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Batteries & Energy Storage Technology

No. 45 Summer 2014

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BATTERIES & ENERGY STORAGE TECHNOLOGY
Batteries and Energy Storage Technology magazine (ISSN: 1741-8666) is published four times a year (January, April, July and October), by Energy Storage Publishing Ltd., 70 Goring Road, Worthing BN12 4AB ENGLAND and distributed in the USA by Mail Right International, 1637 Stelton Road B4, Piscataway, NJ 08854. Periodicals Postage Paid at New Brunswick, NJ.

EDITORIAL
Energy Storage Publishing Ltd
70 Goring Road
Worthing BN12 4AB
ENGLAND
TEL +44 (0) 845 194 7338
FAX +44 (0) 845 194 7339
E-mail: tim@energystoragepublishing.com

PUBLISHER
Gerry Woolf
gerry@bestmag.co.uk

EDITOR
Tim Probert
tim@energystoragepublishing.com

ASSISTANT EDITOR
Laura Varriale
laura@energystoragepublishing.com

ADVERTISING
Les Hawkins
advertising@bestmag.co.uk
+44 7885 910 187

ADMINISTRATION
Sonya Upton
sonya@energystoragepublishing.com

PRODUCTION
Vic Giles
vic@bestmag.co.uk

CHINA AND EAST ASIA ASSOCIATE
Liang Yunchao
lyunchao@vip.sohu.com
+86 136 0324 2669

SOUTH ASIA ASSOCIATE
Dipak Sen Chaudhury
dipaksc@yahoo.co.in
+91 98314 37792

INDIA SALES OFFICE
Faredoon Kuka
kuka@rmamedia.com
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Don't believe the hype

In this edition, we cover six battery conferences– BCI (Battery Council International, lead-acid); the Energy Storage Association annual conference; Battcon (mostly VRLAs); the International Meeting on Lithium Batteries; the International Flow Battery Forum; and Electrical Energy Storage. In addition, there is coverage of Supercapacitors Europe in Peter Harrop's supercaps column.

Battery conferences are similar in so many ways to political conferences.

All too often battery conferences, particularly when centred on one chemistry or application, can get rather carried away. With hundreds of people gathered together high on hype, speakers become like politicians, placing hope before expectation and promising the earth.

It is our job, dear reader, to drill down through the spin and sniff out the naughty fibs. And, as you will read in this issue, there are plenty of them, particularly for energy storage.

The US Energy Storage Association's annual conference in Washington was a prime example. Yes, there is huge growth potