as some salient advice for startups.

Enersys' share price has risen around 350% since August 2011. This can't just be due to the post-crash recovery, so what is the secret of your success?

Investors are happy with our track record and where we are going. We've gone from being a standard industrial company to a growth company as well. Being a growth company, you're going to get a higher multiple in terms of share price than a standard industrial company.

We are highly diversified, not only from a geographic standpoint— we are all over Asia and India, Europe, the Americas and Africa— but also our product differentiation and customer base, whether it's telecommunications or forklift trucks. This is something investors like.

Enersys is a regular acquirer of battery and battery-related businesses? Is there a particular technology or company you like to get involved with?

At the end of September 2013 we were sitting on $273m of cash. We are not utilising that asset as well as we need to, the interest we received on that $273m is very, very low. In order to give best value to shareholders we continue to make acquisitions.

Rule number one for acquisitions is, of course, it has to be ready for prime time and make money, preferably– if not always– from Day One. We're OK with companies that may be dilutive to earnings for a year, in fact I like them, because we can turn them around. Ultimately we have to be sure of a great return.

Rule number two is it may or may not be in the battery space. We spent over $100m buying Purcell, for example, which makes battery enclosure cabinets.

Last year we said our plan is to go from $2.4 billion of revenue to $4 billion within five years, with a minimum of 10% operating earnings. Getting to that number will require additional acquisitions.

We tend to acquire smaller companies because if we acquired a large battery company we could run into government anti-trust regulation problems. This is a roadblock.

Under US law acquisitions valued at below $75.9m do not attract the attention of anti-trust regulators, you don't have to run it through the Federal Trade Commission for review. During due diligence we have our lawyers look into whether we would have to pay north of the reporting threshold.

If we could find a large company that would support what we are trying to do outside the battery manufacturing space, like Purcell, we would do it.

When we look at the acquisitions we have in the pipeline and our projected cash flow in the coming years, we actually have more capital than we need. The objective is to maximise our return to shareholders.

If we're not using it we are going to give it back to shareholders. We have conducted a share buyback and dividend programme and we will continue this for the foreseeable future due to our strong balance sheet.

The battery bubble inflated by the economic recovery programmes has well and truly burst. What went wrong?

The US Government bought the hype and spent a lot of money on a technology that wasn't ready for prime time and a lot of companies bought into battery companies at unrealistic valuations. A123, for example, was a victim of hype.

When I was asked to look at them it was clear their economic models didn't work, I didn't see them making money. When you look at the cost of these things you have to take government subsidies out of the equation to ascertain the long-term viability of a project or company.

We were telling investors this for a long time and what we said would happen has happened. The projects I know of which got big stimulus money aren't making money even though they put only 50% of the money in.

There are several battery companies in financial trouble, and they are finding it difficult to attract investment and many financial guys who invested in batteries lost, and now they are more cautious.

But the future of the battery has a lot of upsides for many years to come.

Do you have any advice to battery start-ups?

First and foremost, no-one wants to buy a battery. They are a necessary evil.

The battery is the weakest point of any system— look at computers, smartphones etc. Electronics may have changed but they haven't dragged batteries along with it: Moore's Law simply doesn't apply to electrochemistry.

Look at all the old projections for EVs and where they ended up. Why didn't they get there? The batteries failed to deliver. Thomas Edison thought electric cars were the future in the 19th century, and he spent ten years trying to develop nickel-zinc batteries without success.

Edison's saying about batteries hangs on our boardroom. He said, "The storage battery is one of those peculiar things which appeals to the imagination, and no more perfect thing could be desired by stock swindlers than that very self same thing. Just as soon as a man gets working on the secondary battery it brings out his latent capacity for lying."

Flywheels, fuel cells, 18650s, lead-acid will die and so on. I've heard it all before. But if you can come up with something that makes the end-user happy, whatever the technology, you can crack the market.

And if you can give the customer more value, an improvement on their existing technology and at a lower price, you have a home run. But failure is not a fun thing.

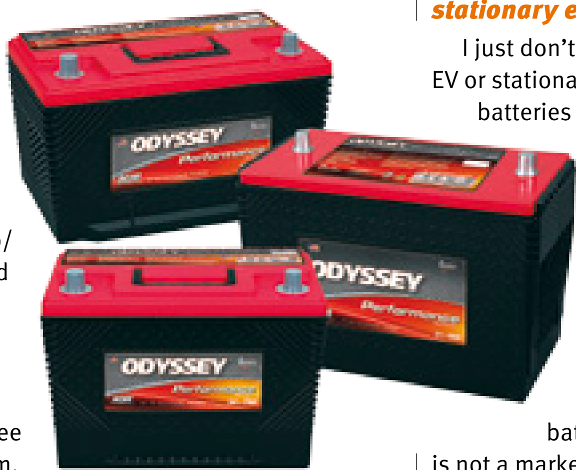
Enforcer IMPAQ chargers

Do you see lithium continuously chipping away at lead-acid sales as inevitable?

It will be a small percentage today and in the future. There are two main reasons for this. Firstly, the cost spread between lead-acid and lithium-ion batteries.

I don't agree with some of the numbers thrown out for different technologies. The real cost isn't where it needs to be. Lead-acid battery packs are $150/kWh, while lithium cells are $270-275/kWh.

But when you add the BMS, the isolation and casing required for a safe lithium-ion battery pack, you're up at $850/kWh. If the spread fell to $50/kWh as opposed to the $700/kWh difference today, then you would see a switch to lithium.



The Odyssey Performance series featuring Enersys thin plate pure lead technology

Secondly, safety. For many years I have said lithium-ion batteries will not fall but actually go up in price, due to the material in the cells and the BMS.

The bottom line is lithium cells have a tendency to catch fire and when they do it's hard to put it out. Our design philosophy, which I put in place years ago, is to assume the cells will catch fire at some point. And when they do catch fire, it needs to be self-extinguishing or isolated.

The potential for reputational damage weighs very heavily on our mind when considering battery technology. We've had lithium projects in the past which I rejected on safety grounds. The risk/reward ratio was not satisfactory for small volume sales and if something was to happen it would have damaged the reputation of the entire enterprise. It's not worth getting into and we walked away from it.

This was a few years ago but at the time our engineers weren't 100% convinced that the BMS was of the required integrity. The BMS is there now but a few years ago when we were developing projects there were still many questions and an unacceptably high probability of an uncontained fire. Today that's not the case.

Can you envisage Enersys getting into lithium for EVs or stationary energy storage?

I just don't see Enersys selling EV or stationary lithium-ion batteries as something that would make money. The lithium we are in is for satellites, pilotable devices, precision-guided missiles, medical and telecommunications.

Even with lead-acid batteries, automotive is not a market I'd want Enersys to enter because I can't see a viable way for us to make a good return. You have to be extremely high volume to be profitable. We would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have to make major capital injections to supply OEMs, and it's a very down and dirty pricing deal.

Selling lithium-ion into the auto industry is even worse than selling lead-acid batteries. The OEMs are going to push just as hard on pricing with lithium-ion as they do with lead-acid batteries.

From the cell manufacturers' standpoint, I'm not sure anybody is making money from supplying lithium to the auto industry. Most, if not all, are not making money.

I would guess that the likes of Samsung, if they are making money, can do it because they are making lithium cells to serve other industries. If they were just making lithium cells for just the auto industry, I think they'd struggle.

When you look at the lithium-ion business you will see that the industry has extreme over-capacity. The reason that 18650 cells are going into the auto industry even though large format makes much better engineering sense, is because the large format cells do not generate the sales volume that justifies the required investment. Cost is a very big issue.

If we could find a way to make money we would reconsider, just because we haven't seen it in the past doesn't mean we won't see it the future.

You launched Optigrid, a grid-scale energy storage solutions concern, in 2012. How is it performing?

It's a market just waiting to be developed. Some have projected a $100 billion dollar market for energy storage. I happen to think that's hype, but if I'm wrong that's okay. If it's $10 billion I'm happy.

The point is, there's enough interest out there that we are investing in it, as are others, but I don't know anyone who is selling a lot of large-scale energy storage systems.

It's a chicken and egg scenario. We believe there is a large market and we have a product that is ready, but the market is not yet totally ready to invest in large-scale energy storage. It's going to take time.

We are not an R&D company, but when I think a market is ready for prime time, we want to take it on to the commercialisation stage. From what we've seen with Optigrid, it could happen and we're ready for it. If it doesn't happen then we wasted some money, but this is a relatively low investment.

Meanwhile, while we are doing that, our engineers are learning a heck of a lot, as these are not off-the-shelf solutions; each installation has to be customised. You have to look at the specific installation and application. Is it for peak shaving? Frequency regulation?

And the offering is not just the battery but the whole system. This is a turnkey system; you drop it off, wire it up and away you go: the electronics, the whole nine yards.

In 2013 you entered a partnership with Ioxus to develop its ultracap technology. Why?

For supercaps, with larger Faradic values, that can use that higher power very rapidly there are applications where, theoretically, it makes sense.

We signed a memorandum of understanding with Ioxus to see if there are some things we could do with the technology in certain applications, such as regenerative braking and energy recovery, which on paper could be very promising. The investment is very low and the potential return could be pretty good, and we keep an eye on it.

I'm not in love with any technology. Our director of product portfolio management Steve Vechy takes a look at new technologies and start-ups. If we can convince ourselves that we can find a way to take the technology to a commercial level, we are very interested - whatever the technology may be. The bottom line is it has to make a good return for our investors.

What that means is customers must want the product so that they are willing to pay for it. Customers aren't always willing to pay for the technology because they're not convinced the income level arising from the improvement is better than a lead-acid battery.

The NexSys range is designed for small traction applications

Enersys sells military, medical and aerospace batteries through the Quallion brand (left)

Are there any sectors in which you specifically want Enersys to grow?

Lithium-ion batteries for medical applications. We sell millions of dollars of medical batteries through Quallion and I want us to grow in it.

We also see potential for nickel-zinc batteries. The PowerGenix technology with which we partnered is just about ready for prime time, so we are going to invest in it.

The problem with nickel-zinc is shorting due to dendritic growth. PowerGenix came up with some ways to, we believe, potentially eliminate the problem. The new battery would potentially be selling into primarily the telecommunications industry as reserve power.

We have a nickel cadmium business in Zwickau, in Germany, but cadmium may not be the most environmentally friendly solution. In Europe, nickel cadmium is used widely in the rail and aircraft industry, but nickel-zinc could potentially displace nickel cadmium.

Do you worry that environmental regulations in certain states or nations will try to put a stop to lead-acid in the future?

There are always people who say a lead-acid battery shouldn't exist, but in reality they can be manufactured very safely with no environmental concerns. There are those who haven't followed procedures or haven't made the necessary capital investment.

We used to joke a few years ago that a Chinese lead smelter was a 50-gallon drum in a fireplace. None of the regulations were being followed and we were at a competitive disadvantage. That has changed now as the Chinese government has cracked down on polluters. Every plant we have in the world, I don't care where it is, will be environmentally safe. We spend the money on the front end, and if we buy a company we upgrade it to the required standards, and beyond.

I don't think there will be a move against lead-acid batteries in Europe or elsewhere. There will be a move against those not doing lead correctly, and I think they would be right to do so. We shouldn't be polluting and putting the health of our children in jeopardy.

Your Chinese factory in Jiangdu was shut down by the authorities. What happened? Do you fear a repeat?

The Chinese authorities shut us down for a few weeks. They came in without prior warning and literally turned the electricity off while they evaluated whether we were polluting.

I reacted very calmly because I was confident in the plant. In fact there was one standard in that very old building we didn't meet. The authorities approved building an apartment complex next to our factory. The law is you can't have a factory within 500 metres of a residential area. They said that was a problem.

We hired a very reputable Chinese engineering firm which said the factory was as clean as could be. There was no pollution or problems of that sort.

In fact, we are going to eliminate the problem because we've had such success in China. We're building a new factory about 20 km away, which will lower our costs. The new factory will open in the first half of 2015, some of the staff will be transferred. Ultimately, we will shut down the old factory.

How did the shutdowns affect your Chinese operation?

The battery factory closures have been of benefit to us because it raised the prices of our competition. Before the shutdowns, our prices were higher than others in many bids we tendered for and in some cases we were the highest price. We are no longer the high price.

The environmental changes in China have also pushed up costs. In Europe, the market for Chinese reserve power products has been greatly diminished because the Chinese products are not as competitive as before the crackdown and when they received the 13.5% VAT rebate.

But you've got to remember that we are Chinese, we have a Chinese company, we compete with the Chinese everyday, in China. It's not China versus the United States or China versus Europe, it's China versus China meeting head-on in their backyard.

You joined Yuasa in 1994 and Enersys in 2000. Compared to your peers, you've been in your role for a long time. Do you have any plans to retire?

The average turnover in CEOs is six years or so. Yes, compared to that it is fairly long time. I am 62 and I've been Chairman and CEO since 2000, although part of that was being President of Yuasa Americas.

I am replaceable. I always say that if you put a finger in a glass of water you see I'm occupying space. But when you remove it the water comes together and you ask yourself, where is John? It's like I was never there.

We have good people at the company. A good leader will set an organisation in place so that he's always replaceable, and I'm replaceable.

Enersys' plant in Shuangqiao District, Chongqing is one of three Enersys plants in China manufacturing industrial batteries

From Ebonex to what's next?

In an epic saga, Applied Intellectual Capital chairman and co-founder of Atraverda Dr. Stephen Clarke tells the fascinating story of developing Ebonex for bipolar batteries and beyond, passing on nuggets of advice from, at times, painful experience gained along the way.

In early 2013, I was among many others informed that Atraverda was in administration and invited to submit offers to purchase its assets. This appeared to be a sad end to the company I had co-founded 22 years earlier.

In the intervening period, my search for low cost, high performance electrodes has led me to Magneli phase materials and a return to where I started as an entrepreneur two decades ago. Ironically, this is also exactly the same point that my father reached, when he founded Ebonex Technologies Inc. (ETI), in 1986. My objective in writing this article is to summarise, our somewhat circular journey in our search for "What's Next?" after Ebonex.

Carbon: the limiting factor in advanced batteries

To use a racing analogy, the anode is where 'the rubber meets the road'. Outside of lead-acid batteries, electrochemistry has two broadly accepted and widely deployed anode choices. These are titanium with precious metal coatings and carbon in all of its forms.

Titanium electrodes are robust, proven and cost-effective for large-scale industrial processes; however they are far too expensive for commercial batteries.

Carbon electrodes are inexpensive and date back to the earliest batteries. However, they have serious performance limitations, foremost of which is that carbon decomposes readily in the presence of many common oxidising agents.

In anodic oxygen evolution, for example, carbon turns rapidly into CO_2, an issue that prevents its use as a bi-functional air electrode in metal-air batteries, a positive electrode surface in a lead-acid battery or as an anode in many redox flow batteries (RFB). This was a lesson we learned the hard way during our development of Plurion's Ce/Zn RFB.

> "My central point is that many areas of battery development have become constrained by the limitations of carbon and there is an urgent and compelling need for better options. **Dr. Stephen Clarke**

Similarly, in anodic chlorine evolution carbon reacts to form various chlorinated hydrocarbons (CHCs). This phenomenon was the bane of the chlor-alkali industry for many years and is now an issue for some halide-based RFBs.

In the mid-1990s, we were beguiled by the promise of newly-discovered 'glassy carbon' as a corrosion resistant anode. Sadly, in the processes of interest to us, they were not.

Following similar disappointments with 'Bucky-balls' and 'Bucky-tubes' by the late 1990s, the first samples of graphene appeared with another promise of oxidation resistance. However, we quickly learned that even graphene oxidised in the anodic conditions of the metal-air batteries and RFBs we were developing.

We have not been alone in our journey to the bleeding edge of carbon's effectiveness. A search for alternatives to carbon for long life catalyst support for PEM fuel cells has been underway for more than a decade. Even the non-aqueous world of lithium-ion batteries is not immune to carbon's limitations and the search for alternative Li^+ intercalation hosts began some time ago.

My central point is many areas of battery development have become constrained by the limitations of carbon and there is an urgent and compelling need for better options.

Going back to my tire analogy, we have a situation that is equivalent to developing an F1 racing car around a stockpile of remanufactured truck tires because they are cheap. Given that anode choice is so crucial to performance, it surprises me that few advanced battery programmes choose to innovate in this area and that venture capitalists generally do not fund materials technologies.

Magneli phase sub-oxides of titanium – a primer

Arne Magneli was an early pioneer in the world of crystallography. A key contribution was determining the crystal structure of metal sub-oxides, which were both electrically conducting and lubricious. He identified what became known as Magneli shear planes. Their presence became the defining feature of a class of electrically conductive, lubricious and oxidation resistant materials.

The most widely researched of these are the Magneli phase sub-oxides of titanium (MPST). These have the chemical formula $Ti_nO_{(2n-1)}$ (the most useful are where n is between 4 and 10). The material properties derive from a structure in which layers of two-dimensional chains of octahedral TiO_2 are separated by layers in which oxygen atoms are missing.

These oxygen deficient layers are the Magneli shear planes. The most conducting is MPST is Ti_4O_7, which is almost three times more conductive than graphite. Importantly, their conductivity declines exponentially as the phases progress towards $Ti_{10}O_{19}$.

Research and development of MPST and related materials grew from the late 1930s onwards. In the US, Westinghouse, Lockheed, Bell Labs and others were important early contributors. By the late 1970s, Kaplan et al had developed a detailed phase diagram for the titanium oxide system and had documented the Magneli phases.

Importantly, by this time Lakkis et al had determined the electrical conductivity of pure phase Ti_4O_7. Their discovery that Ti_4O_7 is substantially less resistive than graphite is highly significant.

Another key feature of MPSTs is their advantageous H_2 and O_2 overpotentials ***(Table 2)***, which have the effect of suppressing H_2 and O_2 evolution: a major benefit in lead-acid batteries and other applications.

In more recent decades we have developed a much greater understanding of the fundamental structure of MPSTs. The combination of electrical conductivity and high resistance to corrosion give MPST advantageous properties in applications as diverse as impressed current cathodic protection, ozone generation, redox electrochemistry, water sterilisation, nitrate destruction, lithium-ion, metal-air batteries, and PEM fuel cells.

Material	Resistivity (µW.cm)
Copper (Cu)	1.7
Ti_4O_7	500
Graphite (C)	1375

Table 1 Electrical resistivity

Material	Hydrogen overpotential	Oxygen overpotential
Platinum (Pt)	-0.07V	+0.77V
Carbon (C)	-0.62V	+0.95V
Lead (Pb)	-0.71V	+0.81V
MPST (Ti_4O_7)	-0.75V	+1.7V

Table 2 Hydrogen and Oxygen Overpotentials

Critical limitations

Unfortunately, conventional MPSTs have a number of critically important limitations, which significantly limit their practical use:

1. Monolithic ceramic MPSTs are porous and hydrophilic making it extremely difficult and expensive to establish non-corroding electrical connectors;

2. At the nano-scale, the surface layers rapidly oxidise to the electrically insulating TiO_2. This makes nano-scale structures of MPST impractical, which is a major limitation to their usefulness in applications requiring very high effective surface areas such as air electrodes and Li^+ intercalation hosts;

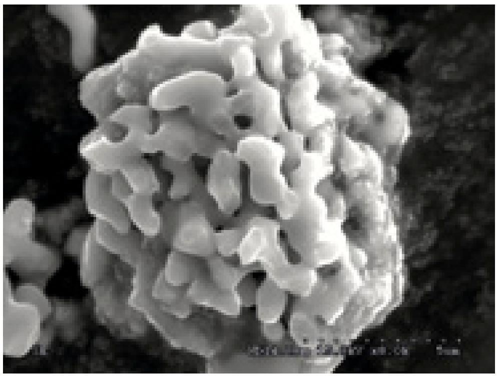
3. Nano-scale instability makes it impractical to apply MPSTs as coatings by commercial high speed processes such as PVD, plasma spray or 'slot-coat and sintering';

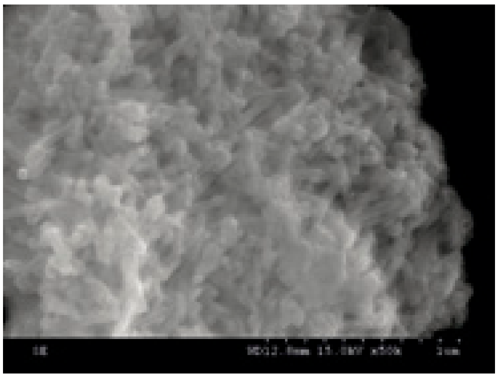
4. MPST's held in polymer matrixes have poor conductivity and lose most or all of their O_2 and H_2 overpotential benefits in off-gas suppression.

Our breakthrough material, S2Magneli, eliminates each of these limitations and for the first time makes large-scale applications practical and cost effective. Getting to this point has taken decades and this is a summary of that journey.

The 1980s: Ebonex and Ebonex Technologies

The name Ebonex was coined by Peter Hayfield, to describe a dark blue-black mixture of MPSTs consisting primarily of Ti_4O_7, Ti_5O_9 and Ti_6O_{11} produced by a novel process he developed and patented while working for IMI Marsden in





Above left: S2Magneli mesoporous micron scale powders

Above right: S2Magneli remains stable at the nano-scale - resulting in a step increase in effective surface area

the UK. In developing a production process, Hayfield solved one of the hurdles in bringing MPSTs to commercial viability.

Another key figure is my father, Robert Clarke, who tested and characterised some of Hayfield's earliest materials. He realised the importance they could have in the advanced batteries, fuel cells and other electrochemical processes that he was developing.

With the help of seed investors, my father was able to acquire the patent and trademark rights to Ebonex from IMI and establish a joint venture with the UK's ICI to form Ebonex Technologies Inc., in Emeryville, California.

Corrosion resistance, gas suppression and catalyst activity

Ebonex offered ETI a number of separate but powerfully complementary characteristics, which shaped ETI's priorities in commercialising its brand of MPSTs:

1. Good conductivity: although not as conductive as pure Ti_4O_7, ETI produced Ebonex with conductivity approaching that of graphite;

2. Corrosion resistance: MPSTs are stable in very aggressive electrolytes, including HF;

3. Catalyst support: MPST are delivering exceptional adhesion and enhanced catalyst activity both with conventional catalysts and with alternatives made possible by MPST's properties;

4. Suppression of O_2 and H_2 as outlined above in ***Table 2***.

Lead-acid battery "paste" additives

Additives are an accepted feature of LABs and are employed to deliver a range of functions including improving the efficiency of 'forming' and inhibiting sulfation in the negative active material (NAM).

Although carbon has since become a popular additive in NAM *(see BESTmag No43)*, it has a fundamental limitation that is often overlooked: it significantly increases H_2 evolution during charging. This is because it has a lower H_2 overpotential (-620mV) than lead (-710mV).

Consequently, H_2 evolution becomes preferred to Pb formation, during charging. This requires careful management to avoid electrolyte loss and cell dry-out, which results in some loss of effective capacity.

MPSTs do not have this limitation because they have a 130mV advantage over carbon and a 40mV advantage over lead, before H2 is evolved. Separately, as additives in PAM, PbO2 formation is preferred over any further oxidation of the MPST.

These features are significant and ETI undertook collaborative projects with a number of battery companies and research entities including, Yuasa, Johnson Controls (JCI), NASA and others.

Bipolar lead-acid batteries

Another of ETI's priorities was a bipolar lead-acid battery that used Ebonex as the bipole. This continued the research my father had pioneered while working for Chloride during the 1960s.

There he had developed a successful high power bipolar lead-acid battery for use as a pulse battery for the UK's Ministry of Defense (MoD), which was probably the first ever successful bipolar lead-acid battery after Kapitza.

As shown in ***Table 2***, MPSTs have an 890mV advantage over carbon and a 750mV advantage over lead before oxygen is evolved. As such, any further oxidation of MPST in a lead-acid battery is inhibited as the formation of beta PbO_2 will always be preferred.

This is critical to understanding MPSTs usefulness in lead-acid batteries (bipolar and monopolar). A key challenge however, was dealing with the ceramic's porosity.

With a bipole material, which resisted both corrosion and suppressed gas evolution (electrolyte loss), ETI had the key ingredients to develop a high performance bipolar lead-acid battery and began seeking partners in the lead-acid battery industry and beyond. NASA's Jet Propulsion Laboratory in Pasadena, California showed early interest.

"Let's boil it in acid" and other nonsensical tests

An early challenge faced by ETI was a typical lead-acid battery industry screening test, which was to boil candidate materials in highly oxidising mixtures of sulphuric acid and/or permanganate. This was a wholly inappropriate test, which did absolutely nothing by way of characterising a material for use in NAM or PAM.

However, many of ETI's samples were needlessly destroyed and Ebonex became labeled as a material that 'oxidises to TiO_2' within the lead-acid battery industry – a view that persists today.

Eventually, ETI was able to show that such screening had zero relevance to the conditions experienced by the NAM or PAM and multiple benefits were proven.

A cancelled order, an asset stripper and ETI's closure

By 1989, ETI was poised for success with the beginnings of a compelling bipolar lead-acid battery and the potential of a sizeable battery additives market. Sadly it was not to be.

After an extensive dialogue and successful testing, Johnson Controls cancelled its order for 19 tonnes of Ebonex, placing ETI into immediate financial stress. Shortly after, JCI had announced that it was working on its own bipolar lead-acid battery employing carbon as the bipole. We can only speculate whether this had influenced JCI's decision to cancel its order.

Distracted by a rumored take-over, ICI was reluctant to provide bridge funds to ETI. Unsuccessful negotiations were held with potential partners and in late 1989 ETI began seeking buyers for its assets.

Numerous other projects were abandoned, including, cathodic protection, hypochlorite generation for water sterilisation and direct anodic oxidisation of water-borne pathogens such as e-coli and crypto-speridia.

On June 4th 1991 Hanson Group made official what many already knew— it had launched an ultimately futile hostile takeover bid for ICI, whose response had been to withdraw from all non-core activities, including ETI.

Belated vindication and ignored findings

In 1995 CSIRO published a report which confirmed that MPSTs were indeed promising candidates as active material additives for lead-acid batteries. This and other more recent work vindicated my father's early discovery of the compelling advantages offered by MPSTs as an active material additive.

> “If you have a game changing technology, make sure you know which game you are changing.

Separately, in 1998 the US Air Force Research Laboratory released its evaluation of JCI's bipolar lead-acid battery. The report noted minimal cycle life, active material shedding and electrolyte consumption, none of which is a surprise to those familiar with ***Table 2*** and the limitations of carbon electrodes in LABs.

Put simply, any carbon (including polymer binders) present in a lead-acid battery electrode will exacerbate H_2 production in NAM and oxidise into CO_2 in PAM. Sadly these facts continue to be relearned to this day.

Atraverda, more boiling in acid and a fund that wasn't

With my longtime associate Darron Brackenbury, I had just started to look for a business opportunity when we learned of ETI's situation. I flew to the US to secure support from ETI's shareholders and my father. Meanwhile, Brackenbury secured a potential source of funding from UK venture capitalists 3i.

Shortly after, we secured ICI's support to acquire ETI's assets. As we pulled the deal together, 3i dropped out but we gained the backing of a new player, Korda Seed Capital Fund (KSCF).

Unfortunately, mistakes were made. The first was relocating the business from California to the UK, moving it away from what would become the epicenter of advanced batteries.

We also failed to verify that KSCF actually had the funds they had committed to invest in Atraverda. This was compounded by our naivety in accepting one-sided corporate agreements and payment milestones. This mistake would ultimately result in my co- founders and I leaving the company.

A more subtle mistake that we made is germane to nearly all game changing technology development and is best encapsulated by what became my mantra: “If you have a game changing technology, make sure you know which game you are changing.”

Our start-up strategy was to continue where ETI left off. We engaged with battery companies to launch sales of paste additives and bipoles. Both quickly stalled.

Again, we found people who insisted in boiling our samples in acid as their initial screening and we had sample bipoles snapped in two “to see how brittle it is”. We also made slow progress dealing with porosity and had yet to figure out the impact that filling pores with a carbon based polymer would have on H_2 and O_2 evolution.

It took some time to realise that potential customers simply did not understand our materials or how to test them. We allowed standardised tests appropriate for conventional lead-acid batteries when we should have required functionally valid test protocols.

Another and much bigger challenge came later, after we had overcome these initial setbacks. This can best be illustrated by a conversation with Dr. Geoffrey May of Focus Consulting that has stayed with me. His point was if we were successful with our Ebonex bipole, he would have to rip up perfectly good production lines and make massive capital expenditure before seeing any benefit.

Coming from an aerospace background where everybody is in a constant fast-paced technological race, this reaction came as a shock – one that served as a valuable lesson in the limitations of operating a high volume, low margin business such as the lead-acid battery industry.

Separately, we urgently needed supplies of powder and ceramics. A challenge exacerbated by moving the company to the UK. Our plight was not helped by a simmering trade dispute between the US and Europe over technical ceramics and the unhelpful practices of both UK and US Customs in breaking pieces off ceramics shipped as samples.

Around this time, painfully slow market progress and continuing supplier issues resulted in an understandably hard dialogue over payment milestones with KSCF. However, what came out of this dialogue was a nasty surprise.

We learned that KSCF had already exhausted their first Seed Capital Fund and were relying entirely on our early success to underpin a second fund, before any further payments could be made.

We decided to finance Atraverda ourselves for several months, while we negotiated a parting of the ways. During this time we took a hard look at alternative markets with fewer barriers to early revenue. We refocused on ETI's water treatment and ground remediation opportunities.

A key factor in this was our development of a new version of the material: Ebonex powder in a polymer matrix. This was substantially less conductive than the ceramic versions and we had discounted it as potential bipole candidate. However, conductivity limitations were irrelevant in the applications we were evaluating and we still hadn't figured out the effect on H_2 and O_2 evolution.

Importantly, we had started working with British Industrial Calendar Cable (BICC) to jointly develop a 'cable electrode' consisting of the new polymer matrix, coated around a conducting core.

Applied Intellectual Capital—a new beginning

In mid 1993 we departed Atraverda with an exclusive license to Ebonex for our 'Cable Electrode' and water treatment applications. Shortly after, we relocated to California to be closer to our core markets and formalised a relationship with BICC as a volume manufacturing partner. Darron initially remained in the UK to manage our relationship with BICC.

Learning from experience, we self-funded the company by selling and delivering consulting services in technology and business development. The US market for water treatment and ground remediation technologies were then expanding rapidly. We grew quickly and by 1996 had substantial revenues, our own fully staffed R&D facility in Berkeley and a reputation for solving difficult problems.

Our relationship with BICC and all the hard work undertaken by Darron, Dr. George Renton and his colleagues at BICC, should have been a cornerstone of our growing business. Unfortunately, what made perfect sense at the time was not to be.

Prototype testing of our Cable Electrode revealed a critical flaw, which seems obvious in hindsight. By placing our conductive ceramic into a polymer matrix, we had effectively surrounded it with carbon. The resulting O_2 and H_2 overpotentials were those of carbon not those of Ebonex.

Crucially, this meant that our Ebonex based polymer matrix evolved H_2 under cathodic conditions and O_2 under anodic conditions. This resulted in all the disadvantages of a much less expensive carbon filled polymer, making it completely ineffective for our purposes.

Around the same time, BICC's enormous bet on fiber optics failed and it went into administration, making the shortcomings of our first Cable Electrodes moot.

Continued growth, arsenic, Plurion and a new take on bipolar

Despite this setback, AIC continued to grow and flourish. In 1999 we began the sale and licensing of our own self-funded technologies. Our first of many successes was the sale of a patented technology for removing arsenic from drinking water, the long term revenues of which were potentially massive.

However, our timing was off. A hugely controversial November 2000 election changed everything. One of President Bush's very first executive actions was to rescind the US's new limits on arsenic in drinking water. Within six months most of the technology businesses active in this market were out of business.

Fortunately, I had prepared for this possibility. Recognising a shift toward big energy and electricity privatisation, we started the development of a new cerium/zinc-based RFB. We named it Plurion after the plurality of ions my father had identified, characterised, and patented. Early prototypes delivered the highest OCV (2.4V) and highest current density (5,000A/m2) of any RFB.

The story of Plurion is worthy of an entire book and is certainly beyond the scope of this article. It was as interesting, challenging, frustrating and ultimately humbling as anything I have been involved in.

We got a lot wrong but we also built a unique and amazing team that delivered completely game-changing breakthroughs in multiple areas, in incredibly difficult circumstances. Its untimely break-up was a massive loss to the emerging RFB industry and a kick in the teeth for all involved.

One big lesson from nine years and over $20m invested in Plurion is that carbon based electrodes, even highly advanced 'super secret sauce' versions developed specifically for us by GE's polymer division— don't survive in even trivial levels of anodic oxygen evolution.

Bipolar back to basics

AIC's most recent battery development was a total rethink on bipolar lead-acid battery—stripping it down to its essential elements.

This was driven by our insights into the sheer scale of China's 130m lead-acid battery powered electric bikes. Our response was to develop a bipolar lead-acid battery that could be produced with existing lead-acid battery production materials, equipment and tooling—heeding Geoffrey May's words from two decades earlier.

Our team was led by Selwyn Mould with Frank Lev as CTO, two product focused and detail oriented geniuses that I am privileged to work with. In essence, we revisited my father's original and successful 1960s work. We added more recent developments in lead metallurgy and lead-acid battery manufacturing technologies, critically important insights into electrode/active material interfaces and decades of developing bipolar batteries and electrolysers.

In parallel to this, I took AIC public and then private again, which is beyond the scope of this article. By mid-2009, we had a series of 12V and 48V bipolar lead-acid battery prototypes that exceeded our 100-cycle specification, delivered energy densities in excess of 35Wh/kg and had the potential to deliver significant cost savings.

During this time we made multiple attempts to secure e-bike partners in China. The last and most serious, was centered on Wuhan in 2009, with local investors, the promise of a 100,000 ft^2 turnkey factory and the backing of a city of 20m people. Months of excruciating negotiations culminated in a very high profile, very well attended and televised launch ceremony.

Four months later it ended, with our Chinese partners in breach of contract, having failed to meet even their most basic obligations.

By the time we travelled to Wuhan to close the deal, I suspected a much darker purpose to some of our investors' interest. We arrived with bogus specifications for our bipole among the sanitised files on our laptops, to misdirect anybody that hacked our laptops— a necessary protocol when travelling in China. Given the subsequent breech, I was not surprised to learn of a Chinese company manufacturing a bipole matching those specifications some time later.

We decided to abandon China, focus on the US and take another look at the energy storage market for bipolar.

In 2009, the production capacity of the lead-acid battery industry was 40 times that of every other battery industry combined. The cost of building lead-acid battery production capacity was one-tenth of that to build lithium-ion battery facilities. So it seemed obvious that the only players capable of moving quickly enough in energy storage would be lead-acid companies.

At the start of 2010 we signed the start of what would become a multi-stage sale of this technology, which we concluded in early 2013.

S2Magneli: Battery electrodes and additives Part 3

Having spent the intervening years between co-founding Atraverda in 1991 and its entering administration in 2013 dealing with the shortcomings of carbon-based electrodes, I recognised that there was no effective leadership in the search for alternatives. So I decided to pull together everything I had learned about Magneli Phase materials and re-enter this market.

The key to this is 'S2Magneli', a new and patent pending material, which unlike conventional MPSTs, resists oxidation at the nano-scale. This makes S2Magneli uniquely compatible with a wide range of commercially available coating processes.

Naturally, our areas of focus include paste additives and we are supplying samples to battery companies for joint evaluation and optimisation.

We have also started evaluating electrode applications in a range of advanced batteries including a novel monopolar lead-acid battery; AIC's patented methane sulphonic acid (MSA) based zinc-air technology; and a completely new bipolar chemistry. This is confidential early stage work, much of which will require funding.

A surprising opportunity in lithium-ion batteries

As lithium reaches ever-higher capacities and power, Goodenough's original choice of graphite as the Li+ intercalation host is approaching its limit. Fundamental limitations are being revealed which impact both capacity and cycle life, while simultaneously undermining safety.

Our work on this area is at an early stage but if we are successful S2Magneli could deliver a lithium cell-level energy density of more than 400 Wh/kg, with improved safety, a simplified BMS, longer cycle life and reduced cost.

EboNEXT is a new company making the most of past learning experiences. As with all young companies we are balancing revenues with growth and exploring investment opportunities.

We currently offer S2Magneli as a coating, a powder and as a ceramic of varying porosity. Our market approach is to supply S2Magneli as an engineered product, taking

Early 48V and 12V bipolar battery prototypes advantage of its stability which allows us to leverage existing large scale commercial manufacturing processes.

Importantly, we do not supply anything on an "arms length, test and see" basis. We view users of our products as strategic partners and work with them to develop a product, which is optimised for a specific application.

An open, two-way sharing of information is implicit in this type of relationship and we require significant commitment and a desire to find success, from our partners. We are currently building strategic relationships and expanding our supplier base and we welcome collaborative research with universities and other research partners.

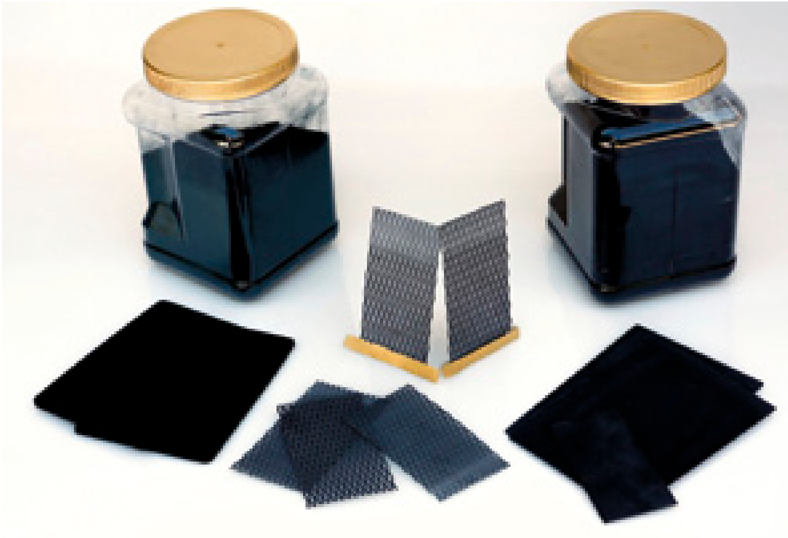
One defining feature that continues to make the carbon industry so successful is the active engagement of raw material suppliers in developing high value added products. It continues to surprise me that for 30 years the TiO_2 industry has been conspicuous by its absence in this regard and we are open to a dialogue.

Valuable lessons learned

Writing this article has been a reflective journey through three decades of our own start-ups and spin-offs, while working with government agencies, legislators, investors and our many consulting clients. Here are a few final thoughts I'd like to share from that experience.

To misquote Churchill: "Governments will support the right technology but only when every available alternative has been exhausted". After decades of trying to disseminate an understanding of carbon's limitations we may just be getting there.

If you have a game-changing technology— make sure you really understand the game. Those who survive on wafer-thin margins in 'legacy industries' know exactly what game they are playing and will fight harder than you could ever imagine to retain control of it.



S2Magneli Materials

If you are going to develop an electrochemical technology— consider hiring electrochemists. I am amazed by how many battery companies don't! Sure you can work it out from first principles using quantum mechanics, wave theory and a supercomputer. You will get there much faster if your staff knows what the electrochemical series of elements is, how to install pH meters without generating a ground loop and how to interpret a CV plot. Alternatively, we can do it for you.

If you are a battery start-up, do not hire your CTO or your technical team straight out of university— you will spend too much effort stopping them from immolating, poisoning and/or gassing themselves and those around them. Far too many of our consulting clients have suffered serious industrial accidents for want of training and experienced technical leadership.

Today's venture capitalists struggle badly with applied science and are hopeless with applied materials— by now this should be self evident but it doesn't make it acceptable. We have some ideas in regard to this.

Finally, I want to thank the many people who have shown extraordinary help, kindness and at times great courage in helping me, my co-founders and our colleagues over the years.

About the author

Dr. Stephen Clarke has spent more than two decades developing and commercialising advanced battery and separation technologies. He is an early pioneer in energy storage and recently helped the California Energy Storage Alliance (CESA) secure California's Energy Storage Mandate (AB2514).

Clarke began his career in aerospace with Rolls-Royce, helping prepare it for re-privatisation in 1985.

In 1991, he co-founded Atraverda with Robert Clarke (his father) and Darron Brackenbury, to continue the business of Ebonex Technologies Inc., (ETI). In 1993, they formed Applied Intellectual Capital (AIC) where he is now Chairman. He is also CEO of Aqua Metals Limited a new battery recycling venture.

Clarke recently returned to Magneli Phase materials with a novel, patent pending Structurally Stabilised Magneli Phase material S2Magneli.

Sovema: Tooling up for the future

Life has been good for Italian battery machinery maker Sovema in recent years but its senior management is riddled with doubt about the future. What's next? What does the future hold? Should Sovema jump ahead of the competition and develop completely new machines? Or should it rest on its laurels and sit pretty as sales roll in? Tim Probert visits Sovema's HQ in Verona to find out.

When this magazine is invited to visit a factory, it does not usually expect to be told about something radical. ***High quality equipment?*** Yes. ***Positive noises about future growth?*** Certainly.

A vision for the future, perhaps moving away from established products to an as yet unknown range of products? Definitely not. Except, in this case, during a visit to Sovema's headquarters in Villafranca on the outskirts of the romantic Italian city of Verona.

Sovema very much had something to say. While the most diversified maker of machinery for the lead-acid battery has been very comfortable selling equipment to make mostly automotive starter batteries— consolidated turnover has doubled to €80m ($110m) in recent years— Sovema foresees important changes in the lead-acid battery business.

Right: Maurizio Masotti, CEO, Sovema

Below: Sovema's Villafranca headquarters

The smart PunchPlus machine

It knows that in the not too distant future, cars will not be powered by only a 12V starter battery. Batteries will need to do other things than just starting once a journey; stop-start cars already do this, of course. Hybridisation, such as e-boosting via electric motors, is expected to become increasingly popular.

Whatever the chemistry— lead-acid, lithium-ion— or whatever the architecture— 12V, 48V, single or dual battery— Sovema believes change is coming. Moreover, the market for batteries overall is growing. Lithium-ion may be taking a larger slice of the pie, but the pie itself is getting bigger. Grid-connected energy storage is also viewed as a major opportunity.

As CEO Maurizio Masotti puts it, there are good times on the horizon, but it must open its eyes to new ideas. "For too long the industry has been reliant on selling the same type of battery," he says, "But the lead-acid battery industry can no longer afford to be conservative. There is a clear need to improve the performance of lead-acid batteries, be it cycling or weight.

"People are telling us the new batteries the market wants are not going to be manufactured simply by improving our current equipment, even with lead-acid. We need to start investing now."

The strong feeling is that if Sovema does not start today, it won't be able to take the revenue of tomorrow. But what does that investment look like? Well, for starters, it means a €2.5m expansion of its headquarters.

This will increase Sovema's production footprint by 3,000 square metres to 13,000 square metres. This area will be used to enlarge Sovema's power electronics and its SoLith lithium-ion workspace.

As BEST went to press, Sovema was in the process of completing the expansion of its office space by 1,200 square metres.

Crucially, the expansion also means increasing the brainpower of the organisation to, in essence, work out what are the next machines it needs to make beyond its existing expanded metal, punching and assembling machines. To this end, Sovema is planning on recruiting a further 15 engineers in an effort to enhance its product development ability.

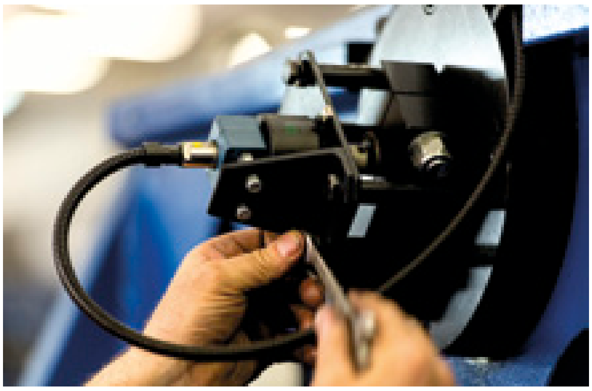
Above all, discussions with customers have convinced Sovema of the need to pursue new ideas and projects, says Masotti. "In recent years we have had a growing number of requests from customers to design new machines. But before we do that we have stepped back to see the big picture before we move forward towards the future and we came to the conclusion that we need a more solid and diversified R&D capability.

"Sovema has understood that the theme points towards a trend for an advanced lead-acid battery and different electrodes for very thin new plates." Due to non-disclosure agreements, Masotti was extremely tight-lipped. "We are moving from the traditional plates towards different, lighter electrodes. We have to increase our ability in handling ever thinner material which resembles a piece of paper."

While he couldn't speak of anything in detail, Masotti says Sovema strategy's for the future is to commit itself with lithium-ion cells and with those other battery types that use very thin electrodes, that involve different technologies.

Power electronics

Sovema has created its 'power electronics' unit because, says Masotti, "It is our vision that to be successful in our market you need to offer customers in the world the complete product range and also because increasingly the chargers are non-isolated machines. Instead they are rather well integrated in



Sovema cares for the accuracy of all details

the formation modules. "At present both for lithium-ion cells and advanced lead-acid, the 'charger' element is integrated in the formation module, which means you have a combination of mechanics and chargers."

"At the end of the day, for whichever batteries we are making equipment, if formation will be an important part of our improvements. So we need more power electronics skills for formation."

To this end, Sovema has recently taken on Dr. Luca Lucchese, a University of Padua electrical engineering undergraduate and contemporary of general manager Massimiliano Ianniello, to head up Bitrode Europe.

"Power electronics is in the middle," says Ianniello. "We developed our chargers brand in 2005, then we acquired Bitrode in 2008. We are now trying to use our collective experience to enter into formation for different lithium-ion

chemistries. We have started interacting with different people, such as lithium-ion electrode makers, battery pack makers, the end user, potential customers or potential colleagues for joint ventures or projects to make new equipment."

Brainstorming over espresso

Ianniello, due to take over from Masotti as CEO by mid-2015, explains his philosophy for Sovema.

General manager Massimiliano Ianniello

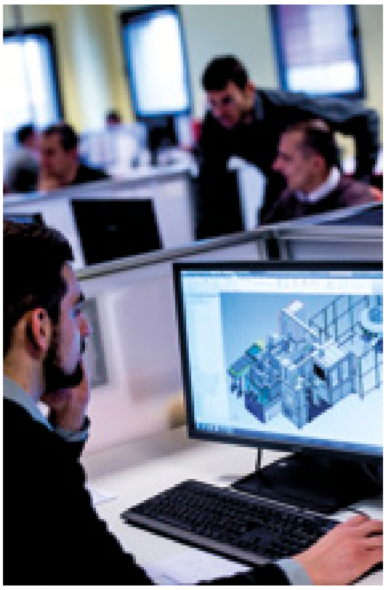
"I don't like being in a comfort zone," he says. "The lead-acid industry has been asleep for 30 years. But it has to do something or it won't be around in the next 30 years. The younger people in the industry, and I include myself as one, have to be greatly concerned about this and do something about it— it is the only way we can survive in the long term.

"So the vision is to combine, under one roof in the same company, the knowhow of Sovema— the automation and mechanical knowledge of lead-acid and lithium-ion, and power electronics for approaching the formation process— with our investment in R&D and new competences. This is starting from what we are well known for, moving towards something that is still on paper and is largely unknown. Ultimately, we are trying to prepare ourselves for an uncertain future."

Ianniello believes an important part of preparing for the future is to facilitate a creative environment, where employees mix rather than work in silos. For many years, Sovema employees have exchanged their ideas in front of the vending machine and this has led to conceive and formulate new ideas.

Sovema wants its staff, with knowledge of different technologies and processes, to work together rather than having three different companies– Sovema, SoLith and Bitrode- making 'Product A', 'Product B' and 'Product C'. It believes it would be much more effective if its people working on different areas interacted to help each other and come up with new ideas.

Therefore, the old office space will be dedicated to developing new products and perhaps, in turn, new businesses. The new office space includes a brainstorming room, with additional vending machines, to serve as a breakout place for employees to reason out on the future of the battery industry over coffee.



"The brainstorming area is about doing things differently, taking people out of their comfort zone, and exchanging ideas," says Ianniello. "I like dreamers. I believe in Sovema employees being stimulated, to come up with ideas, rather than constantly being told what to do on a day-to-day basis. I believe that any successful company should foster a creative environment rather than having a few executives telling everybody what to do.

"Our employees have incredible ideas, but sometimes they don't tell us because they are not used to doing so. The problem with this approach is you don't have tangible results every day. But maybe in ten years this approach will have borne fruit and I can say I was right."

Ianniello is rubbing his crystal ball feverishly to see what the future holds for Sovema in the 2020s and beyond. "For the next five years at least, the future is defined: improving the quality of production of standard lead-acid batteries. This is clear but this is not a fundamental change. We are looking beyond the next five years towards the 2020s.

"We see a big question mark as to what will be the correct technology for the future, either for energy storage, off-grid applications or increased electrification of vehicles. You cannot exclude the evolution of lead-acid batteries within this, nor lithium-ion. There could be a hybrid technology, perhaps combining lead-acid and lithium-ion."

Sovema sees an opportunity with research programmes such as the European Union's Horizon 2020, which has a budget of a whopping €79 billion ($109 billion). Sovema has been approached to participate in a €5m ($7m) programme to design and make new equipment for one such Horizon 2020 project, but turned it down.

"There are many opportunities for new projects and equipment. In fact, there are probably too many opportunities. In the past year, the number of requests from customers old and new has exploded, mostly for lead-acid. It's now time to select which opportunity to pursue.

"The SoLith team is doing the same but on a different scale, i.e. pilot plants. They also working on a new area and bringing in new concepts and experience, they have been asked to design a module assembly line.

"While we may be the experts in battery making equipment, we're not the expert in making complete systems. And we can't be the experts in every area of battery manufacture but we have selected some areas for engaging in projects, which generate revenue."

Ianniello is under no illusions that he has a difficult job on his hands in managing the transition to a 'new' Sovema when he takes the helm in 2015. Calling his job "80% dreaming", he knows his people must not only work on today's turnover but also focus on the future.

"The new approach is more difficult because we have new people, new potential customers to make new technologies. We are not a giant company but we have to do this because we believe it will give us a big competitive advantage.

"I'm not sure if our competitors have similar ideas to combine lead-acid machinery with different competences like power electronics, automation and so on, but I know we're not the only one seeking to diversify into other areas."

Existing products

By squeezing the milk of the cash cow of lead-acid equipment the company can afford to invest in the future, but for all the talk about vision and the future, Sovema is not neglecting its sales opportunities in the present.

This year Sovema is launching an improved drum paster, as well as a 30 tonnes ball mill, a significant increase on its previous model of 24 tonnes.

After two to three years of testing and trials in various locations around the world, in the next quarter Sovema will launch an improved version of its enveloping machine.

"We have solved the reliability and other issues," says Ianniello. "Some of the parts were unreliable meaning we were unsure how long the machine would last. We like to put our machines in the most unflattering places where the customer is effectively abusing the machine.

"We cannot pretend that the first or second machines we make of each model will be perfect. Every machine has a weak point, the most important part is the concept is not the weak point, but the manufacturing process is."

Ianniello sees good prospects for sales of the enveloper in Asia, particularly in China. "We're competing head to head with BM Rosendahl and TBS. We're fighting hard in a competitive market on quality rather than on price."

Sovema is also developing a new punching machine, one which Ianniello claims is unlike any other on the market. "We want to have a 'smart' punching machine that allows the operator to know exactly what is going on with each phase of the process."

Ianniello says the ability to immediately identify and isolate faults would be of great value to a battery manufacturer. "When a punching machine works, it's OK. But when it's down, everything has to stop.

"These machines may last for life but you don't know where they stopped and why they stopped. At present the market demands the installation of very sophisticated and precise sensors."

Ianniello notes a big demand for quality lead-acid battery making equipment with process control, especially for customers who make products for automotive OEMs. They want tracking capability for every step. Fast production speed is not enough, they need to track and control quality.

"We know that our customers want to have constant quality assurance. If you can control your process constantly, like with a strip caster, you can control the process constantly. This gives the machine an added value, not just speed and productivity, but quality. We don't aim to reach higher speeds only, we would rather improve reliability and consistency of quality of the finished product."

Sovema has already installed two 'smart' punching machines, one of which is in Italy, with another two due to be installed shortly.

For its strip casting machines, again Sovema wants to be seen to be competing on quality rather than price. Of course, the quality of the product depends on what a battery manufacturer wants to achieve: speed, quality, the reduction ratio from the roll strip to final strip and so on. All this affects the quality of the lead strip.

Sovema says it is also exploring the option of a 'smart' strip caster, but these are already important investments.

"Our competitors would like to have Sovema's quality at a lower price. Price could be a disadvantage but the advantage is the solid quality of the final strip, which nobody else can touch.

"It depends on whom you sell this equipment to. We know we could sell a strip caster to a customer at 50% less cost, but it would come with a 50% or more reduction in quality. Customers want the same quality at a lower cost. Perhaps in the future it may be possible, but at the moment we are ready. It's not an easy job but it's a direction we can pursue.

"We are not focused on having expensive options to raise the price, this must become a standard product. If I have to raise the price I try to do it only by the bare minimum. The aim is to achieve higher quality at the same price."

Sovema knows that in the lead-acid battery there is likely to be an attack on its business on two fronts. For the time being, continuous product development will keep them ahead of its competition, not least Asia, for existing products.

But it also knows there is a long-term danger of being a maker of machinery for potentially obsolete products. There is a war to win and Sovema knows it.

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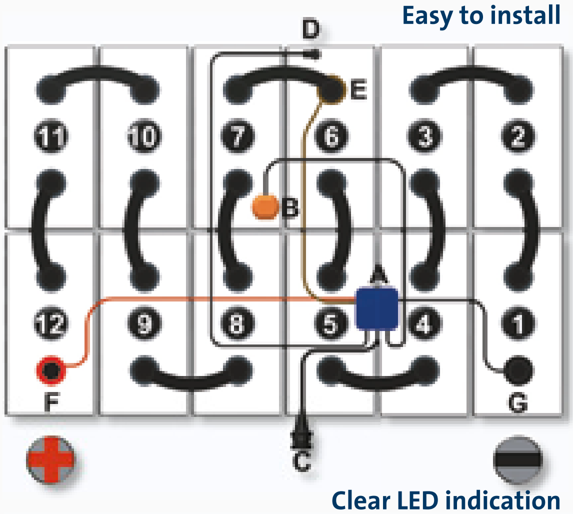

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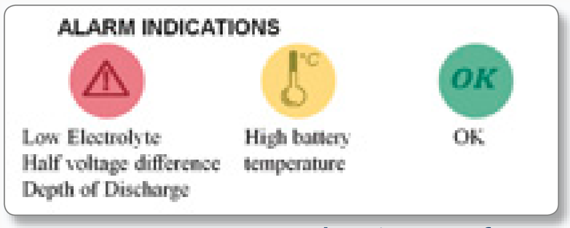

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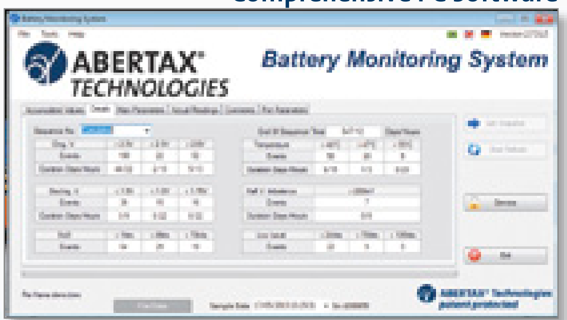

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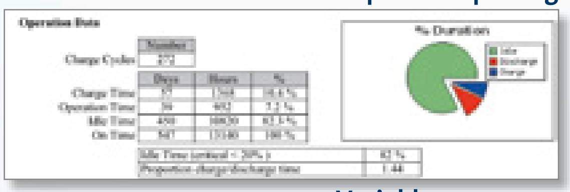

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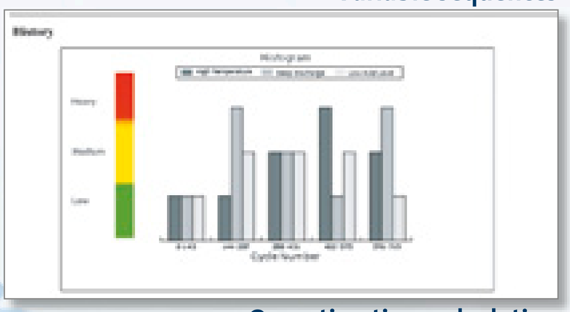

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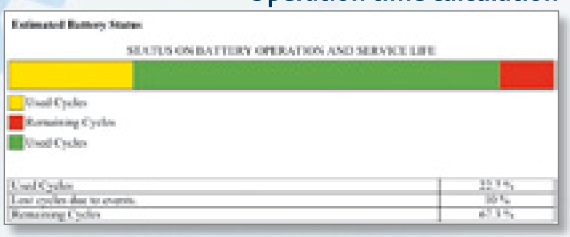

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One shot or two? Flooded container formation methods

In the ninth of a comprehensive step-by-step guide to the manufacture of lead-acid batteries, resident expert Mike McDonagh looks at methods of flooded container formation.

In the previous article the physical and chemical principles of converting cured pasted plates and lead oxides into formed active material were discussed. Included was an examination of the side reactions which reduced the efficiency and consumed energy and resources.

The dry cured green plates are either assembled into batteries (container formation) or supplied separately for dry charging (tank formation). An electric current is applied which supplies the electrons necessary to convert the cured or pickled plates into the formed active mass according to the following reactions:

Positive:

$$PbSO_4 + 2H_2O = PbO_2 + H_2SO_4 + 2e^- + 2H^+$$

Negative:

$$PbSO_4 + 2e^- + 2H^+ = Pb + H_2SO_4$$

As can be seen, the positive plate generates sulphuric acid, hydrogen ions and electrons. The negative plate consumes the electrons to produce lead and sulphuric acid. Because the acid is dilute, it contains water. This is broken down at higher voltages to produce hydrogen and oxygen ions which are released as gases according to the following simplified reactions:

$$2H_2O \rightleftharpoons O_2 + 4H^+ + 4e^-$$

at the positive electrode

$$2H^+ + 2e^- \rightleftharpoons H_2$$

at the negative electrode

These reactions are common to all lead-acid formation methods including flooded, starved electrolyte, gel and single plate tank formation. This articles examines container formation for the majority of lead-acid flooded battery systems, including automotive, traction and semi-traction, monobloc and 2V cells.

It is evident that the production of sulphuric acid, the breakdown of water as the voltage rises and the heat evolution from chemical conversion and polarisation effects, reduce the process efficiency. Additionally, the loss of water, the safety hazard due to the production of the explosive gas hydrogen and the acid mist created by vigorous gassing within the acid electrolyte are equally concerning.

The major factors inhibiting efficient conversion are:

- Increasing concentration of sulphate ions in the electrolyte, which raises the cell voltage and increases the internal resistance;
- Electrolytic decomposition of water with evolution of hydrogen and oxygen gas;
- Heat generation.

The causes of these effects were discussed in the previous article. This title examines current lead-acid battery formation methods and how well they address the above issues. The methods in common use are:

- Single-shot formation (1S);
- Two-shot formation (2S);
- Acid recirculation.

When discussing energy efficiency it is a commonly held view that this is referring to the coulombic efficiency. It is important to understand that the quantity of amps put in over the formation time period is not the energy input. The energy consumed must be calculated by multiplying the ampere hours by the voltage of the circuit or per battery.

For instance, an ampere hour input of 120Ah at an average voltage of 2.44V per cell uses 8%

less energy than a programme which has the same ampere hours but has an average voltage of 2.65V per cell. This is without taking into consideration the heat generation associated with each programme.

The processes address, to varying levels, the need to maximise energy efficiency and to reduce loss of water and gas evolution, whilst minimising the throughput time. The different formation methods have varying degrees of success in reducing the effects of the competing reactions. The amount of water loss due to gassing, for instance, is influenced by the charging voltage and the current input.

However, as temperatures rise, the voltage at which the gassing reaction occurs is lowered. This results in higher gassing rates and an increase in the water lost from the batteries on charge. Clearly, keeping voltages as low as possible and temperatures as low as possible is desirable, however, these measures will inevitably result in extending the formation period with loss of throughput and loss of revenue for a fixed capital spend.

Inevitably the formation department of a lead-acid battery manufacturing company is a capital intensive and high maintenance area. The charging equipment has to control the current input to a high degree of accuracy with distinct profiles for different sizes and types of battery.

This necessitates the use of programmable formation equipment with computer controlled outlets, charging in accordance with stored algorithms. Cooling is generally carried out using water baths, and in some installations the water temperature is measured and used as feedback information to control the current input.

Evolution of explosive gases is a serious problem, as is the production of sulphuric acid mist. This mist is the result of the vigorous production of bubbles in the electrolyte from evolved hydrogen and oxygen gases. ***Figure 1*** shows a typical set up for charging of flooded monobloc batteries. Note the covered area under extract and the water baths with running recirculated water.

The processes are listed in ***Table 1*** which makes a comparison of the ability of these methods to address these problems. These are on a relative scale of 1 to 10, where 10 is the most efficient and 1 the least.

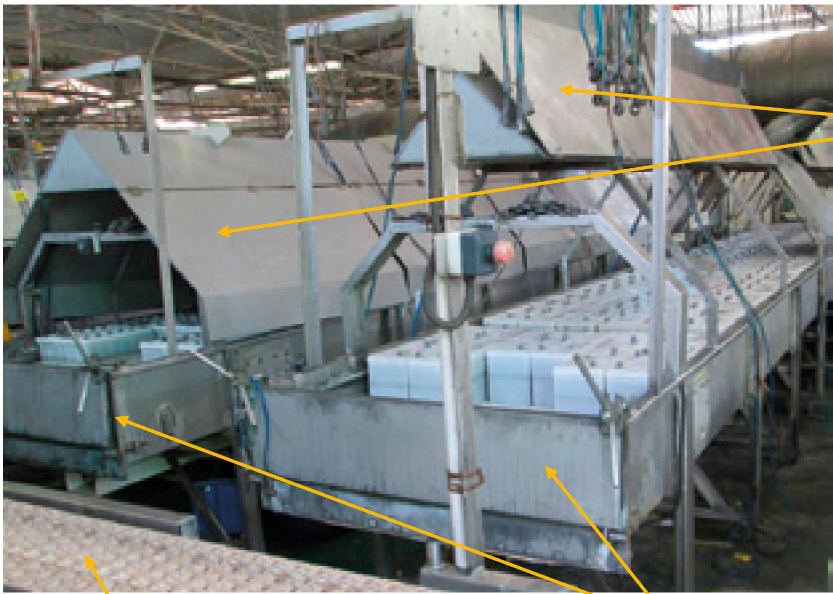

Figure 1: Typical charging area with water cooling extract and acid proof conveyors

Formation methods

The methods listed above, to a greater or lesser extent, are subject to the unwanted chemical and physical processes occurring as side effects from the basic conversion process of lead sulphates or oxides into the positive and negative active materials. Each method is described separately with the aim of seeing how far it addresses or minimises the progress of the side reactions which reduce the process efficiency.

As a general principle for all formation methods, it is necessary to ensure that currents are not excessive. Generally the current per unit of plate area is controlled to limits of 5 to 15 ma/cm². The lower currents will be representative for thicker traction plates such as 2V tubular and standby power batteries.

Table 1: Relative comparison of formation methods

Process	Energy efficiency	Water loss efficiency	Heat efficiency	Time efficiency	Capital spend	Product suitability
1 shot formation flooded	3	3	3	4	7	Automotive/traction
2 shot formation flooded	6	5	4	6	6	Automotive/monobloc
Recirculating electrolyte	7	4	7	6	3	2V traction

Typically these will take 36 to 48 hours to complete the formation process. For the automotive range with thinner plates, higher current densities up to 15ma/cm² are often used. These levels of current density would result in formation times of 15 hours or less for automotive batteries.

Common to all processes are:

- The conversion efficiency of paste or oxide to formed active materials (including residual free lead in the positive);
- The control of temperature rise due to exothermic reactions;
- Exhaust and treatment of harmful gases and acid mist;
- The energy efficiency of the process in terms of Wh/kg and Ah/kg of active material;
- The initial performance and the shelf life of the battery.

The relationship between current and the amount of decomposed water or the equivalent volumes of gas generated can be evaluated from using the Faraday constant. Faraday constant is the amount of electric charge per mole of electrons = 96487 coulomb (As)/mole) of 26.8 Ah.

Negative electrode: $\mathbf{2H^+ + 2e^- = H^2}$

Positive electrode: $\mathbf{O^{2-} = 1/2\ O^2 + 2e^-}$

The molar weight of H_2O is 18g. 1 Ah will decomposes 18 / 53.6 grams of water = 0.3360 g/Ah.

The level of the resultant gas volume generated by the decomposition reaction depends on temperature and pressure.

For a temperature of 25°C (and normal pressure of 1 atmosphere), the quantity of gas is 0.4564 litres hydrogen gas and 0.2281 litres of oxygen gas per hour per 1 amp overcharge. This equates to 1.267 x 10^{-4} litres per second.

This matches the IEEE 484 norms where the maximum hydrogen evolution rate is 1.27 x 10^{-7} m^3 per amp per cell at 25°C normal pressure. This represents the maximum evolution rate but should be used to calculate the extraction required to dilute the concentration to the required safety standards for hydrogen explosive levels.

With increasing temperature the charge acceptance of the batteries will increase so the current will rise if the voltage is kept constant. This effectively means higher levels of hydrogen gas to extract. The combination of overcharge current, temperature and charging voltage are critical factors for controlling the gas evolution as well as the charging efficiency.

The following describes the formation methods most commonly used by manufacturers for flooded monobloc and 2V cells, including traction, semi traction, industrial and standby power use.

Single shot formation (1S)

This is the simplest method of formation: batteries are filled with dilute sulphuric acid and placed on charge after an acceptable soak period and when the initial temperature rise has halted. The initial filling specific gravity (SG) of the dilute acid is calculated so that after formation it gives the desired value. The filling SG is lower than the final SG.

The increase can be estimated by calculating the contribution from the mass of sulphates in the pasted plates and using prior knowledge of the loss of water from hydrolysis and evaporation. The latter factors can be gained from experience rather than calculation, and in case of doubt it is better to arrive at a lower value rather than a higher SG in order to minimise any time and effort taken to make final adjustments.

This method is common for automotive, traction and semi-traction monoblocs and traction 2V cells including stationary batteries. Typical processes would involve automated acid filling machines filling two batteries simultaneously with dilute sulphuric acid, using automated transport to a water bath where the batteries are connected in series to computer controlled rectifiers.

The total time from filling to switching on the current is normally between 30 and 45 minutes for automotive batteries and 30 minutes to 2 hours for 2V traction cells. This gives the minimum time for the acid soaking reactions to progress and for the temperature to stop rising.

Once on charge, the current is controlled to give optimum energy efficiency whilst minimising the process time. This time restriction arises from several requirements: to reduce the capital employed, to minimise space requirements and to meet production output schedules. This inevitably leads to a compromise in the process to achieve maximum output whilst ensuring the integrity of the battery.

It is generally recognised that the charging current starts with a low current, which effectively conditions the battery by reducing the internal resistance. The battery voltage can reach initial levels in excess of 3V per cell, but then drops as the battery's internal resistance decreases.

The resistance is basically the result of the acid soaking process where the grid/paste interface becomes sulphated. The initial low current is designed to break down this layer forming lead dioxide on the positive and pure lead on the negative plate AM/grid interfaces respectively.

The total energy input is normally in the range of 2.5 to 4.5 times the C_{20} capacity for automotive batteries and 4.5 to 7.5 times the C_5 capacity for traction monoblocs and 2V cells. The main reason for this divergence is the thicker construction of traction plates when compared with an automotive design.

Once the voltage has dropped to a stable lower level, generally around 2.1V to 2.3V per cell, the current is rapidly ramped up to levels as high as 0.25 times the C_{20} or C_5 value (1.25 I_5). This level is maintained until voltages reach 2.7V per cell or temperatures increase to above 50°C. Current is then dropped to lower values, generally 0.08 to 0.12 times the capacity.

Generally a formation programme will consist of 5 to 10 steps with an initial low current for up to one hour to reduce the internal resistance. This is followed by a higher current at a maximum of 1.25 I_5 until temperatures and voltages climb to high levels.

At least one pause or discharge is desirable, this reduces the acid concentration at the electrode/electrolyte interface and can assist in the conversion of free lead in the positive into lead sulphate. The latter effect is useful in ensuring low self-discharge and good shelf life as well as giving better initial capacity.

The process finishes with low currents which reduces gas and heat evolution in the final stages. This has another benefit for traction batteries, namely it gives a better working environment for staff, who need to adjust the final SG of the batteries or cells.

The trigger points for these algorithm steps are usually controlled by time. They can be controlled by other criteria, for example, temperature, voltage or accumulated ampere hours. In any event, it is good practice to have safeguards which prevent over-temperature and high voltages, which can lead to excessive gassing and even plate damage.

In order to implement these charging patterns, it is desirable to have formation equipment which is computer or microprocessor controlled. There should also be feedback of temperature and voltage from the battery banks in order to provide information for the charging process or to trigger an alarm or cut-off system.

Temperature control can be achieved independently from the charging equipment, and a stand-alone system measuring cooling water temperature, which then regulates the water flow to control the temperature, is also common practice.

Single shot formation has the following drawbacks:

- Acid concentration and resistance increase: 1S formation does not alleviate this and is the worst method available;
- Electrolytic decomposition of water: due to the high SG achieved, the internal resistance increase is the most pronounced of all available methods. The result of this is that the electrolyte SG during formation is higher than that of the other methods. This produces high voltages with consequent higher levels of gas evolution. Again 1S formation is the worst process available;
- Heat evolution resulting from the increased internal resistance is again a maximum with this method;
- The effect on charge acceptance of the higher on-charge voltage due to the higher SG during the entire process is also significant. Higher voltages are required to ensure that the input current is sufficient to maximise the material conversion efficiency;
- The thermodynamic activation energy required is affected by the concentration of the products and reactants. This can be demonstrated using the following simplified formation reactions:

Positive:
$$\mathbf{PbSO_4 + 2H_2O = PbO_2 + H_2SO_4}$$

Negative:
$$\mathbf{PbSO_4 + H_2 = Pb + H_2SO_4}$$

As the formation time increases the level of sulphate increases in the electrolyte. The driving force of the reactions is related to the concentration or activity of the reaction products. From the Nernst equation:

$$\mathbf{\Delta G = \Delta G^{\circ} - RT\ lnK}$$
(where K is the equilibrium constant)

$$\mathbf{K = [H_2SO_4].[PbO_2]/[PbSO_4].[H_2O]^2}$$
for the positive

$$\mathbf{K = [H_2SO_4].[Pb]/[PbSO_4].[H_2]}$$
for the negative

Since lead and lead sulphate are solids and hydrogen is given off as a gas, then their activities are unity. In this condition, K is entirely dependent on the concentration of sulphuric acid. From this, it is evident that, as the concentration of sulphuric acid increases in the electrolyte, the rate of reaction will slow down, inhibiting the conversion of lead sulphate into lead dioxide at the positive electrode and into pure lead at the negative electrode.

Therefore, the increasing acid concentration inhibits the efficient formation of the electrodes and creates high levels of heat due to the increasing internal resistance. The higher voltages, produced from the higher IR and acid SG, result in high levels of gas evolution. All these factors result in higher levels of sulphate in the positive plate and increased formation times when compared with more efficient methods.

Two shot formation (2S)

In this method, batteries and cells are filled with sulphuric acid of lower SG than used in 1S formation, typically 1.05 to 1.10. This lower SG increases efficiency for the reasons given in the introduction, namely, the concentration of sulphuric acid in the products is reduced. This facilitates a higher conversion to lead dioxide and pure lead for the same energy and time input.

Conversely it can be used to reduce time or energy input depending upon the manufacturer's priorities. The downside is that the final SG resulting from the initial

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filling density and the release of sulphate from the plates is normally too low to provide the capacity requirements for the battery.

In order to increase the SG the formation acid is dumped by emptying the battery or cell, and then refilled with a suitable density acid which is calculated to achieve the required density after mixing with the remaining acid in the plates and separator of the newly formed batteries.

This measure reduces the problem of high acid concentration leading to low active material conversion efficiency. There is also a reduction in gas evolution due to the lower on-charge voltages, whilst heat generation is reduced due to lower IR values. It is possible to use higher formation currents as the charge acceptance is increased and heat generation is reduced.

However, there is still a need to control temperatures and a water bath is essential to keep temperatures at optimum levels. Gas extraction is essential and suitable extraction equipment is also required, (see Figure 1).

The method of tipping and refilling the batteries invariably leads to floor damage and reduced lifetime of transport equipment. Additionally, the acid can be recirculated many times from emptying, adjustment and refilling of batteries. Any contaminants picked up from the materials used in the manufacture of the equipment (e.g. nickel from stainless steel) will gradually increase in concentration and may form a contaminant in the batteries produced.

Figure 2 shows a typical piece of equipment used to empty newly-formed batteries. Basically it is a rotating drum which turns the batteries upside down and holds them in this position for a fixed period until almost all the acid has drained out. The near empty batteries are then turned upright again and moved onto the acid filling section and filled with a higher density acid to give the required final SG.

After this procedure they are washed in a machine, removing all the acid, then dried in a continuous process, before the labels are attached automatically. The batteries are then packed on pallets for storage or dispatch.

With this process formation times are normally lower, typically 12 to 18 hours for automotive and 15 to 36 hours for monobloc industrial and semi-traction. It is not normally used for 2V traction or 2V standby power flooded batteries. This is primarily due to the engineering difficulties of dealing with the variety and shape of 2V cells.

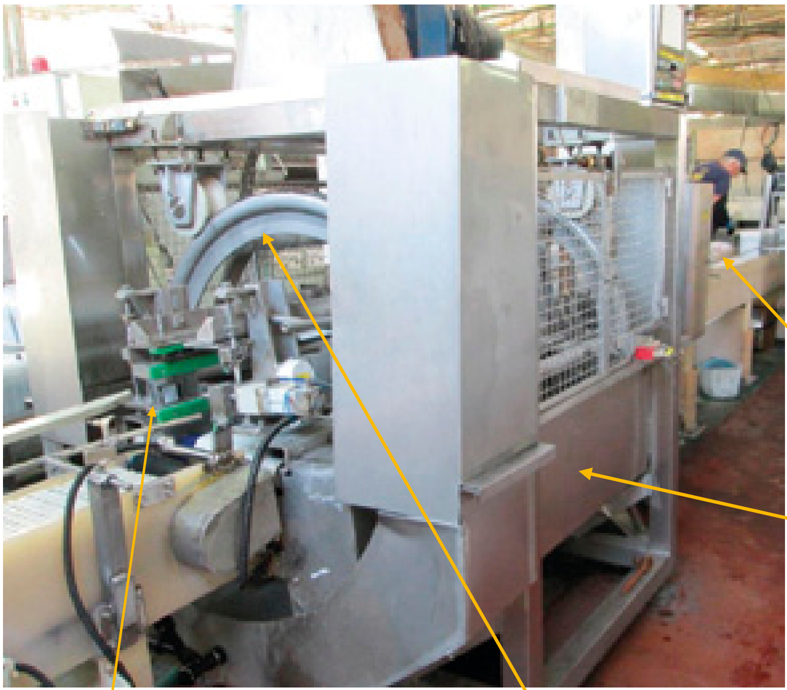
Recirculating electrolyte

It is clear from the above that increasing concentration of acid during the formation reactions will both inhibit the efficiency of conversion to active materials and also increase the tendency to produce inefficient and damaging side reactions. A solution is to pump the acid from a central reservoir into the batteries or cells, which is then recirculated via an acid adjustment and cooling station.

The gases and acid fume are also removed from the batteries and cells and treated via extraction fans and scrubbers before venting to atmosphere. The idea is to ensure that the concentration gradient of sulphate between the plates and the electrolyte is maximised.

This is effectively achieved by lowering the concentration of the reaction product, sulphuric acid, in the electrolyte. By keeping the concentration of this product at low levels, it is possible to keep the efficiency of the conversion process at the same optimum rate throughout the process. This in turn reduces the total energy and time required to achieve reasonable conversion rates of lead sulphate to the positive and negative active materials.

Figure 2: Two shot formation, automatic battery emptying machine

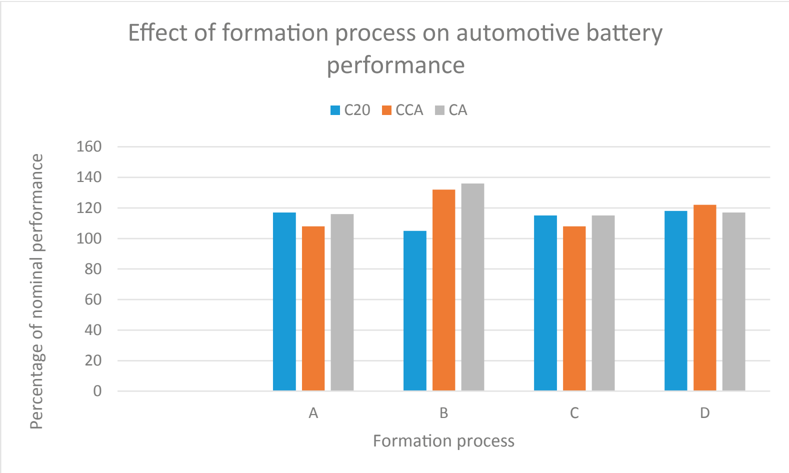


Battery feed into acid dumping machine

Acid tank for recirculating and adjusting acid

Empty batteries exit, 4-6 batteries per cycle

Rotating wheel clamp turns batteries through 360°



A = 2 shot no circulation (5-10mA/cm²), B = 2 shot with circulation (5-10mA/cm²), C = 2 shot with circulation 5-15mA/cm²), D = Single shot with circulation (5-15mA/cm²)
Based on results taken from Kumar et al. *Int. J. Electrochem. Sci.*, 7 **(2012)** 1060 - 1070

Figure 3: Study comparing 2 shot and recirculating electrolyte formation methods

Studies carried out in laboratory scale tests have shown that the efficiency of conversion, measured by percentage of retained sulphate in the positive plate, is comparable with 2S formation but can be carried out in less time.

Figure 3 shows one of the results of a study carried out by Kumar et al when comparing the degree of lead dioxide formed from 2S formation with that of recirculating acid formation under different conditions. The study showed that recirculating systems could significantly reduce formation times (25%) and still give results comparable with 2S formation methods.

These results show that two shot formation with recirculation gives the best results for charge acceptance and cold crank performance but with lower current densities and longer times. However, where speed is important and final acid adjustment is required, single shot recirculation formation is very effective.

The other big advantage is the lower operating temperatures which the researchers found despite using higher current densities, up to 15 ma/cm² compared to a maximum of 10ma/cm2 for the 2S process.

Significantly, some lead-acid products do not lend themselves to being formed by the 2S process. In particular, larger 2V traction and standby power cells would require significant engineering effort to enable the rotation of tall narrow cells to facilitate emptying, not to mention the problems of disconnecting the individual cells after charging, protecting bolt on inserts in the terminals and the cleaning of the cells after tipping and refilling.

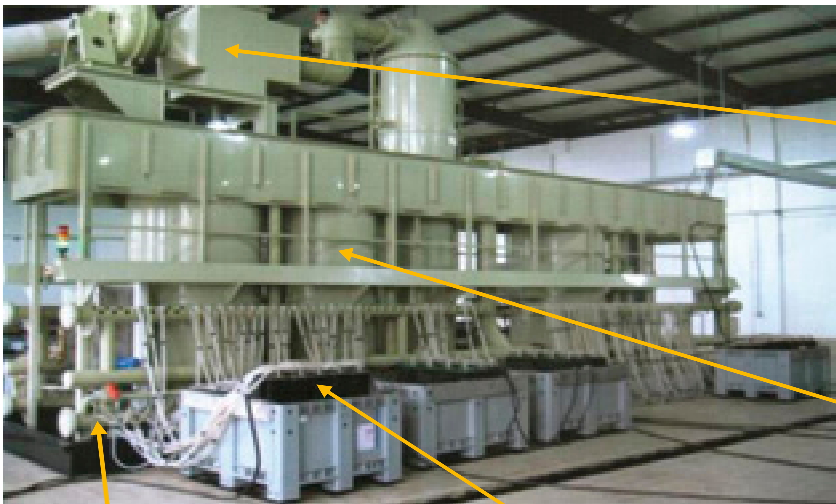
For this reason many traction battery manufacturers are turning to acid recirculation as a means to reduce time of formation and to remove the time consuming and labour-intensive adjustment of the electrolyte SG at the end of formation.

Figure 4 shows a typical arrangement for a 2V cell acid recirculation system. The maze of tubes is connected to a pumping system which circulates the removed acid through a gas and mist extraction system, then a chiller, then a mixing/adjustment vessel, then back into the acid feed to the cells.

The system has advantages for 2V cells as it saves time, energy and labour costs, principally as it obviates the need for final SG adjustments. However, the additional plumbing required makes this process less attractive for monoblocs, particularly 12V batteries. The time saved in the process can be lost in connecting and disconnecting the acid pipes at the start and end of the process.

However, there are some companies who are offering fixed position connections in the lids of sealable tanks. This enables the automatic plumbing for the recirculating acid to be attached to each vent hole in the battery as the lid is closed.

Figure 4: Acid recirculation system for 2 volt traction cells



There are drawbacks, due to the number of individual connections. The system is prone to allowing individual cell failures to go undetected unless they are performance tested. Loss of pressure in a single cell or a blockage in a pipe can result in acid flow being prevented. Additionally, active material differences may result in there being differing levels of internal sulphate in the battery's paste mass.

If the process is not optimised or continued for long enough, those batteries with higher sulphate content may have higher sulphate levels left in their active masses. This will result in batteries or cells becoming out of balance during service, leading to early failure under cyclic conditions or parallel series configurations. However, provided that these processes are properly designed, this method should provide the least variation of all the described processes.

While acid circulation gives the advantage of reduced cycle time, one should be careful in maintaining optimal charge current density. Too high a charge rate can have a detrimental effect on formation efficiency and initial capacity. Further, flow rate and inlet acid temperature play a vital role, and adequate methods should be employed to control all of these factors.

Higher flow rate may physically disturb the paste material from the surface. The practical viability of adopting the new method as an industrial practice needs a thorough analysis, particularly from the view point of operational issues. The complexity of the equipment i.e., numerous pipes, conduits, valves, pumps etc. pose practical challenges. Hence overall energy consumption is a critical factor to decide upon.

Briefly the advantages of this method can be summarised as:

- Heat and gases produced in the process of formation are taken away in time, enabling high-rate formation time. Real time adjustment of gas production, enhanced high current utilisation rate and energy saving;
- The whole system can be operated in the state of negative pressure, gases and acid fumes are treated in system, minimising environmental impact;
- Continuous circulation of electrolyte and controllable temperature and density ensure consistency between single cells;
- The use of a low density acid improves the efficiency of the electro chemical transformation of the paste. A higher level of PbO_2 is achieved in the positive electrode and with lower energy usage when compared with the other methods;
- The continuous circulation of acid helps the release of gas molecules on plate surfaces, again improving the charge efficiency;
- Better temperature controls avoid the risk of damage to separators and plates;
- Possible reduced charging times.

Typical formation problems

Control of current input, time of formation, current density and temperature should ensure uniformity of product performance with active material structures optimised for their particular application. Good initial performances and long shelf life are also achieved by optimised process controls. However, there are pitfalls to avoid as well as process errors and stem failures which may be the cause of poor performance or battery damage.

Since the formation reaction forms PbO_2 on the positive plate, the grid is also oxidised as part of the process. If this oxidation is excessive it can lead to grid growth or buckling of the plates. Even if it is not so severe, it will reduce cycle life as this is often determined by the corrosion of the positive plate. This condition is exacerbated by high temperatures and high current densities.

Under-formation can also occur, leading to poor initial performance and low shelf life. This is a particular problem if there is excessive residual free lead left in the positive plate. In this case self-discharge is extremely rapid leading to very poor shelf life and early battery failure. Under-formed batteries can result from incorrect Ah input, low formation temperatures and high electrolyte SG. This condition will also give poor initial performance and if these batteries are used in series or parallel connections, they will soon become imbalanced.

There have been cases of batteries being undercharged whilst having grid growth and buckled plates. This condition resulted from batteries formed at high temperatures with high SG electrolyte and incorrect charging algorithm (high current densities).

Table 2 lists common formation defects along with their causes and consequences for battery performance.

In the next article, single plate tank formation and methods of filling and forming VRLA batteries including Gel and bipolar, are considered. In addition, optimised formation programmes for all the methods described in this article and the next will be proposed.

Table 2: Common formation defects

Defect	Cause	In service consequences
High SG	• Incorrect acid filling SG • Excessive formation • Poor final adjustment	• Low CCA in automotive • Undercharging due to higher on charge voltages, particularly in voltage controlled charging • Increased positive corrosion and grid growth in non-voltage regulated charging
Low SG	• Incorrect acid filling SG insufficient formation • Poor final adjustment	• Low capacity, serious for 2V traction and semi traction applications
Low CCA (automotive)	• High formation temperatures leading to large PbO_2 crystals • High internal resistance	• Poor starting characteristics, particularly in cold weather • Early failure under warranty conditions
Low charge acceptance	• High SG see above	• Battery performance reduces with time • Early failure under warranty conditions
Reduced life	• SG imbalance between cells due to poor adjustment • Corrosion of positive due to high formation temperature or excessive current (automotive)	• For traction series connected cells it is a common cause of poor cycle life • Batteries on float charge fail from positive corrosion. High corrosion in the formation stage will reduce the time to positive failure
Low capacity	• Batteries under-formed due to insufficient current or time or too low formation temperature • Low SG	• Reduced cycle life for traction batteries. • Unable to meet performance requirements and fail under warranty terms.
Short shelf life	• Insufficient formation • High residual free lead in the positive	• Poor performance after storage at customers or manufacturers warehouse. Common cause of warranty returns in automotive markets

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NAATBatt: Happy days are here again?

The Editor escaped from England's soggy clutches to determine whether the time is now for stationary energy storage. Is the hype making way for sales?

Having suckled and then disengaged from the taxpayer teat in recent years, some battery firms are not in great financial health.

Since A123 went to the wall, which ultimately resulted in taxpayer-funded factories and expertise being bailed out by the Chinese for a song, battery companies are no longer flavour of the month with the investment community.

The firms that may have bagged finance in the bad/good old days are struggling to raise capital. And NAATBatt attracts exactly this type of start-up.

The author found NAATBatt to be an agreeable conference. Maybe it's due to leaving the soggy shores of England – experiencing its wettest winter since records began in 1767 - for the sunny, warm climes of Southern California, or maybe it was just the warm optimism emanating from the more idealistic delegates who want to play their part in changing the world.

John Craig, CEO of Enersys (right), imparts his wisdom to delegates

Yet despite this optimism about renewable energy storage—particularly in California— there was a faint hint of bitterness in the air. The good times/bad times of the Federal stimulus in the aftermath of the big crash are over.

Boom time for storage?

NAATBatt is something of a beauty parade. There are dozens of 'flash' presentations by companies ranging from tiny to small to medium to large giving an update on their latest battery and battery-related tech.

With no less than Enersys CEO John Craig in attendance, there was much dangling of ankles. But Craig made it abundantly clear that unless you're the head of a multinational battery empire, preferably selling lead-acid batteries, you may struggle to be as rich as him.

What prospective suitors like Enersys want is know is how much will a battery company add in terms of cents per share today, rather than what the tech may offer in the long term.

And Craig was just one of many speakers to beat delegates around the head with one key message. No one wants a battery.

While battery companies can get hung up on IP and product differentiation, what the market wants is a solution able to integrate different revenue streams such as frequency response and other ancillary services for which the extremely rapid ramping rate of battery energy storage is rewarded. That is where the value lies.

If the days of investors almost blindly diving in to back the next big thing in battery technology are over, the same cannot be said for energy storage. Delegates heard energy storage is where solar PV was a decade ago – on the cusp of a boom.

Incidentally, it was once thought that the solar boom would inevitably comprise solar thermal, rather than solar PV. Things do not always work out as thought…

With a few exceptions, investors have not made money from energy storage. For every Enersys and JCI there is an EnerOne, Xtreme Power or Exide.

US Energy Storage Incentives

California ISO

- ES Procurement target of 1,325MW by 2020
- Flexibility Products – Capacity and Ramping 2014/2015
- Vehicle2Grid and Behind-the-Meter Storage participation in CAISO markets 2014/2015
- State funding: Self-Generation Incentive Programme (SGIP), Electric Programme Investment Charge (EPIC)

Texas/ERCOT

- Fast-Responding Regulation Service (FRRS) 2013/2014
- Ancillary Services Market Redesign 2014 - 2016
- Fast Frequency Response, Pay-for-performance

New York

- Long Island Power Authority (LIPA) Energy Storage RFP
- Grid Resiliency (Hurricane Sandy) and Microgrid funding
- Distributed Energy Resources

PJM – Mid Atlantic

- NJ Clean Energy Programme – Storage RFP 2014
- Stakeholder initiative to develop rules for Storage in the Capacity market, 2014 - 2015

ISO New England

- Massachusetts PUC Grid Modernisation for utilities 2013/2014
- Maine PUC pilot to evaluate Non-Transmission Alternatives
- Connecticut Microgrid programme

Non-ISO/RTO Regions

- FERC Order 784 (July 2013) – 'Third-party provision of ancillary services and the accounting and financial reporting for new electric storage facilities'
- Multiple reforms to ease restrictions on sales of ancillary services
- Utilities must take into account the speed and accuracy
- Accounting rules for Utilities that have storage

Table 1 Energy Storage Incentives. The US is something of a Mecca for energy storage

The investors who listened to the hype and wanted in on the ground floor lost out. Once bitten, twice shy, investors are being a great deal more selective than in the last wave.

Besides, are investor returns there yet? The answer is: possibly. The projects of developers like AES Energy Storage and S&C Electric are beginning to generate positive feedback about the rate of return from grid-scale storage.

Grid-storage opportunities

The upside of the stimulus money is that prices have fallen dramatically for lithium-ion and lead-acid. These signals are encouraging for storage. And, certainly, grid-scale energy storage offers huge opportunities.

The US is to add 90GW of new peaking plants by 2040. As solar and wind power capacity grows, this will be an increasingly inefficient and expensive use of fossil fuel to meet power demand.

Energy storage could be useful to utilities to soak up surplus PV storage, but there is also an inherent advantage to storage in its fast ramping capability to balance the grid by reducing inefficient usage of polluting fossil fuel plants as spinning reserve.

In California particularly, who's not to say the planning process for fossil fuel plants will grow from a pain in the ass to a total nightmare?

The roadmap may not be clear and there's a lack of consensus about which technology is the answer (Lithium? Lead-acid? Sodium? Flow batteries?), but regulators have woken up to the opportunity offered by storage to mitigate grid problems caused by the ever-increasing penetration of wind and solar.

Customised Energy Solutions' (CMS) Judith Judson McQueeney gave a run-down on energy storage development in the US, all 385MW of it, with thousands more under development. As ***Table 1*** shows, there is a plethora of initiatives driving energy storage in the United States.

CMS' shtick is calculating the optimal battery solutions for particular applications in the different electricity markets in the 50 states. Different markets have different rules, and pay differently.

Some markets reward just for being there, others pay for performance as well. CMS puts this all into a computer model and comes out with the right battery solution; more often than not it's lithium-ion rather lead-acid due to cycle duty.

There was some positive feedback from the recent FERC orders – 755 and 784. PJM, the East Coast Interconnector – has reported to FERC that energy storage had resulted in an 18% reduction in energy procurement costs, meaning slightly lower bills for consumers, even though storage is paid an incentive.

Behind the meter storage

There was also much talk at NAATBatt about behind-the-meter storage, i.e. at the residential level rather than the grid. This could come as soon as 2014/15 in California.

The great thing about behind-the-meter storage is it competes with the retail price rather than the wholesale price, potentially making it an attractive option to the companies supplying storage to the hundreds of thousands of Californians with solar PV.

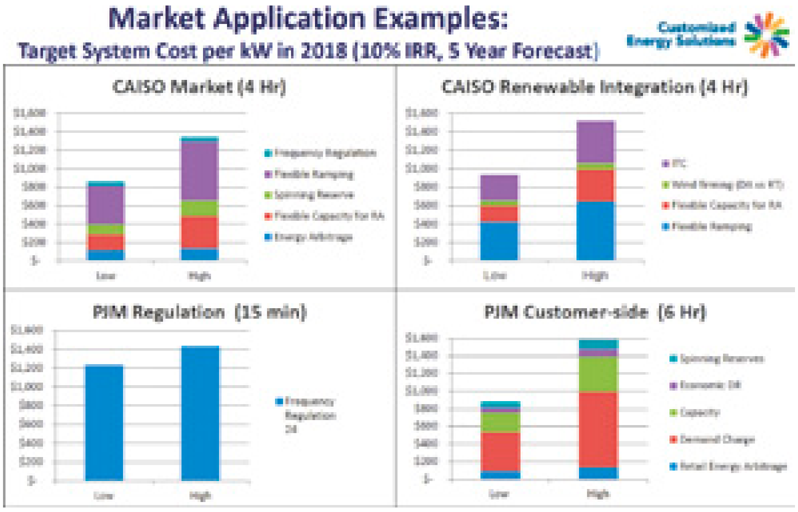
With an average spread of \$50/MWh (rarely hitting \$200/MWh or more), arbitrage opportunities are very limited for wholesale power prices, partly due to solar power flattening the curves by at times overloading the grid during the afternoon and early evening.

California Public Utilities Commission's recently introduced regulation AB327 reintroduces the element of time-of-use for tariffs. With dynamic residential tariffs, however, consumers could charge their batteries at off-peak times to discharge at peak load and make significant savings.

SolarCity already rents used Tesla car battery packs to be used as storage for domestic solar PV for \$10/month (benefitting from unique Californian rebates which make that price point possible), but utilities like San Diego Gas & Electric (SDGE) and Duke Energy are looking at installing them too.

Investors, too, are looking at business models focusing on peak shaving to commercial users, while frequent blackouts in New England also offer opportunity for residential storage; indeed, any situation which offers an opportunity to trade off retail against wholesale prices is of interest.

Capturing multiple value streams is critical to most energy storage projects



Before we get carried away, a significant caveat is California has 'net metering', which requires utilities like SDGE to pay retail rates when solar PV production exceeds on-site demand. This somewhat quells the desire for storage; so, too, does the cost of lithium-ion battery packs, especially when compared to a diesel generator.

Further, it will be a challenge to make customers charge batteries to discharge at times of peak load. But, one day, net metering will disappear; and utilities like SDGE will have to cope with ever more (unwanted) solar PV...

IPPs worried about battery performance

A panel discussion exploring energy storage from an independent power provider (IPP), i.e. non-regulated utilities, perspective. IPPs are seen as a better bet to develop energy storage in the US rather than the regulated utilities; PG&E in particular has turned its back on energy storage, perhaps fearing where it may all end up.

Ultimately, it's all about the Benjamins: financing. Power purchase agreements for energy storage would be the usual commercial model to provide revenue certainty. But what is the provider exactly providing: is it power or capacity? The number of starts? And how is it calculated?

In California, an energy storage request for proposals utilise a tolling model, offering a constant revenue stream, thus making it easier to finance projects expected to offer a rate of return of circa 10-15%.

The panel expects the first energy storage projects will be equity financed rather than going to the banks, just as solar was. Solar PV farms are typically now financed on a 70:30 equity/debt ratio.

Non-recourse debt financing for PPAs would be even more helpful, but the project risks for energy storage are relatively high— as the technology is relatively unproven— pushing up the cost of capital. The merchant risk is too high.

The discussion zeroed in on the bankability of energy storage batteries. The industry is yet to prove the batteries are technically reliable. The panel suggested start-up level battery firms align with universities to independently test and verify to provide warranties.

Another issue for battery firms to consider is the utility/IPP

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desire to dictate the design and performance parameters of the ESS system. Furthermore, the performance data of batteries is not like gas turbines, with their thermal efficiency data etc., and the validation of performance is crucial to acceptance.

Battery warrantees are essential but not necessarily sufficient. A one-year warranty is not going to cut the mustard to obtain finance; for Californian energy storage you're looking at 20-year PPAs—tough for a battery.

Furthermore, the overall system needs warranties, i.e. the inverters, the BMS, not to mention cast-iron maintenance procedures and documentation about how battery duty impacts asset life.

The message is start-ups will find it almost impossible to get financing if they have limited experience and no warranties. It all points to integrators like S&C Electric and AES as big winners from the growth of energy storage in the US.

Technical Tour

Being in San Diego, NAATBatt was located just a short drive to the University of California, San Diego's East Campus, which can only be described as a playground for energy storage tech.

Firstly, there's a 2.8 MW fuel cell, said to be the world's largest, which uses methane piped in 17 miles away from a wastewater treatment works. There's also a 100kW/300kWh Enerstore flow battery made by ZBB and in July there will be a 2.5MW/5MWh lithium-ion battery.

In June, Maxwell will install a 2.9kWh/28kW ultracap connected to a 28kW concentrating PV array–this will be the world's first grid-connected ultracap. There's also a 100kW/180kWh container of used Mini Cooper EV batteries.

The University will test how these 'second life' batteries perform for energy storage and also how they perform connected to a 300kW car park rooftop array, the latter researching how weather forecasting affects charging algorithms of lithium-ion.

This may ultimately lead to 'Happy Hour' tariffs - if a utility expects a greater need for charging one hour ahead, it may drop prices to encourage the use of power from storage batteries. Maybe.

Delegates also visited SGDE's Energy Innovation Centre in what used to be a derelict supermarket. If the University ponged a bit of greenwash, this place utterly reeked of it.

How useful all the toys and ecogadgets on display were seemed secondary to making sure there's a showcase for how taxpayers' money has been spent.

Thomas Bialek, SDGE's Smart Grid chief engineer, explained how energy storage is a growing part of the business, with 5MW/14MWh of new projects due to be installed by the second quarter of 2014. This includes storage as a means of network investment deferral rather than mere technology demonstrations.

SDGE is also exploring using the inherent islanding capabilities to hook up storage rather than provide a second feed to reconnect power after an outage. Perhaps not just nice toys after all?

But in another blow to the NAATBatt ankle-danglers, Bialek reiterated the point about not wanting batteries (and caring even less about the chemistry) and that utilities do not like buying serial numbers #0001, #0002 and #0003 of a technology...

Battery safety session

With stationary storage on the cusp of growth, safety has become a serious concern. And you could see the pain on the face on Dan Cass, in charge of loss control and engineering services at GCube Insurance, as he recalled the 2012 fire in Hawaii that destroyed the largest operating wind energy storage system in North America.

GCube, which claims to be the world's largest renewable energy project insurer, had the 15MW lead-acid project on its books and it has cost the insurer tens of millions of dollars. Cass and other members of the panel spoke of concerns about the quality of testing, verification, codes and standards of lithium battery safety engineering. These are lagging behind the technology

Fuel Cell Energy's 2.8MW fuel cell, said to be the world's largest, at the University of California, San Diego and quite obviously so.

To this end, the not-for-profit product safety testing and certification organisation Underwriters Laboratories is developing new safety standards for lithium-ion and energy storage.

IECCD62619 is for secondary cells and batteries containing alkaline or other non-acid electrolytes and concerns safety requirements for secondary lithium cells and batteries, for use in industrial applications.

IECCD62897 concerns safety requirements for stationary energy storage systems with lithium batteries. UL9540 concerns safety for energy storage systems and equipment.

Cass was particularly concerned about lithium's copper bus bars and gases leaking. An answer could come from DNV GL an advisor to the energy industry, which is working with NexTech Materials to develop a sensor for enhanced monitoring of off-gas in lithium-ion batteries.

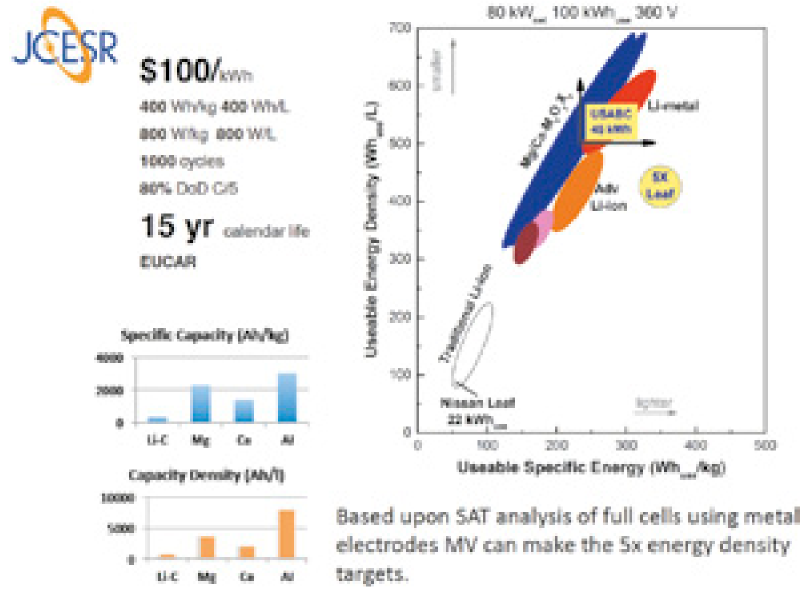
By alerting the presence of off-gas, the sensor would lead to an 'early warning system' for thermal runaway. DNV GL is also developing 'Battery XT', a performance modeling and economic value assessment software tool for second life EV batteries for stationary applications– a market to watch.

More stimulus wastage?

If there were any younger, more impressionable delegates under the illusion electrochemistry is a straightforward pursuit, Argonne National Laboratory's presentation would surely have illuminated them. There was no better illustration of how the US government bought into the hype.

In 2013, the DoE awarded the Argonne National Laboratory $125m to establish a national hub for advanced battery research. The mission of Argonne's Joint Center for Energy Storage Research (JCESR) is to develop an EV battery with five times current energy density, at one-fifth the cost, within five years.

The parameters of Argonne's Joint Center for Energy Storage Research's '5:5:5' battery project– a tough nut to crack



The project includes Argonne, Laurence Berkeley, Sandia, SLAC and PNNL. Not to mention five universities and firms like Dow and Johnson Controls.

Easy peasy, lemon squeezy? Er, no. To achieve $100/kWh for an 800W/h with 1000 cycles, lithium-ion is not going to cut the mustard.

JCESR's 'Beyond Lithium-ion Concepts' boiled down to four streams:

i. Multivalent intercalation chemical transformation, i.e. replace monovalent Li+ with di- or tri-valentions;

ii. Non-aqueous redox flow, replacing solid electrodes with liquid solutions or suspensions;

iii. Chemical transformation to replace intercalation with high-energy chemical reaction (Li-S, Li-O, Na-S); and

iv. Designer organic molecules tailored structure-function relationships, i.e. redox couples.

The project is colloquially known as 5:5:5. It's now effectively 5:5:4, and not a huge amount of progress has been made.

One got the impression that the programme is expected to fail and all involved knows it. A lithium-air/lithium-sulphur battery in five years? No chance.

Moreover, the funding will not be sufficient money to develop a pack, but only a cell. The end game will likely be the development of a metal anode with two electrons per cation, i.e. magnesium.

And magnesium electrolyte is a "killer"; it was heard, needing "a few discoveries within the next year or two". Is this worthy of $125m funding? You decide, dear reader.

Speaker Tony Burrell, a New Zealander, said the project team held weekly meetings. One can only imagine how these meetings go. Perhaps it's like a child in the back seat who repeatedly asks their parents, "Are we nearly there yet?" 15 minutes into a seven-hour journey.

Burrell visibly deflated the audience, as this flagship research project began to resemble a con trick. It was certainly quite depressing to hear a how such a major research project with hundreds of millions of dollars funding the best brains in the US is seemingly up the creek without a paddle.

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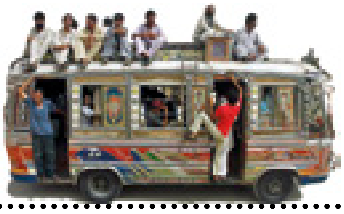

Beyond lead-acid: India calling

South Asia correspondant Dipak Sen Choudhury rounds up recent developments as India seeks to scale up its energy storage capacity and technological competence.

The past few months have seen the arrival of a number of big names in the world of energy storage systems in India along with their technologies.

South Korean battery giant Samsung SDI has tied-up with ACME, an energy management firm in India, for the manufacture and marketing of lithium-ion batteries in the country and abroad. As per the agreement, ACME will be the sole partner of Samsung SDI in the Indian and African markets, having exclusive right to use Samsung SDI's technology and will aim to achieve sales of 110 MWh of lithium-ion batteries by 2016 in the two regions.

In India, this technology will primarily be directed towards the challenging telecom tower application, as well as in other diverse applications in utilities, defence, off-grid, logistics and so on. With an eye at the huge and ever expanding Indian telecom market, Coslight of China has initiated the development of their manufacturing facility in India.

While the principal product planned to be manufactured in this unit would be an AGM VRLA battery, Coslight also has a successful lithium iron phosphate technology in their portfolio and could, in the near future, be planning to include this technology in their Indian operation.

Indian government initiative

In a major boost to encourage advanced energy storage system technology manufacture in the country, Power Grid Corporation of India (PGCIL), the state-owned central transmission utility, has invited national and international manufacturers, or consortia, to indicate their 'Expression of Interest' in forming a joint-venture company for the purpose, with the state owning 51%.

PGCIL is the lead government agency responsible for the development of smart grids across the entire nation. In an 'open house' discussion recently, PGCIL made its point clearly that the biggest financial and logistical issue it faces on moving ahead with their plans is that India does not produce any 'advanced energy storage systems' capable of storing multi-megawatt-hours, essentially from non-conventional sources, which this country has in abundance.

Based on the surveys of different countries working on grid-scale power storage, PGCIL has identified lithium chemistry as the most promising, followed by sodium nickel chloride, prompted and promoted by Italy's FIAMM, for energy storage system technology.

PGCIL's technology choices were strongly contested by Indian lead-acid manufacturers, who attended the meeting in full strength, with a tentative claim that, in general terms, lead-acid technology itself could be an adequate solution for the expectations of the applications. Decisions on appropriate technology, as per the meeting deliberations, will be made once the exact performance specifications and the operational conditions are well defined.

PGCIL accepted the suggestion that multiple pilot projects of 250 KWh storage size with different, competing technologies may be set up at different locations, which will serve to identify the most effective solution. As a follow-up of the meeting, PGCIL has now invited companies to participate in the pilot studies on a cost-sharing basis.

On a different note, it may be added that no major global technology owner is likely to share their technology in a set-up where they are minority equity holders, with the majority ownership resting with the state. It is therefore up to Indian corporations to grab the opportunity and urgently invest in setting up manufacturing units for advanced batteries in the country through the route of technical collaboration, if available.

Otherwise, the only option for the country will remain to import from... you know where! The ACME-Samsung is a tie-up in the right direction and with possibly other, similar associations in the near future.

Tie-ups continue to happen in the lead-acid domain too. Sukam Power Systems, a leading power backup solution provider in India, has announced plans to create a joint venture with Trojan Battery of the USA. The Indian company has already launched a co-branded, deep cycle battery– INV 150– targeted towards the huge home UPS battery market in India. Sukam will surely look to push the technology into the fast-developing Indian solar battery market too.

Top to bottom:

Environmentally friendly manufacturing facility

Pilot plant for pre-production trials

Battery testing centre

Quality control experiment in progress

Raman Fibre Science: Taking it one step at a time

In the world of lead-acid battery separators there is actually not much scope of doing anything path breaking. Yet, a team of dedicated professionals led by inspirational leadership are doing exactly that in the sleepy small city of Mysore, some 130 km from India's IT capital Bangalore in the southern part of the country.

The team at Raman Fibre has been in the process of developing a separator material that is unique in many senses and includes the fact that the material can be used as a sleeve, a pouch or as a single leaf with or without ribs.

Hi Sep separator material is the first non-PE composite, based on a blend of imported and in-house developed constituents which include glass fibres and special binders amongst others. Hi Sep battery separators impart unique battery performance characteristics due to high oxidation resistance and suitability for high operating temperature conditions.

The separator can be used for all battery applications from motor cycle to automotive to standby power, industrial and gel battery applications. The product can be supplied in rolls to be used on any automatic plate enveloping machine, as leafs or sheets, as sleeves for tubular batteries and for gel battery applications thereby being the only separator that can be supplied across all forms and battery applications. It is the only non-PE based composite separator that can be enveloped, it claims.

Raman Fibre Science has had many years of direct hands-on experience in the wet laid area, and it is assisted by a core team of research and manufacturing professionals who have spent a good part of their working careers in these technical areas particularly on product development side of specialty papers. They have a fully fledged research & innovation centre and also a pilot plant for trial manufacture of any of their new developments. Additionally, they have a very good battery test facility, so they can generate their own data on performance of their separator during the operation of a lead-acid battery.

The company was established in 2007 and has a present manufacturing capacity of six million square metres of the separator material. This was scheduled to have been expanded by 30% by end of March 2014.

Close to 30% of Raman Fibre's output is exported to various Asian and Latin American battery OEMs. The company also has the capabilities to, and in fact in the past briefly did, manufacture AGM separators too. To meet the growing demand, a plan is being put in place to set up a manufacturing facility in the Middle East, essentially to be close to the emerging customer base and to be able to pass on the cost advantage to them. This is a company on a fast track and definitely one to watch.

Plastic Components

BIASIN srl has been working in the sector of battery moulding for over 40 years. The experience acquired in the production of components for batteries (boxes and lids of various models and dimensions) allows BIASIN Srl to supply the main international batteries manufatures. The production system has advanced injection moulding presses which are run by elettronic systems for the automatic regulation and the statistic control of the proces. Besides, the presence inside the firm of a mould creation department allows us to comply with request of special products in a short time. BIASIN Srl, in order to further improve the performance of their components, has held the Quality System Certificate for the Standard ISO 9002.

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The dummy's guide to carbon additives for lead-acid – Part II

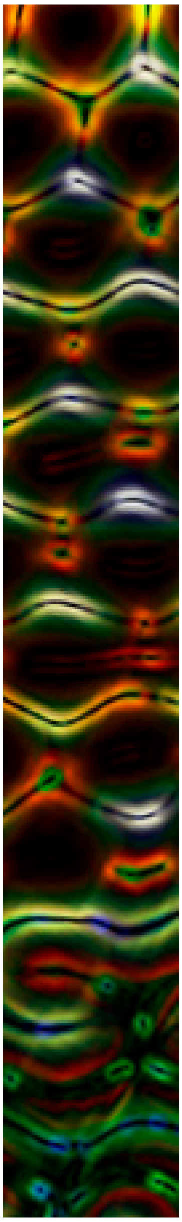
In the second of a two-part examination of carbon additives for lead-acid batteries, ALABC programme manager Boris Monahov explores the physical and chemical properties of carbons for battery applications.

Properties of carbon which are important for the battery

The most important carbon properties for battery applications are grouped below:

Technological properties These are usually described by the carbon producer. Examples include the precursor material (natural or synthetic, pitch, paper, sugar, polymers, etc.) and the production history (including technological steps, temperature, pressure, gas atmosphere, heating/burning/cooling rate, etc.).

Carbons are characterised also by their ash content. Carbon additives used in batteries have ash contents between 0 and 2.5 wt.%. This parameter is an indication about the presence of compounds which cannot burn out completely and probably play a different role for NAM performance than pure carbon. The ash can contain impurities which have a negative impact on the plate (stronger gassing). The importance of ash content has not been studied in detail.



Physical properties These are either specified by the producer, or can be measured.

a. Particle size. This depends on production technology and carbon type. The average size of graphite and activated carbon is usually larger (about 10 microns) than that of carbon black (about few microns and less). Particle size depends also on the producer.

b. Micro structure. Graphite has a layered microstructure. The particles have flake-like solid areas with large open pores. The large particles of activated carbon (mainly amorphous) have a highly developed surface area and fine pores in their bulk. The bulk of carbon black particles (mainly amorphous) is not homogeneous. They are built of agglomerates of interconnected clusters, the latter built of fine particles. These clusters form the so-called 'structure' of carbon black. Recent studies by Cabot have shown that the structure plays an important role for the effect of carbon black, along with its surface area [1]. The bulk of particles are not fully amorphous. The structure contains areas where the carbon

atoms are ordered similar to a graphite crystal lattice. A study performed by Volkswagen [2] showed that carbon blacks with highly ordered microstructure increase cycle life up to twice when added to the NAM.

c. Specific surface area (SSA). Depends on carbon type and on production technology. 3D carbon structures like carbon foam and RVC have low SSA, comparable with that of NAM. Graphite powder has an SSA ranging between 4 and 40 m^2/g, carbon blacks– between 20 and 1800 m^2/g, and activated carbons– 500 and 2 300 m^2/g.

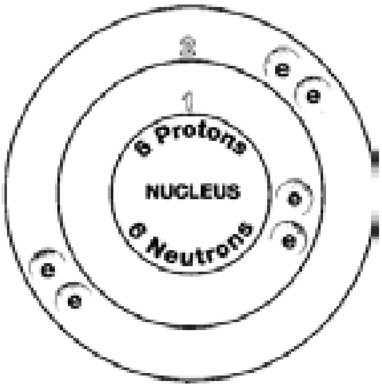
d. Porosity. 3D carbon materials have very large (100 – 1000 micrometers), interconnected, open to the electrolyte pores. They can be loaded with active material and the electrolyte can easily penetrate them, which offers a serious utilisation benefit compared to regular pasted plates. Carbon powder particles have fine pores in their bulk. Some are closed inside the carbon bulk, while others form caverns or channels through the carbon particle body. Studies by EnerG2 have shown that these pores have a strong influence on the polarisation properties of carbon.

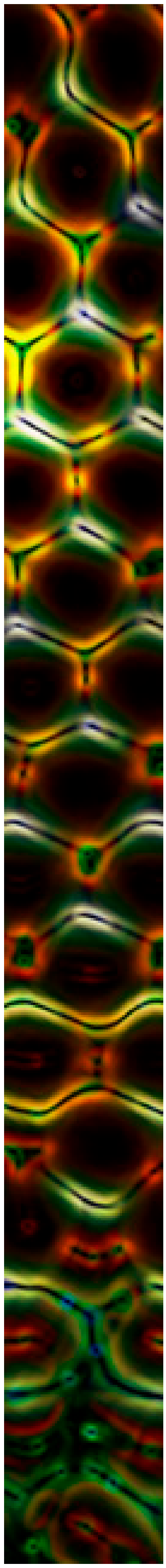
e. Electronic conductivity. Amorphous carbon has low conductivity, but graphite is conductive. The conductivity of a graphite crystal is strongly anisotropic: high along the graphene planes, and low across them. Polycrystalline graphite powder, where several particles of different orientation stay in touch, is conductive. The conductivity of graphite (5.9 x 106 S/m) is similar to that of metallic lead (4.7 x 106 S/m), but lower than that of copper (58.5 x 106 S/m). When added to a powder of non-conductive particles, graphite can increase strongly the electronic conductivity of the mixture. Graphite powder has a similar but weaker effect when contained in discharged NAM. Conductive graphite particles, which stay in contact with Pb crystals, can transfer electrons from the current collector to the reaction site. The active mass can be utilised more efficiently.

f. Thermal conductivity. The negative paste is not homogeneous. The good thermal conductivity of graphite (129 W/m.K, four times better than this of metallic lead), assists in heat distribution through the bulk of NAM. The active mass utilisation and service life of the cell is improved. Graphene and carbon nanotubes (CNT) have extremely high thermal conductivity.

g. Bulk density. Various carbons have different bulk densities, ranging between 1.8 to 2.3 g/cm^3. Since the density of carbon is much lower than that of leady oxide (9.3 g/cm^3), adding more than 0.5 wt. % of carbon to the paste, this causes difficulties in paste preparation and changes the paste density. The well-known dependence between paste density and NAM performance needs to be re-written for carbon added pastes. One wt. % of carbon will replace 5% (by volume) of the lead crystals (11.34 g/cm^3).

h. Intercalation in graphite. The relatively large distance between the graphene planes in the crystal lattice of graphite provides good conditions for intercalation of foreign ions or molecules. This effect is used in lithium-ion batteries. In sulphuric acid solutions intercalation of sulphate ions (HSO_4^- or SO_4^{2-}) or of entire H_2SO_4 molecules in graphite can proceed. Electrochemical intercalation is observed at potentials higher than 0 V (vs. Hg/Hg_2SO_4 electrode). The crystal lattice of graphite gets expanded and can be destroyed by large amounts of intercalating material. The graphite turns into a fine powder (expanded graphite) of high electric conductivity.





Chemical properties

a. Purity. Carbons have various levels of impurities. The total levels can be between 20 and 12,000 ppm. Abundant foreign elements are iron, nickel, copper and zinc, but also silicon, potassium and sulphur are found. Impurities on the carbon surface can increase the rate of hydrogen evolution and must be strictly controlled and avoided.

b. Interaction with water. The interaction of carbon additives with water through the mixing and curing processes is of high importance for battery production. This interaction has four aspects:

1) Solubility of carbon: carbon and graphite are not soluble in water.

2) Water intercalation: observed in graphite oxide layers formed on the surface of graphite [3, 4, 5].

3) Wetting: it is different to that of lead oxide particles and depends on carbon type. Graphite and carbon have different wetting angles. Graphite is hydrophobic, while carbon black and especially activated carbons are hydrophilic. Oxidising the graphite surface dramatically improves wetting. Wetting of activated carbons depends on the functional groups at the surface. Wetting of carbons strongly depends on pH, being better in alkaline solutions. Wetting of high surface area carbon additives consumes substantial amounts of water during paste mixing and changes the consistency of the paste. Extra water needs to be added to the paste in order to maintain pasting quality.

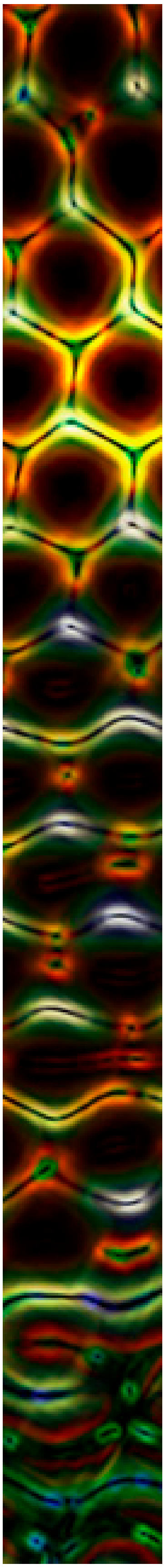
As a result, the density of the paste decreases, and fine tuning of the paste recipes becomes necessary, based on the feedback from plate performance.

4) Thermodynamics of the electrode system C (solid)–H_2O: in the negative plate potential region the cathodic reaction of methane formation is possible (about 150 mV below the H/H^+ equilibrium), but the process is probably slow. No studies on it could be found in the literature.

c. **'pH of carbon powder'.** The specific adsorption of OH^- and H^+ ions on carbon depends on carbon type, production technology, precursor, etc. When carbon powder is suspended in water, a large number of ions are adsorbed at its surface, and pH of the liquid changes. The values observed by EnerG2 in an ALABC study were between 2 and 10 (different types of carbon, different producers). The 'carbon pH value' has been found by EnerG2 to have a strong impact on the rate of hydrogen evolution on carbon electrodes prepared.

d. **Interaction with sulphuric acid.** No chemical reactions of carbon with sulphuric acid (at reasonable rate) have been reported. Intercalation in graphite was mentioned above. The electrochemistry of the carbon electrode in sulphuric acid solution is not well studied yet.

e. **Surface chemistry.** As an element carbon will react chemically with hydrogen, oxygen, nitrogen and other elements to form a wide variety of carbon compounds through specific bonds. Metals in turn can react with the resultant organic compounds. Pure carbon is considered stable in water or in sulphuric acid solution because the rates of its possible chemical reactions are low. The rate of electrochemical oxidation or reduction of carbon in the potential range where the negative plate operates, is also slow. Besides the cathodic processes of hydrogen and methane evolution (Pourbaix), anodic oxidation can occur at the carbon surface related to formic and carbonic acid formation, and CO and CO_2 evolution above 0 V (vs. Hg/Hg_2SO_4). An XPS study performed by Firefly Energy has identified the presence of bond hydrogen (C-H) at the carbon surface. The presence of carbonyl (C=O) and carboxyl (HO-C=O) groups have been detected, but only after polarising the carbon in the negative plate potential region [6]. The presence of organic groups or compounds on the carbon surface changes the physical and chemical properties of carbon and its interaction with lead and lead sulphate.



f. **Specific adsorption in sulphuric acid solution.** Ions and molecules of additives or impurities can be adsorbed on carbon. This is important for the NAM– especially in the case of impurity metal ions and expander molecules. Studies in this field are still in the initial phase. Specific adsorption is probably the reason for the strong interaction between carbon additives and lignosulphonates in the negative plate observed in a recent ALABC study (D. Pavlov, ALABC 1012G project).

g. **Interaction with lead.** Molten lead has no adhesion to graphite or carbon. Lead and lead sulphate crystals formed in the presence of carbon in solutions containing Pb^{2+} lead ions, have a different affinity to the carbon surface. In some cases they remain perfectly detached from it, in others– stick well to it. This depends on carbon type and surface chemistry. In relation to its contact to Pb and $PbSO_4$ crystals carbons can be 'plumbophyllic' and 'plumbophobic'. Added to the paste, particles of the first type will be covered by lead, integrated in the lead skeleton microstructure of formed NAM, and will be involved in electronic conductivity and surface area development. The second type will have little impact on the capacity of NAM but will form additional pores around themselves which can be filled with electrolyte and form local electrolyte storages for supporting deep discharge. They can contribute to increasing the utilisation of the lead active mass. Lead dioxide, formed in the presence of carbon, has much better contact to the carbon surface and can form a thin layer over it.

h. **Interaction with lead sulphate.** Lead sulphate crystals don't grow well on carbon surface. They will grow close to the oxidising lead surface, forming gaps between themselves and the carbon surface.

i. **Interaction with oxygen.** Oxygen bonds easily at the carbon surface. It influences the adsorption of ions (OH^-, H^+, SO_4^{2-} or HSO_4^-) available in the electrolyte) and of organic molecules (expander). In valve

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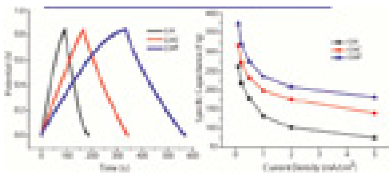
regulated cells oxygen gas will reach the negative plate and remain in contact with the carbon surface (wet or dry). Once bonded to the carbon surface, oxygen can form bonds with other oxygen atoms, metal ions, OH-ions and organic molecules. All these species change the local chemical conditions not only at the carbon surface, but also at the neighbouring Pb or $PbSO_4$ crystal surface. The interaction of the carbon surface with oxygen is of major importance for the effect of carbon additives.

j. **Interaction with hydrogen.** XPS studies have shown that small amounts of hydrogen atoms are always bound to the carbon surface. This is observed in all three cases: clean and dry sample never soaked in sulphuric acid, a sample soaked in sulphuric acid, and a sample polarised electrochemically at the potential of the negative plate in sulphuric acid. Hydrogen bonds are formed right after production with hydrogen contained in air. Probably hydrogen ions adsorb specifically on carbon in aqueous solutions.

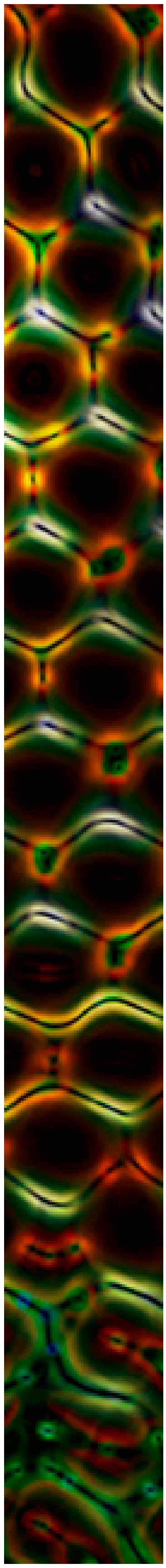
k. **Interaction with lignosulphonates.** Carbon additives have strong interaction with lignosulphonates contained in negative active mass expanders. ALABC studies (Project 1012G, D. Pavlov et al.) showed that if the NAM contains high surface area carbon additives, the amount of Vanisperse A should be very low in order to get high cycle life [7]. This effect has not been observed with lower surface area carbon in another ALABC study (project 1012J, D. Boden, T.McNally) [8].



Electrochemical properties of carbon electrodes polarised in sulphuric acid solution

a. **Electric double layer (EDL) composition.** Because of the high surface area of carbon powders their double layer capacitance in a battery's electrolyte can be comparable to the Faradaic capacity of the active mass. This is why the EDL capacitance of carbon is of great importance for the battery. The carbon particles with electron conductivity, staying in contact with the current collector and at the same time to the electrolyte, can form local electrochemical capacitors with the positive plate which has high capacitance. The double layer formed on carbon electrodes in battery electrolyte hasn't been studied yet. The chemical composition of the carbon surface can play an important role in the double layer.

b. **Equilibrium potential.** The open circuit potential (OCP) of pure carbon electrodes is between 0 V and -0.25 V (vs. Hg/Hg_2SO_4), depending on carbon type (graphite or carbon), polarisation pre-history and surface chemistry (activated carbons). This value is close to the equilibrium C/HCO_2H (formic acid) and is 800 to 1,000 mV more positive than the open circuit potential of the $Pb/PbSO_4$ electrode, i.e. of the charged negative plate. If the carbon particle stays in electronic contact to the current collector and in contact with the electrolyte, it



will form an electrode couple with Pb in NAM. At open circuit self-discharge, reactions could take place between carbon and lead, in addition to the self-discharge of the negative plate through hydrogen evolution. The reaction at the carbon electrode could be a reason for additional self-discharge processes at the lead electrode. At longer stay at open circuit (over 20-30 minutes) the OCP of carbon will slowly shift towards higher values. This is an indication that the surface of carbon undergoes slow chemical oxidation when dipped in the electrolyte, probably by dissolved oxygen.

c. **Cathodic processes.** When a carbon electrode is polarised at potentials between 0 V and -0.80 V (Hg/Hg_2SO_4), a small cathodic current flows. It might be caused by the reduction of surface compounds formed by dissolved oxygen. At potentials below -0.80 V the current increases due to hydrogen evolution. The current density is much smaller than that of pure lead electrodes and depends strongly on carbon type. The presence of carbon in the NAM will not contribute much for hydrogen evolution. This can happen, however, when the surface of the carbon microelectrodes is high compared to that of lead, or when the surface area of the lead active mass is increased by carbon, and of course when the carbon has a high level of impurities.

d. **Anodic processes.** Oxidation reactions of formation of carbonic acid and formic acid (and their ions) proceed above -0.40 and 0.0 V (vs. mercury/mercurous sulphate, Hg/Hg_2SO_4)

Shandong Jinkeli Power Sources Technology Co., Ltd was founded in 1982 and is currently member of Lead-Acid Battery Industry Standard Board in China. Shandong Jinkeli has close relationship with many Chinese Lead-Acid battery producers with more than 70% market share in Lead-Acid battery additives supply.Shandong Jinkeli is a strategic partner of Borregaard AS in China.Borregaard AS is a Norwegian base company and global leading Lignosulphonate producer.

There is a professional team of engineers equipped with advanced testing equipments in Shandong Jinkeli's technical center to provide technical services to the Lead-Acid battery industry. The company of Jinkeli was accredited by ISO9001:2008 certification.

To be global leading suppliers of Lead-Acid battery additives is Shandong Jinkeli's goal.

Jinkeli Expanders (Composite additive available by the customer request)

- **CuringBon® (4BS Crystal Seed)**
- **Humic Acid**
- **Sodium Humate**
- **Ultrafine Barium Sulfate**
- **Short Fiber (Polyester Staple Fiber)**
- **Sodium Lignosulphonate**
- **Carbon Black**
- **Graphite**
- **Oak Powder**
- **Cork Powder**

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respectively. This is the potential of a deeply discharged negative plate. Several oxygen– and hydrogen– containing carbon compounds can be formed at potentials above 0.0 V (vs. Hg/Hg_2SO_4). The reaction rate is slow compared to a pure lead electrode, but the products remain for a long time at the carbon surface and can influence the precipitation rate of Pb or $PbSO_4$ crystals.

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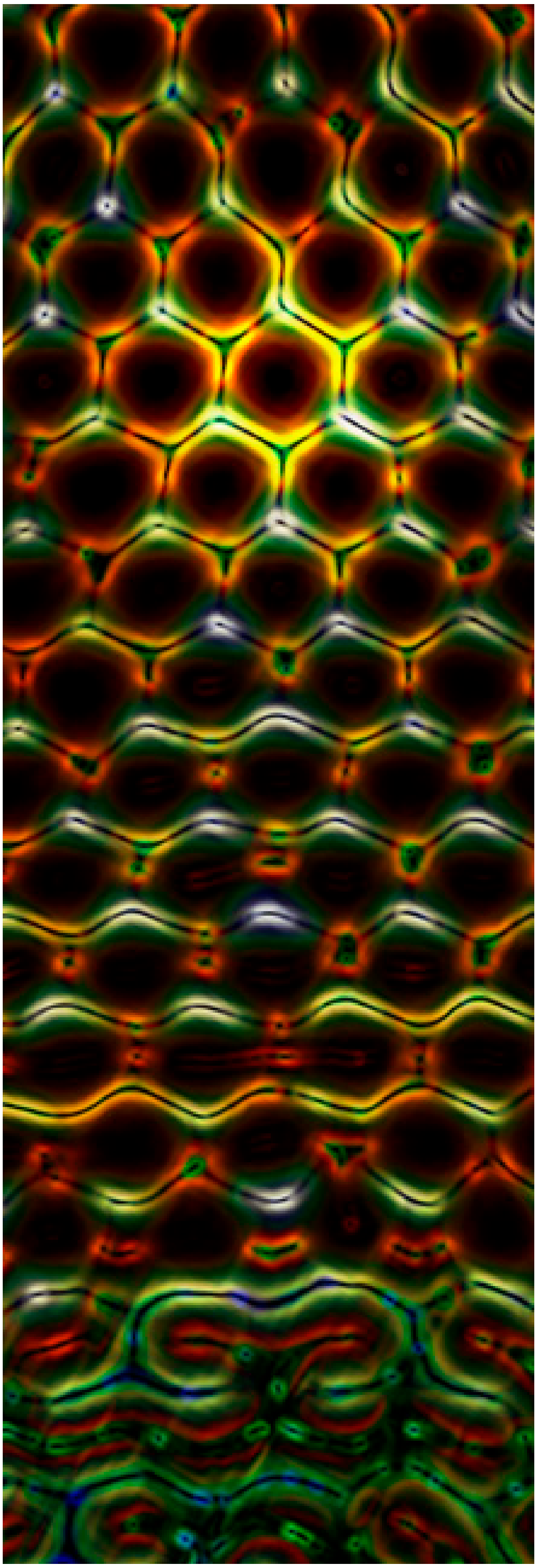


Producers of carbon powder additives for lead-acid batteries

ALABC members:

- **Atomized Products Group (APG)**, USA. Producer of TEXEX negative expander *www.atomizedproductsgroup.com*

- **Cabot Corp.**, USA. Producer of carbon blacks, activated carbons, silica *www.cabot-corp.com*

- **EnerG2**, Seattle, USA. Producer of activated carbons *www.energ2.com*

- **Hammond Expanders**, USA. Producer of pre-mixed negative expanders *www.hammondexpanders.com*

- **Kennametal, USA.** Producer of special carbon powders *www.kennametal.com*

- **Lignotech-Borregaard**, USA, Norway. Producer of lignosulfonates and other expanders *www.lignotech.com*

- **Orion Carbons (Degussa)**, Germany, USA, Producer of carbon blacks *www.orioncarbons.com*

- **Superior Graphite** (Sweden, USA). Producer of natural, synthetic, amorphous, crystalline flake, vein, expanded graphites, carbon black *www.superiorgraphite.com*

- **TDA**, Denver, USA. Producer of fully engineered activated carbon *www.tda.com*

- **Imerys**, Switzerland. Producer of natural & synthetic graphite powders and highly conductive carbon black *www.timcal.com*

The weird and wacky world of supercap applications

Dr Peter Harrop of IDTechEx surveys the supercaps scene and finds potential applications in some perhaps surprising situations.

Supercapacitors continue to improve faster than lithium-ion and lead-acid batteries. There is near consensus that commercial lithium-ion batteries will not improve more than a factor of two in cost and energy density in the next decade.

In contrast, Lux Research expects a 15% fall in supercapacitor cell costs per farad from $0.0096/F today to $0.0082/F in 2018 due to performance and manufacturing efficiency gains. Higher voltage operation at 3.5V instead of 2.7V could lower cell prices by another 40%, energy being proportional to the square of voltage, of course.

Given this rapidly changing situation, it is important to keep reading BEST for the latest news and analysis. The opportunities— and the vulnerabilities for the losers— are changing rapidly.

Supercapacitors, unlike Li-ion batteries, are a small business today with Lux Research putting the global market at $466m in 2013 and IDTechEx putting it at $465m in 2014, the leader Maxwell Technologies being in the region of only $100m. Considerable secrecy and a doubling in the number of manufacturers every few years makes it difficult to be accurate.

For example, who will make the supercapacitors for Meidensha of Japan to service the world's largest supercapacitor order that it landed in 2013 at $25m or so— or will it make them itself? Nobody knows. However, annual growth of 30% (on IDTechEx estimates), continuing recent manufacturer growth rates, and Lux's 79% growth predicted in the next five years, show that simply volume increase should get costs down substantially.

Changes in format

In this article we look at how changes in format are making certain supercapacitor performance parameters more important. In particular, we look at electric vehicles with Volvo taking a lead, and the newly popular wearable technology that is now attracting huge investment and a string of product launches from Google and its Chinese equivalent Baidu, Sony, Samsung and a host of startups, all needing energy storage in their new devices.

If we consider all potential applications, the biggest opportunity for supercapacitors is in replacing rechargeable batteries. There are secondary opportunities in replacing aluminium and tantalum electrolytic capacitors.

In all these cases, there can be an element of making new things possible as well. For example, the small Cellergy supercapacitors replace small batteries and tantalum electrolytic capacitors in electronic circuits. The larger supercapacitors made by Maxwell Technologies, Nippon Chemi-Con and Ioxus have had success in replacing, or partly replacing, both lithium-ion and lead-acid batteries.

To understand what will be possible in the near future, one must consider the big picture of what applications and therefore what formats will be needed and also the relative speed of improvement of supercapacitors compared to the alternatives. Some supercapacitor attributes will matter more and others will matter less in future. Some of the current attributes of supercapacitors compared to rechargeable batteries include:

- Charge and discharge exceptionally rapidly – high power density;
- Operate at wide temperature ranges – nearly all the energy available at -20°C and some work at -40°C;
- Have about four times the life (cycle or calendar life) so for the life of a typical vehicle or electronic device etc to which they are fitted, they are 'fit and forget';
- More reliable.

Some of the disadvantages remain:

- Cost much more and are much larger and heavier per energy stored –volumetric and gravimetric energy density-though the gap may be narrowing;

- They change electrical characteristics during charge, discharge and life;

When compared with electrolytic capacitors, the advantages and disadvantages are largely turned on their head. To over-simplify, the supercapacitors can be smaller, lighter and lower cost per farad but inferior in performance in some respects versus electrolytics.

The future

So what of the future? Oddly, we see no significant progress with the green agenda. Although about half of the 80+ manufacturers of supercapacitors now use alternatives to acetonitrile; those landing the biggest business continue to use it.

There is plenty of evidence that prospective purchasers increasingly value reliability and particularly long life and are prepared to pay for it, partly because a high proportion of new applications render it impossible to change the power storage device. We refer to millions rising to billions of wireless sensors and actuators, to wearable electronics discussed later, to supercapacitor wallpaper and supercapacitors in packaging or on the back of vast areas of solar panels, smart skin on vehicles and structural components in them.

The case of the electric vehicle

Consider an electric bus with a life of about ten years. The lithium-ion battery is likely to need replacement within that timeframe at an appalling cost of up to $20,000, whereas the supercapacitor alternative will not. We therefore have a binary decision: do we or do we not want to replace a major component at a cost so high that we shall probably trash the vehicle prematurely – the opposite of green?

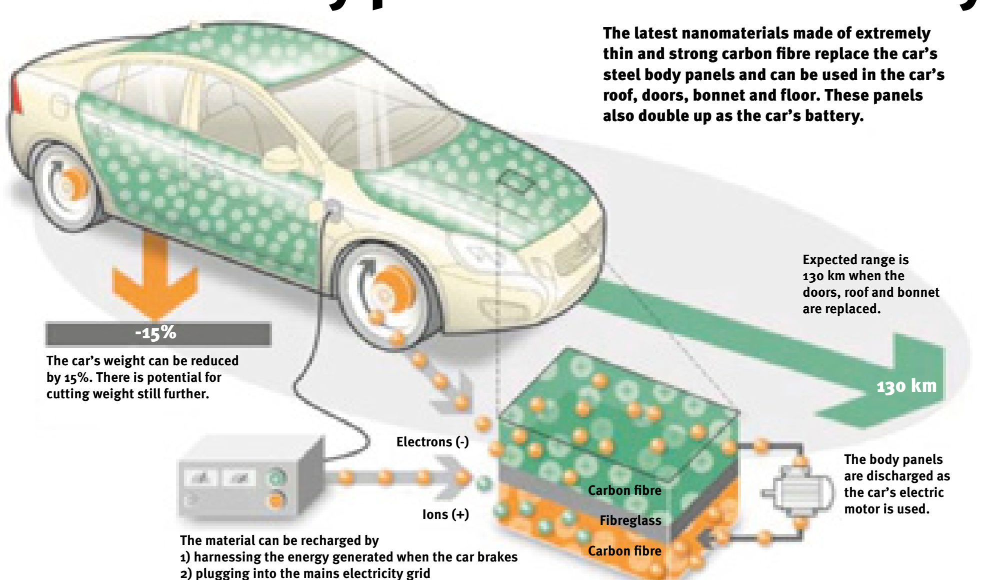
Bear in mind even the early resale price is collapsed by this hanging over you. Indeed, at a working meeting in the European Commission recently, a major motor company said the lack of an official resale price for pure electric cars was severely impeding their adoption.

The Lola B12 69/E, an electric racing car that recently set a land speed record for electric vehicles of 328 kilometers (204 miles) per hour, incorporates supercapacitors and a fully-integrated drive train within the body of the vehicle. Toyota uses supercapacitors instead of batteries in its Formula One hybrid car and hybrid buses commonly use them.

Now Swedish automobile maker, Volvo, owned by China's Geely Holding Group is also trying to dispense with the traction battery entirely, substituting a supercapacitor made from advanced carbon fibre-based nano-materials, which can be integrated into the body panels of the vehicle. It will use the S80 model to demonstrate this concept.

The vehicle's side body, doors, hood and roof panels will be made of nano-material that replaces the electric batteries used by conventional EVs. The vehicle plugs in to initially charge and then recharges the supercapacitor panels during braking. A single body panel should easily supply all the energy needed to run the vehicle's internal electronics. Additional panels can power the drive train, they claim, rather surprisingly.

The car's body panels serve as a battery



Source: Volvo

Volvo structural supercapacitor project

So far, supercapacitors are used on their own in a minority of pure electric buses, but not in any pure electric cars on their own. Their cost and size per unit of energy is not yet acceptable for mainstream use. To put it another way, when they are the right cost and size, they need recharging too often for most applications. However, for hybrid electric buses they are mainstream because here the recharging is very frequent from the on-board engine and the superlative cycle and calendar life are prized, though not by everyone.

In stop-start 'micro-hybrid' systems for conventional vehicles,

Medical, healthcare, fitness, wellness	Wellness such as electrically-heated apparel will be the smallest part and have the least commonality. Biggest subsector for the next few years: Diabetes blood glucose tests, increasingly non-intrusive, and fitness monitoring
Infotainment - Basic	Including Bluetooth and with microphone and basic electronic wristwatches including expensive Swiss and Japanese versions with solar power and satellite calibration but otherwise basic functions. Not connected directly to web
Infotainment - Advanced	Major subsectors: smart glasses, smart wristwear, 3D realisation headware for gaming. Energy harvesting and web connectivity increasingly involved
Industrial, commercial, military	Location often in 3D, communication, information, display and visible messaging all increasingly with integral energy harvesting
Fashion	Smart apparel and accessories such as handbags, rucksacks

Source: IDTechEx report, "Wearable Technology 2014-2024"

Above: Segments of the emerging wearable technology market, almost all need energy storage. Largest markets for the coming decade are shown in blue

there has recently been an announcement of lithium-ion being replaced by advanced lead-acid. The battle for stop-start is now between advanced lead-acid and supercapacitors often combined with lead-acid batteries to replace both the starter/hotel facility battery and perform stop-start, the life/performance/price compromise of lithium-ion being simply unacceptable here.

Wearable technology

Wearable technology is now on everyones' lips because it promises to become a business as big as mobile phones, though not necessarily replacing many of them. It consists of devices such as Google Glass eyewear, which is basically starting as a hands-free phone peripheral that has WiFi access, to less impressive smart watches. A speaker at the 11th Wearable Technologies Conference 2014 event in Munich, Germany in January described as using web-connected smart watches as, "Trying to assemble a ship through a keyhole".

No matter: better versions of smart watches, mind-controlled 3D virtual reality headsets and other wearable devices are coming along – even exotica such as exoskeletons for soldiers and the disabled and stick-on pancreases for diabetics. Then there are fitness monitors, already a $400m new business, mainly involving wristwear.

Diabetes glucose level monitors take the form of wristbands; Google contact lenses with displays are planned for this purpose. Almost all need power storage and batteries are winning with little use for supercapacitors as yet though some may provide backup or deep discharge of batteries. Set against that is the disruptive major advance represented by wearable technology in the form of smart fibre, where supercapacitors certainly have a place.

European supercapacitor yarn

The European Commission Powerweave project brings together 13 European partners from seven countries. The project started in June 2012 and it will last 42 months and the total grant is €4m.

Powerweave's objectives include developing a knitted or woven fabric that will generate power from sunlight or ambient lighting and store the energy within itself. The aim is to generate 10W/m^2 peak and to store 10Wh/m^2.

They will develop photovoltaic PV fibres of diameter 150µm, generating 1.5mW/m and rechargeable energy storage fibres also of diameter 150µm, storing 2mWh/m, with a view to combining them later. The participants seek to design and develop reliable interface and interconnection methods combined in a fabric structure of the photovoltaic and the energy storage fibres. They will connect the fabric and demonstrate operation in large

Where wearable technology is intended to be used- Source: IDTechEx report, "Wearable Technology 2014-2024"

	Number of devices sold in the year billion	Ex-factory unit value $	Market value $ billion ex-factory	Number of developers and manufacturers
Medical, healthcare, fitness, wellness	0.6	40	24	5,000
Infotainment – Basic (not connected or diagnostic): electronic wristwatches including expensive Swiss ones	1.5	5.8	8.7	3,000
Infotainment - Basic earphones, some with Bluetooth and microphones but mostly ear buds	5	0.1	0.5	
Infotainment - Advanced	0.73	30	22	5,000
Industrial, commercial, military	0.1	100	10	1,000
Fashion	0.5	10	5	1,000
Generally useful technologies across most sectors	-	-	-	2,000
Total	8.4		70.2	17,000

Source IDTechEx report, "Wearable Technology 2014-2024"

area PV/storage applications.

The chosen PV technology is dye sensitised solar cells (DSSC), which employ a photoelectrochemical effect not a p-n junction. Though relatively inefficient, they are flexible and much less sensitive to angle of incidence of radiation than silicon cells and perform over the widest range of light conditions. They are much less sensitive to shadowing than silicon and can be diode-free.

DSSCs utilise commonly available low cost processing equipment and materials so they should be very affordable eventually. Partners in the project are EPFL (École polytechnique fédérale de Lausanne) in Switzerland, where DSSC was invented and Cyanine Technologies will develop dyes, electrolytes and structures suited to fibre format DSSC.

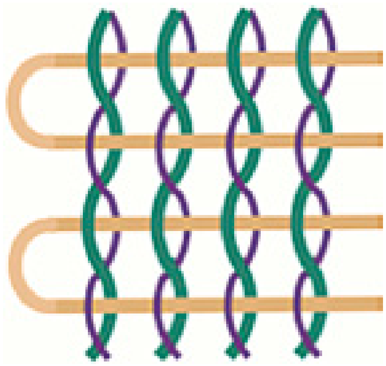
In this project, it is interesting that supercapacitors, not batteries, have been chosen as the power storage layers on the fibre, though the brief permits batteries to be considered. It is argued that they have high power density, long lifetime and low internal resistance, and they can be constructed from commonly available, low cost materials, so, like DSSC, they are potentially low cost.

Brunel University UK is developing chemical structures suited to fibre format supercapacitors. Multi-core melt spinning is being developed at CeNTI. Diverse fibre coating and deposition methods are being utilised at Centexbel and CeNTI.

Multi-layer fibres with good adhesion and resistance to bending are sought, followed by yarn twisting. Transparent conductive coatings will come from TWI and outer protective polymers from PPC. Centexbel work with BTF and VdS to develop weaving, knitting or embroidery using the active fibres.

Integration of PV films into textiles

Source: Sefar and CETEMSSA



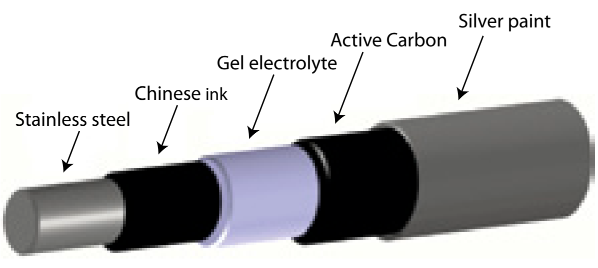
Powerweave demonstrations planned involve a small woven solar-powered airship and woven greenhouse shading that will provide power for ventilation, pumping water and lighting in remote regions.

The Powerweave project has made initial fibre samples demonstrating photovoltaic

Powerweave solar airship concept-source: European Commission operation in one case and energy storage in another. Work is now proceeding to construct the fibres in larger quantities and to integrate into a textile. With applications being considered in aerospace, agriculture and clothing, the approach will, for the first time, provide this added functionality in a true textile format, with benefits of reduced weight, an unobtrusive appearance, flexibility, conformability, easier storage and transportation than existing systems, they claim.

The development provides application and design opportunities in smart clothing (biomedical diagnostics and monitoring, sensing and display), telecoms (power for mobile devices and base stations), transport and safety (integrated power in inflatable rafts, safety clothing), disaster relief (smart energy generating tents, rescue gear) and leisure wear (sports goods incorporating sensors, telecoms and wearable portable devices).

There are plenty of other developments of smart textiles, particularly in Europe, the woven carbon and glass versions at Imperial College London being another example. Most smart textiles need power storage that cannot be changed. For example, Alphafit, based in Waldbüttelbrunn, Germany, has developed functional intelligent textiles for pressure measuring, with applications as diagnostic systems in sports, orthopaedics, medicine and technology.



Source: Phys Chem Chem Phys 2013

Dip method fibre supercapacitor

Supercapacitor yarn in Australia

In Australia, the University of Wollongong UOW has a strong, flexible yarn that conducts and stores electricity and could be used to create wearable medical devices and smart clothes. They even turn small fibres into "powerful storage with ultrafast charge and discharge rates" by means of a flexible, wearable supercapacitor yarn - about the width of a human hair - that is made by weaving two nano materials together to form a super-strong carbon nanotube.

Hundreds of layers of nanotubes, coated with small molecules of plastic, are woven with a thin metal wire and this is then spun into a yarn in a similar way to spinning wool into thread. The highly functional fibres can be integrated into complex 2D and 3D structures using our integrated knitting braiding machines. These facilities were recently commissioned as part of an Australian National Fabrication Facility Materials Node expansion.

Source Angewandte Chemie Nov 2013

Stretchable supercapacitor yarn

The yarn's flexibility means it can be knitted or sewn into clothing to power wearable electronics, which could be used to monitor movement during training or physiotherapy or to power high-tech fashion accessories, they say. The mechanical properties of the yarn mean it can add strength to composites often used in automotive components and could be especially useful in electric vehicles, it is suggested.

In the journal Angewandte Chemie, Chinese researchers have now introduced a new type of supercapacitor that also may fulfil this requirement. Its components are fibre-shaped and based on carbon nanotubes.

In this article we have seen that supercapacitors continue to improve faster than batteries. In new applications, their benefit of lasting longer than the product they are in is increasingly significant and they have replaced a minority of PbA and Li-ion batteries in road vehicles for example, without coming anywhere near their energy density.

You cannot change the energy storage layer on woven smart yarn half way through its life so they are favoured in early research on this. However, supercapacitors are a long way from being a threat to most of the lithium-ion or PbA battery business.

We have seen how the new big priority for investors and industry – wearable electronics – may one day employ supercapacitor fibre, possibly with solar cells as a top layer. However, this part of our study reveals a much bigger opportunity for the lithium-ion battery industry because most wearable electronics for the coming decade will be devices like smart wristwatches and smart glasses, not the more futuristic e-textiles, and here batteries win hands down.

Wearable technology is a new market calling for billions of batteries and wearable electronics will not replace mobile phones within the decade, so that battery market remains intact.

IEEE 1188: The game-changer of the decade for users of VRLA batteries?

Ahead of Battcon 2014, Battery Research & Testing's Peter DeMar tries to persuade that the 2014 version of IEEE 1188 standards for lead-acid batteries are the game changer of the decade.

Have you ever seen anything in any IEEE 1188 publication that would be considered radical or a game changer? Of course not! But when you get your hands on the 2014 version and read 'Section 5.3.3 - Special Recovery Process', you will realise that the game has indeed changed for the users of VRLA batteries.

When you read that opening statement you most likely thought the person writing is either:

1. The person who originally called VRLA batteries "maintenance free"; or
2. Someone who realises that the users of 2V VRLA cells have been getting the short end of the stick for far too long.

If you chose option 1 you should opt for one of the following: camping in the Antarctic in the winter, a hiking trip in Death Valley in the summer or a job in used car sales. If you chose 2, then you have been following the progress made throughout the past 15-plus years with the VRLA technology.

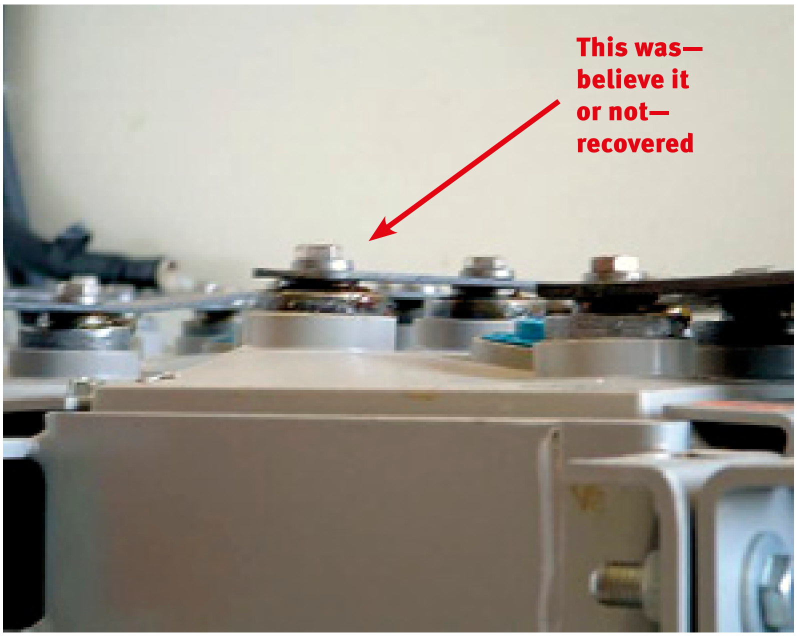
As anyone reading this publication understands, the 2V VRLA cell of today is a far cry from what first came into the market. I will only address battery strings made up of individual 2V cells and not mono-bloc ones, as the individual 2V cells have a removable vent, which is a requirement to perform the Special Recovery Process.

Users that make the decision to utilise a Special Recovery Process instead of just replacing batteries that have failed from premature capacity loss (PCL) can save their companies anywhere from a few thousand dollars to millions of dollars.

Over the past 20 years there has been substantial global research into why there were catastrophic failures under load, along with failure to perform as expected. The VRLA battery turned out to be a little bit more unpredictable than its vented brother. Over time, manufacturers figured out their problems with materials and manufacturing, but while sudden violent failure under load was almost eliminated, many or most still suffered from PCL.

In other words, when a discharge test was performed the battery would fail to perform as expected very early on in its designed or warranted life. And there still was that ugly little bastard named thermal runaway which it was believed came out of nowhere without any warning. Or so we all thought back then; sort of like the troll under the bridge.

So the manufacturers had cleaned up their designs and manufacturing processes, but the users were still stuck with paying for a battery that would not last anywhere near as long as advertised, nor would it perform as stated. We now have something that is unlikely to explode when called upon - Hallelujah! - but will still not support my loads over time. Gee! I feel like I paid for a pint but they only poured a half.



Battery string raised posts at a microwave repeater site.

The need for standards

In the Americas, insurance carriers require battery users to follow the applicable IEEE standard, or they can pay a higher premium if they decide not to do so. The insurance carriers require that these battery standards be followed because they realise that if you follow the guidance in an IEEE battery document you are doing the best you can to assure reliability of the battery string, and that you will have no sudden failures.

In the US, the original maintenance and testing document was the IEEE 450 standard, which was created for the nuclear industry, and was for vented cells only. The batteries in that application damn well better work when needed, with no exceptions.

After the VRLA battery came into widespread usage it became very clear that the maintenance and testing checks required for vented cells did very little to predict how a VRLA battery was going to perform. With vented cells, in a non-nuclear safety-related application the normal interval between load testing is five years; with VRLA cells, the original IEEE 1188 document called for capacity or capability testing every year.

This was because individual cell voltages were pretty much meaningless unless the cell was physical falling apart internally. Nor did we understand internal ohmics or have meters that could correlate a good value to a suspect or bad one; neither had we yet realised float current could be used like the canary in the cage in the mines. We just did not know the unknown unknowns.

The subsequent revisions of IEEE 1188 were, in essence, a facsimile of IEEE 450, leaving out references to specific gravity, electrolyte levels and visual inspections. All of us involved in the creation and subsequent revisions meant well, but we all missed the boat in one important area.

IEEE 450 allows a user to perform an equalise charge or to take other corrective actions if the battery fails its capacity test. Performing properly during a capacity test means it needs to make 80% of its published rating at a specified load and end voltage.

From the very beginning, IEEE 1188 stated if the battery fails to make 80%, then you need to replace it. There was never any allowance for 'try this or try that'.

Maintenance-free – really?

Remember these were originally promoted as 'maintenance-free', so if they were indeed maintenance-free then one was supposed to assume no corrective maintenance could be performed.

In reality maintenance-free only meant there should be no need to add water. However, it is now understood in most cases there is a need to add water to these cells in order to obtain maximum performance and life.

Luckily for users, there were people who wanted to know the root cause of these early failures, and these people came from all across the globe and attacked the problem from a very wide spectrum. As far back as 1995 Battery Research & Testing was attempting to recover performance in VRLA cells by adding water to the cells, as were manufacturers at that time.

We learned this action alone was a sticking plaster and not long-term solution. While we did make improvements in internal ohmic values as well as run-time and capacity, within a year or two the cells degraded again.

In other words we had not addressed the root cause of this PCL, just one symptom. I presented the results of that effort at Battcon 1997 and made the bold statement that I would never put a VRLA battery in anything that I wanted to be able to rely upon when needed.

Boy, I sure have changed, as I would put today's 2V VRLA cells into any application, including nuclear plants. In fact I got into a spirited disagreement with Gerry Woolf of this publication at Battcon 2008 on how reliable VRLA batteries had become.

The manufacturers now have a much more mature product and we the users now know how to properly maintain them. That some users fail to follow proper maintenance practices and blame the product when it fails to perform is far too common a practice and shame on them, but that is reality. But let's not jump ahead yet.

Real progress was not made until the work led by Will Jones along with Dr. Brendt from Germany and Dr. Feder from the USA determined the root cause of the PCL across the different manufacturers products was degradation of the polarisation on the negative plates, which led to the creation and introduction of a catalyst that could be installed in the head space in the cells.

And because everyone was afraid of thermal runaway, many manufacturers said users should never equalise their batteries. Too bad, as users did equalise and often for too long, thus accelerating the dry-out of the cells and a much higher risk of thermal runaway.

Of course, for months prior to any battery going into thermal runaway an observer would notice an increasing temperature differential between the cells and the normal ambient due to float current increases. This is another canary in a cage signal to draw your attention. If you are paying attention.

A battery that has not off gassed to such an extent it needs rehydration will indeed benefit from an annual equalise. And if a recovery process is performed the all cells can benefit from being high rate charged. The battery just needs to be monitored during this period.

IEEE 1188 – A game-changer

Now to the game-changer part! Throughout the past decade or more there has been substantial documentation that 2V VRLA batteries which failed due to PCL, and which are structurally sound, can be recovered into perfectly performing battery strings.

This recovery from PCL can be accomplished through what IEEE 1188 2014 calls a 'Special Recovery Process'.

Though our company's original attempts at recovering capacity through water addition alone was not a long-term success, as the industry progressed and more understanding was gained we continued our research. With our modified recovery process trademarked under the name IOVR and then, after further improvements, IOVR+, we believe we now have a long-term fix for 2V VRLA cells.

We addressed the loss of saturation first, the negative plate polarisation and sulfation issues second, and then the long-term performance with the addition of a catalyst to the head space.

The members of the IEEE Stationary Battery Committee realised they needed to inform users of IEEE 1188 there are some options outside of merely "replace the battery". I want to clearly state 2V cells only, because in order to replace the water that has been off gassed, the vent needs to be removable. Plus to maintain the capacity/capability recovered the original vent must be replaced with a catalyst equipped one.

The game-changer part is users now have a choice. Do you try a Special Recovery Process or do you just replace the battery?

Some users have published how their utilisation of the IOVR process (which we named the process that we developed, long before others called it 'Re-Hydration' or 'Capacity Recovery', or the IEEE gave it the name of 'Special Recovery Process') has saved their organisations hundreds of thousands of dollars and some in the millions. Those are US dollars, not dollars.

While most 2V VRLA cell designs in the US come with a 20-year warranty, which usually has a few years with a full replacement guarantee, and then the remainder of the 20 years adjusted by the amount of months used before the warranty is performed. That sounds fair, but the user normally still has to pay for the freight for receiving the new cells and sending the old back, and gets to pay removal and installation costs. These costs can run into many thousands of dollars.

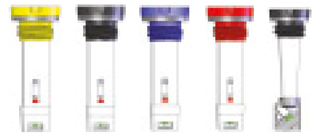
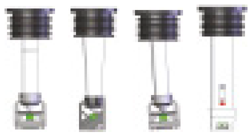
Because of the wide variety of locations, battery sizes, cell layouts, and site conditions there is no one price fits all for the work that we do at Battery Research, but a ballpark number per cell is normally between $75 and $100.

This is not a user-performed process as one can create as much damage by improperly attempting this recovery. This must be performed by properly trained individuals in order to be successful, and when properly performed will yield substantial benefits for many years to come. Of course, just how much damage the user sustains before they take action will have a direct impact on how much can be recovered.

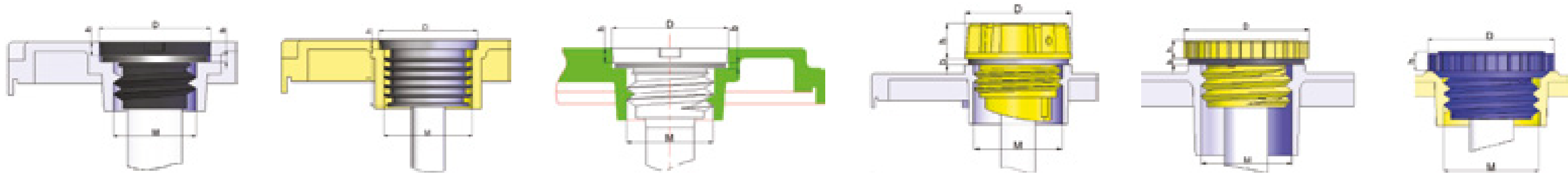
The amount of recovery and the useful life that is extended is dependent upon the extent of the degradation, and the recovery actions performed. If our company determines that a battery string is a candidate for performance of the IOVR or the IOVR+ process, we will guarantee improvement in the string, or the user does not have to pay. Almost any structurally intact string made up of individual 2V cells, with removable vents is a candidate for this process.

The present day 2V VRLA battery is not the battery of yesterday, as manufacturers have made great strides forward. Although they can still fail earlier in design life than expected due to PCL, just because your battery fails to perform as expected, it does not necessarily need to be replaced.

Products Catalogue

Serial	S1 Plastic Head with Screw		S2 Push-In Type		S3 Plastic Head with Screw		S4 Transparent Head with Screw		S5 Vent Plug Indicator	
Sketch										
Specification	S1-A1	Φ20×M16×P2.0	S2-A1	D21.30/M19.16	S3-A1	Φ20×M16×P2.0	S4-A1	Φ20.5×M16×P2.0	S5-A1	Φ24×M18×P2.5
	S1-A2	Φ20×M15×P1.5	S2-A2	D22.90/M20.77	S3-A2	Φ20×M15×P1.5	S4-B1	Φ20.5×M16×P2.0	S5-B1	Φ25.5×M18×P2.5
	S1-B1	Φ23×M16×P2.0	S2-B1	D21.30/M19.16	S3-A3	Φ20.5×M16×P2.0	S4-B2	Φ20.5×M15×P1.5	S5-B2	Φ25.5×M18×P2.5
	S1-B2	Φ23×M15×P1.5	S2-B2	D22.90/M20.77	S3-B1	Φ23×M16×P2.0	S4-C1	Φ23×M16×P2.0	S5-C1	Φ28×M22×P2.5
	S1-C1	Φ24×M18×P2.5	S2-C1	D21.30/M19.16	S3-B2	Φ23×M15×P1.5	S4-C2	Φ23×M15×P1.5	S5-C2	Φ28×M22×P2.5
	S1-D1	Φ20×M16×P2.0	S2-C2	D22.90/M20.77	S3-C1	Φ24×M18×P2.5	S4-D1	Φ23×M16×P2.0	S5-D1	Φ36×M28×P2.5
	S1-D2	Φ20×M15×P1.5	S2-D1	D21.30/M19.16	S3-D1	Φ27×M20×P2.0	S4-D2	Φ25×M16×P2.0	S5-D2	Φ36×M30×P2.5
	S1-E1	Φ23×M16×P2.0	S2-D2	D22.90/M20.77	S3-E1	Φ20×M16×P2.0	S4-E1	Φ23×M15×P1.5	S5-E1	Φ34.5×M25×P3.0
	S1-E2	Φ23×M15×P1.5			S3-E2	Φ20×M15×P1.5	S4-F1	Φ20.5×M16×P2.0	S5-E2	Φ34.5×M25×P3.0
					S3-F1	Φ23×M16×P2.0	S4-F2	Φ20.5×M15×P1.5	S5-F1	Φ34.5×M26×P3.0
					S3-F2	Φ23×M15×P1.5	S4-G1	Φ20.5×M15×P1.5	S5-F2	Φ37.5×M26×P3.0
							S4-G2	Φ23×M16×P2.0	S5-H1	Φ25×M20×P2.5

Assembly Instruction



Gravity Ball Density (g / cm^3 / 25℃)	Ball	Density
	● - Red Ball	0.835 & 0.920 & 1.020 & 1.050 & 1.150
	● - Blue Ball	1.150 & 1.160 & 1.170 & 1.180 & 1.190 & 1.195
	● - Green Ball	1.200 & 1.210 & 1.220 & 1.228 & 1.235 & 1.250

Length Range (mm)	38 / 40 / 42 / 45 / 48 / 50 / 52.5 / 55 / 58 60 / 62.5 / 65 / 68 / 70 / 72 / 75 / 77 / 80

For More Information, please visit our website or contact us by e-mail.

http://www.yucry.com E-mail: yucry@yucry.com TEL: +86(595)22787042 FAX: +86(595)22783392 Address: No. 32, Gaocuo, Qunshi, Beifeng, Fengze, Quanzhou, Fujian, 362000, China

Frustration mounts at British electricity storage policy inertia

Anthony Price, director of the UK Electricity Storage Network (ESN), reports from ESN's annual symposium in London, which took place in late January.

Electricity storage has had an exciting two or three years in Great Britain. With 23 projects of various scales, there is 5.1 MW of 'new' storage commissioned and a further 7.2 MW under construction or planning.

Much of this has been brought on-stream through funding such as the Low Carbon Networks Fund, or the Department of Energy & Climate Change's (DECC) Innovation Fund, so we ought not be too hard on those in DECC and the Office for Gas and Electricity Markets (Ofgem) who have made this possible. But frustration mounts when so much effort has been made by DECC to push electricity market reform onto the pitch in the form of its new Energy Act, but left storage, well beyond the side-lines, and probably closer to the dressing room.

"We just need a simple structure that pays for storage," said one of the delegates to the recent symposium organised by the Electricity Storage Network, "Let's avoid the complexity and come up with a simple approach."

This was not a lone voice in the crowd, but representative of the views of many delegates, who were clearly not happy with the way that the electricity storage industry has been pushed to the sidelines by successive government departments. The analogies are plentiful.

We can look at DECC as setting the rules, and Ofgem the referee, making sure that everyone plays by the rules. If there is a contravention, then the referee investigates and corrects the game to ensure compliance with the rules. "If there are any regulatory barriers to storage," asked Dora Guzevela of Ofgem in a fast-moving panel session, "Please tell us so we can change them."

But regulatory barriers are not the problem that is holding back storage, the overwhelming view of the symposium was the power market structure itself is the barrier. You have two teams on the football pitch, everyone keeping to the rules and the whistle never blows, so the referee is happy. But if no-one is actually kicking the ball, no-one will score a goal. And that seems to be the case for electricity storage in Britain.

Left to right: Andrew Ryan of OFGEM; Philip Bale of WPD; Peter Taylor, Quarry Battery; Ian Arbon, I Mech E; Jonathan Radcliff, University of Birmingham; and Mike Wilks, Poyry

Jane Ellaway of DECC explained the process of the Energy Act's capacity market and the ways in which storage might be able to take part. That lit the touch paper, for in a provocatively titled presentation, "Can We Leave Storage to the Market?", Mike Wilks of Poyry Management Consulting started by reminding everyone that storage is the most diverse of the flexibility tools available to the system operator, and it should not simply be treated as another generation tool.

Wilks was backed up by other speakers, representing both large scale and small scale pumped hydro, as well as developers of a range of battery systems, compressed air and other new technologies. And it is the diversity of views that is the strength of the industry's call for action.

The ESN wants to see 2,000 MW of new storage developed in the UK by the end of 2020. That's about 24 MW a month. When questioned how much energy that represents, there was an informed debate on the roles of storage, ranging from applications for power requiring relatively low storage capacity, and applications for energy, where four or more hours storage might be required.

And the location of storage is similarly diverse – we will need storage at residential, community, distribution and transmission levels, explained Philip Bale of Western Power Distribution.

At the beginning of the meeting, Ian Arbon, as chair, explained the background for the symposium and the reasons for focussing on the market development – there was no doubt that energy storage in general, and electricity storage in particular, would be completely necessary in the power systems of the future.

The question that had to be addressed was how to create the market framework to make this happen. There are far too many conferences on storage and what is needed now is a call for action— a debate to be started and realised with the delivery of a strategy that opens the way for widespread electricity storage to be deployed.

Our belief in setting up the Electricity Storage Network is to express a few simple principles:

1. There should be an official or an office in DECC responsible for storage. Carbon capture, nuclear power, solar, wind and electric vehicles all have dedicated teams, responsible for strategy, implementation and delivery. Why not storage?

2. The UK government has already agreed that it wants to have energy storage, it has said that in numerous policy statements and in its plans for other sectors, so it is now time for Government to make up its mind, set out a strategy and implement it. If it does not want storage, now or in the future, then tell the industry, and we can use our resources elsewhere.

3. Sort out the mess of legislation and regulations that confuse, obscure and penalise storage in comparison to other technologies. If that means introducing a new licence category for storage, that would be a good thing.

4. Provide a long-term, stable market framework in the power market for storage— either throw out the other subsidies and start again, or provide the incentive that enables storage to happen.

How do we maximise the value of electricity storage?

I feel quite honoured that I am often asked to speak at conferences and events on the topic of storage. Sometimes I wonder if the only way to make money from storage is to run a conference on the topic.

Not so many years ago the storage conference season consisted of an annual meeting run by the ESA and an occasional conference organised by one of the professional engineering groups. But not any more. Last year, I was invited to speak at or attend more than two dozen events, and it's simply not possible to go to them all. But we can think about the process.

Conferences fall into a few groups: those organised within the industry and aimed at the industry's current members, those which are aimed at informing those who are not yet in the industry, and the meetings where storage has been included as an add on to the programme.

So I recently attended Ecobuild— a large trade show in London aimed at all things environmental in the building and construction industry. I was invited to speak in a special session on energy storage. The first thing that I noted was just how much the building industry has addressed sustainability, with 'eco this' and 'enviro that' taglines on almost every imaginable product.

Manufacturers were keenly trying to reduce their carbon footprint and persuade others to buy products to save the planet. The second noticeable point was how Chinese companies were all over the exhibition with products covering all aspects of energy, water and materials. Just looking at the companies from Shenzen would have taken several hours. Our worldwide competitors can tell where the market is heading.

So, against this background, I was invited to talk about maximising the value of electricity storage. Naturally, it is not an easy topic – so I started with the role of electricity in society and the need to balance supply and demand.

We could then address the issues of balancing and the environmental and financial cost of changing from a system where generation always matched demand, to tomorrow's paradigm where we will need to actively manage our power networks so that demand is more closely aligned to variable generation – typically from wind and solar resources.

And quite simply that presents a real challenge to the industry, for we have yet to see a market model that gives the right signals for investment in storage. The 'free market' in electricity tends to be skewed by subsidies for renewables, while grid balancing is done at least cost by low-cost gas turbines with corresponding high emissions. It's not the easiest job to create a financial case for storage based on this uncertain future income stream.

There is only so much that you can cover in a short presentation, but 15 minutes is long enough to describe the need for storage, the economics of considering the whole system benefit as well as the finances for individual participants and to set out where the flows of money might end up.

It is worth remembering that the energy storage business is constantly changing, and the trends towards small scale solar PV at residential level will create a market for small scale residential storage, which has a totally different economic model to multi-megawatt storage installed on the transmission or distribution networks, but both solutions have their own merits.

We could have 2m homes each with 1 or 2 kWh of storage and that would amount to perhaps 2 GW of new storage in Britain, or we could see some new pumped hydro as proposed by SSE, Quarry Battery or Scottish Power, Compressed air developed by Gaia Electric, and a mix of batteries, liquid air and other systems.

I was quite alarmed that one of the following speakers came out with the tagline that batteries were a 19th century solution to a 21st century problem and the only sensible future was probably compressed air.

Just looking at the range of installed batteries of all types on the energy storage database shows that his comment was a little wide of the mark. As we really do have a major problem balancing our grid, overcoming constraints and making best use of wrong time energy, we need all the technologies we can get.

While the motivation of individual manufacturers and developers is to maximise the value of their own products, services and energy storage facilities, there is a requirement for us to consider how to maximise the value of storage for the whole system, so that we can all benefit from improvements to the system.

Sustainability does mean ancillary services such as frequency control and reserves provided from batteries and flywheels, energy balancing provided by pumped hydro, control of PV with large and small scale batteries and a greater acceptance that electricity storage does have a role in the sustainability of the overall power system.

If you just want to make money from energy storage— because you see it as the next big energy play, then find a niche product or service and exploit it ruthlessly. If you manufacture electricity storage products you probably know that it is a tough competitive world to get customers to buy your product.

If you are a network operator, then you will see value in owning and perhaps operating storage, but you may not necessarily be able to attribute a definite value to it. If you want to buy storage to make your PV work in they way that it should do— giving you power when you want it, then the satisfaction of knowing that you are doing your bit for sustainability will be maximising the value for you. Saving the planet for future generations depends on us all doing our little bit.

Welcome to
the Largest Battery Fair in the World

CIBF2014

第十一届中国国际电池技术交流会/展览会

11th China International Battery Fair

18-20,June , 2014

Shenzhen Convention & Exhibition Center

(Add.: Fuhua Third Road, Futian District, Shenzhen China)

Organizer

China Industrial Association of Power Sources

China International Battery Fair

CIAPS is the organizer of China International Battery Fair (CIBF) and held the first CIBF in Tianjin in 1992. In the past twenty years, CIBF has been held ten times, and has become the regular battery event in China. CIBF has had great impact on the domestic and foreign, and has been regarded as a trade place for battery manufacturers and users to exchange ideas on new technology, expand their markets and promote their products and services to customers in the worldwide marketplace. The CIBF is the only registered trademark for battery exhibition and conference in China and is held biennially in China. The CIBF is the preferred meeting venue between battery manufacturers, equipment and instrument suppliers, raw material suppliers, electronic device suppliers, environment and recycling specialists and battery users.

Scope of Exhibition

（1）All kinds of Batteries: Li-ion, Li-Polymer, lithium primary, Ni-Cd, NiMH, lead-acid, VRLA, advanced lead-acid, Carbon Zinc, alkaline manganese, zinc-air, Ni-Zn, Na-S, fuel cells, solar cells and supply systems, super-capacitors, other new battery types and thermoelectric cooling modules;

（2）All kinds of battery pack: battery packs for mobile phones, walkie-talkies, cordless phones, laptop computers, digital cameras, mobile DVD, emergency lighting, electric toys, UPS, railway locomotives and passenger cars, and ships;

（3）Power batteries and management systems: power batteries for power tools, electric bicycles, electric vehicles, and hybrid vehicles;

（4）EV charging station and related facilities: intelligent network for charging station, EV charging station products, charging station power distribution equipment, charging and replacing batteries and battery management system, parking facilities and intelligent monitoring device, charging station power supply solutions, charging station-smart grid solutions;

（5）All kinds of energy storage batteries: energy storage batteries for wind power, solar power, wind and solar systems, solar street light, lawn lamp, landscape and traffic lights and energy management system;

（6）Battery manufacturing equipments, testing instruments, chargers, raw materials and components for all kinds of batteries;

（7）Battery recycle technologies and processing equipments.

67500 m^2 Exhibition area, 900 Exhibitors, 3000 Booths

History of CIBF

Year	1992	1995	1997	1999	2001	2004	2006	2008	2010	2012
Exhibitors	56	118	180	237	256	323	401	470	670	850
Booths	75	126	236	305	374	460	596	892	1455	2450
City	Tianjin	Beijing	Beijing	Beijing	Beijing	Beijing	Beijing	Tianjin	Shenzhen	Shenzhen

For more information, please contact:
CIBF2014 Office
Fax: +86-22-23380938 E-mail: luhui@ciaps.org.cn
Contact: Ms. Lu Hui,
Tel.:+86-22-23959049, 13622009937
Web site: www.cibf.org.cn

14 – 15 May

Energy Storage 2014

Luxembourg

Examining the roadmap to commercialising energy storage systems. The conference will have a heavy focus on case study examples of global electrical energy storage projects, discussing how they overcame challenges such as costs, lifecycle, safety and many other obstacles to development & deployment. The event will feature an optional site visit to the Vianden Pumped Storage Plant.

Info: www.wplgroup.com

28 – 30 May

2nd Annual California Energy Summit

San Francisco, US

It has often been said that where California leads the rest of America will follow. And it has certainly led the way in terms of energy policies. This three-day conference will bring together executives from utilities, energy storage companies, renewable energy sector, demand response companies as well as policymakers and regulators to explore the prospects for energy resources within California.

Info: www.informationforecastnet.com/events/ca-energy

4 – 6 June

Energy Storage Association Annual Conference

Washington, US

The Energy Storage Association (ESA) (previously the Electricity Storage Association) is hosting its annual conference in Washington featuring speakers from industry and governmental departments as well as major manufacturers from the energy storage industry.

Info: www.energystorage.org

5 – 6 June

Eurobat AGM and Forum

Brussels, Belgium

Annual gathering of Eurobat's members and stakeholders to attend the annual AGM and forum to recap on the past year's activities, the state of the battery industry and issues affecting its members.

Info: www.eurobat.org

19 – 23 May

AABC Asia

Kyoto, Japan

The first Asian AABC brings the conference and exhibition closer to the carmakers and suppliers of the xEV market and battery technology innovators. Top energy storage technologists from Asian carmakers and their suppliers will assess the Asian electrified vehicles market and the battery technology that will power it. Simultaneous English/Japanese interpretation will be provided for all presentations.

Info: http://advancedautobat.com/conferences

29 May

Fourth Israeli Power Sources Conference

Herzelia, Israel

A day out in Israel to discuss the latest advances in the field found in Israel and abroad and support the electrochemical, e-mobility and smart grid industry in Israel. The annual conference brings together worldwide participants from private and public companies, start-ups, investors, academics and businesses that are interested in the energy field. An exhibition runs alongside the conference.

Info: www.sdle.co.il

4 – 6 June

Electrical Energy Storage Conference

Messe München, Germany

This conference sessions at this event will cover the entire spectrum of energy storage related aspects stretching from global market analysis, storage markets in Europe, the USA and Asia, battery production techniques, safety, development of materials, large-scale applications and off-grid markets, second life and recycling, and renewable power sources. Co-located with the Intersolar Europe Conference.

Info: www.ees-europe.com/en/conference.html

9 – 12 June

46th Power Sources Conference

Orlando, US

The Power Sources Conference looks at large-scale energy storage technology, focussing mainly on the electrochemical field. The technical conference will be accompanied by a poster session and exhibition. Conference topics will include devices, materials, mechanisms and power management, prototype development, manufacturing technology, device and system engineering, and economic and environmental considerations.

Info: www.powersourcesconference.com

10 – 13 June

LABAT 2014

Albena, Bulgaria

Technical conference and exhibition with open discussions in each of the conference sessions set in a beautiful Bulgarian beach resort. Topics include advanced lead-acid battery design and cell technology; electrolyte and paste additives; materials for advanced batteries and lead-carbon electrodes; supercapacitor systems; industrial machines and battery production equipment; the electrification of vehicles; and recycling.

Info: www.labatscience.com

11 – 12 June

2014 Battery Congress

Troy, US

A forum for engineers, managers, scientists, academic researchers, and industry executives to discuss advances in battery technology, applications and management systems. The conference and exposition is dedicated to the integration of new technologies in vehicular and other energy system applications. Topics include EVs and plug-in hybrids, lithium-ion battery systems, safety and modeling, nickel-metal hydride batteries, thermal management, global and national programmes.

Info: http://batterycongress.org

18 – 20 June

11th China International Battery Fair

Shenzhen, China

The China International Battery Seminar and Exhibition, organised by China Industrial Association of Power Sources (CIAPS), brings together battery manufacturers and users to view and discuss technological developments. Visitors and exhibitors include manufacturers of all battery chemistries; PV companies; battery manufacturing equipment makers; testing instrument companies; recycling plants; charging system developers; and raw materials and components producers for all battery types.

Info: www.cibf2014.com

6 – 7 August

Battery Power 2014

Denver, US

An international conference and exhibition highlighting the latest developments impacting mobile and portable battery systems for consumer products including power tools, smart phones, tablets, laptops and medical devices. Conference topics include new battery designs, improving power management, predicting battery life, regulations and standards, safety and transportation, battery authentication, charging technology, emerging chemistries and market trends.

Info: www.batterypoweronline.com

10 – 14 June

IMLB 2014

Como, Italy

The 17th International Meeting on Lithium Batteries is a forum for discussion on the progress on lithium-ion batteries for energy storage and conversion. Organised by research institutes around the world including universities and national laboratories, IMLB features presentations and posters on all areas of primary and secondary lithium battery-related science, including: national projects; advances in component materials; materials; recycling; cell design; developments and industrial production for electrified vehicles.

Info: www.imlb.org

Lake Como, Italy.

9th INTERNATIONAL CONFERENCE ON LEAD-ACID BATTERIES

LABAT'2014

10-13 June 2014 , Albena, Bulgaria

ORGANIZED BY:

Lead-Acid Batteries Department
Institute of Electrochemistry and Energy Systems
Bulgarian Academy of Sciences

LABD SINCE 1967

Traditionally very informative event where:

- Leading research scientists and technologists from all over the world present their latest experimental results and research achievements in the field of lead-acid batteries
- New trends for future development of lead-acid battery technology are outlined in the course of interesting discussions and spontaneous exchange of exchange of ideas on topical issue
- Manufacturers and suppliers to the lead-acid battery industry present new products, machines, equipment and services
- Professional networks expand naturally in a friendly atmosphere among the calm and the beauty of this wonderful seaside resort

DEADLINES TO REMEMBER:

Pre-registration, Short Abstract submission and reservation of exhibition space	30.10.2013
Early bird registration and submission of Extended Abstracts	15.03.2014

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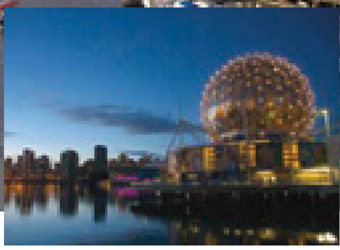
Mrs. Mariana Gerganska
Secretary of LABAT'2014
gerganska@labatscience.com

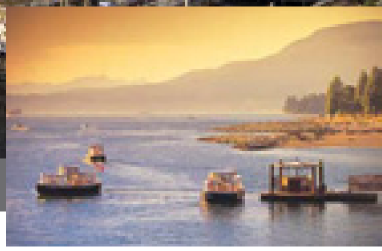
http://www.labatscience.com

Call for Papers - 36th International Communications Energy Conference

The Vancouver Convention Centre East, Vancouver, Canada

September 28 - October 2, 2014





Resilient Communications Energy for our Connected World.
INTELEC®, International Telecommunications Energy Conference, is the annual world-class technical forum presenting the latest in communications power systems, energy storage and energy conversion. This year's exciting conference program will include key note and plenary sessions from today's industry leaders as well as technical presentations, continuing educations tutorials and workshops and poster sessions. This leading conference will also include a comprehensive technical tour and social program for networking amongst industry peers.

SCOPE OF THE CONFERENCE

The scope of the conference will include but not limited to the following communications power and energy systems topics:

Communications Power Systems

- Outside plant power systems (twisted pair, customer premises etc.)
- Renewable energy generations (Wind, PV, Hybrid)
- Islanded and grid-connected autonomous power systems
- Power systems (High and/or low voltage DC; High and/or low voltage AC) for central offices/data centers
- Power distribution architectures for communications equipment
- Wireless power transfer for handheld communications devices

Energy Storage for Communications Systems

- Architectures for energy storage
- Battery technology (lead, zinc, lithium, sodium)
- Flow battery technology
- New fuel cell technology
- Energy management techniques
- Energy modeling and simulation

Power Conversion for Communications Equipment

- Circuit topologies and control techniques for AC/DC, DC/DC and DC/AC power converters
- Utility interface inverters for energy generation and storage
- AC and DC UPS
- High efficiency and high density power supplies

Site Support Systems

- Disaster recovery and mitigation
- Engine generator technology
- Physical and thermal design
- Grounding and EMC
- Codes, standards and specifications

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Buhler	grinding.dispersion@buhlergroup.com	buhlergroup.com	30
CAM	cam@cam-srl.com	cam-srl.com	58
CellCare Technologies Ltd	info@cellcare.com	cellcare.com	27
Cellusuede Products	sales@cellusuede.com	cellusuede.com	92
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Chongqing Yuanfeng Machinery Co.	salesjiangling@163.com	cqjiangling.com	102
CIAPS	luhui@ciaps.org.cn	cibf.org.cn	139
Continuus Properzi	sales@properzi.it	properzi.com	35
Dalton Electric Heating Co	sales@daltonelectric.com	daltonelectric.com	27
Daramic		daramic.com	IFC/3
Digatron	info@digatron.com	digatron.com	95
Dross Engineering SA	info@dross-engineering.com	dross-engineering.com	76
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Ferrazza	info@ferrazzanet.com	ferrazzanet.com	27
Froetek	info@froetek.de	froetek.com	54
GEA Process Engineering	gea-niro.chemical@gea.com	gea.com	77
Glatfelter	dynagrid@glatfelter.com	glatfelter.com	53
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Inbatec	info@inbatec.de	inbatec.de	46/47

Company	E-mail	Website	Page
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International Thermal Systems	sales@itsllcusa.com	internationalthermalsystems.com	57
Jayachandran Alloys (P) Ltd	sales@jcalloys.com	jcgroups.net	11
JBI Corporation	joe@jbicorp.com	jbicorp.com	137
Jiangsu Huaxing	office@hxdg.com	hxdg.com	130
Jinfan Power Technology	public@jsjf.com.cn	jsjf.com.cn	124
Kallstrom	office@kallstrom.com	kallstrom.com	75
Kustan	geku@kustan.de	kustan.de	40
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Mac Engineering	maceng@mac-eng.com	mac-eng.com	BC
Maccor	sales@maccor.com	maccor.com	50
Microporous		microporous.net	32
Oak Press Solutions	sales@oakpresses.com	oak-battery.com	42
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PC di Pompeo Catelli	info@pompeocatelli.com	pompeocatelli.com	122
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Yucry Traffic Appliances Co. Ltd	yucry@yucry.com	yucry.com	134

Where lethal voltages and rhetoric pass harmlessly to earth

The Luddites in a world unplugged

I was taking time out recently to read *The Luddite* magazine. You must know of it, the one that rejects new technologies from advanced batteries to the Internet and beyond.

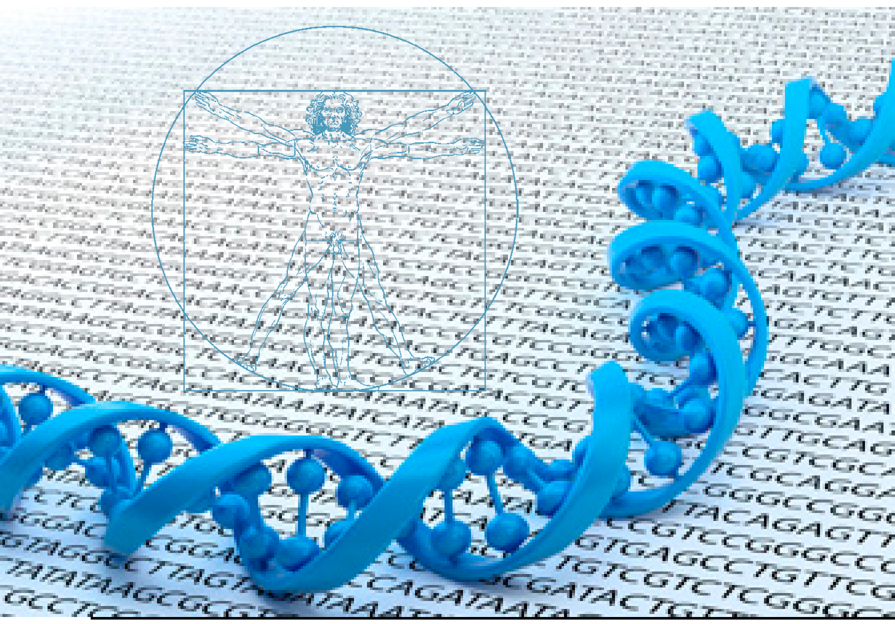
I felt very sorry for the editorial team because I knew that if I took that kind of view on things new and technical, well, it would be time to take the one way ticket to Dignitas in Switzerland and sample the Pina Colada, laced heavily with barbiturates.

I think it was a good 15 years ago that I realised the Nerds had won in the great game of life. And are still winning. More than 25 years ago, I met the team and saw the machines that sequenced the genome of a tiny worm, the precursor to the human genome project.

Cost of one sequence then? Several hundred million dollars. Cost now? About $10,000 for you and they throw in an iPad with your personal results! Benefits? Not so easy to sum up but in the future we'll look back at current cancer therapies as barbaric as surgery without anaesthesia.

Beware the future naysayers—in your company and elsewhere. They really are the "enemy within", as Margaret Thatcher would have said. Too scared to try something new or too lazy to investigate, their negativity helps nascent projects fail and their lack of engagement with new ideas can poison the enthusiasm of others.

The *Scribe* has seen it on both sides of the shop floor, from both unions and management. It's easy to understand why. Trying the new involves more work, which scares bosses who need to see how productivity gains can be made and workers afraid of redundancy.



No-one considers how things might be done better, or even that things could be more enjoyable. That's why the *Scribe* does what he does— it's fun (sometimes). Technology made it possible to do all of ESPL on a small bank loan.

And the *Scribe* has rarely regretted a tech purchase yet— it's the people hires you get wrong! We've been blessed with a cornucopia of technical goodies and innovations, so use them, and not just Ipads and smartphones.

The power to work out time-consuming problems, from compound interest to tomorrow's weather, resides in the processing power of ubiquitous computers available to millions of people. Education and knowledge is available at the click of the mouse. Or all the pornography you can handle, the choice is yours.

The *Scribe*, as some of you may know enjoys relaxing in the kitchen and cooking. One of his favourite kitchen gadgets is the pressure cooker. This isn't at all new technology, the concept was developed in the 17th century. But it was not manufactured in volume until the last century [Neither were lead-acid batteries! – Ed].

Yet try finding someone with enough basic physical chemistry to explain how it works. You won't. The *Scribe's* housekeeper is terrified of the device.

Still, the *Scribe* can knock out a heartwarming soup in under 30 minutes. But it's no fun decanting the super-heated material— way beyond the boiling point of water— into a blender afterwards. So wouldn't it be great if there were a cordless hand blender to do the job? There is, and it's lithium-ion powered.

In fact there's no limit to the amount cordless lithium-ion powered gadgetry you'll find in your local hardware stores and on the webpages of Amazon. Yesterday's chemistries are more than Goodenough (pardon the pun) to power a whole range of relatively low torque machines and the smart manufacturer is quick enough to work out that in some cases, you need more than one battery to get through the job.

Razors, beard trimmers, toothbrushes, shoe polishers, robot lawnmowers, all better and cheaper than their old NiCd predecessors. $LiFePO_4$ is great in the right places and so by the way, is lead. It's the application that's the decider, then the price.

And somewhere in Shenzhen, there's a sharp guy building the latest novelty power booster you can pack in your "man bag" to get you through your power hungry day.

Now if you have a serious a high torque job on your hands, like cutting up the tree that crashed into the road in front of your house, don't reach for the lithium-ion powered chainsaw that nobody is making right now.

To deliver three or better four horsepower, you'll need for the chainsaw, that's a lot of battery for a hand held tool and it doesn't make sense, a bit like the lead-acid powered smart phone — it runs all week, but weighs a ton!

Once you understand what the problem is, you scan component makers for the parts so you can provide a solution, estimate the price to market and question whether it's one the market will stand it and give you a return (Clue: volume sales help!). It's good engineering practice and business sense.

Now that the auto industry has worked out what the problem is— emissions reduction, fuel economy— and has learned a lot about batteries these past ten years, what do you think they'll be offering under the hood in 2025? Oh, and see if they make the same prediction in *The Luddite*.

The Acme $P_b$hone, not coming to a store near you (probably)

Lasers

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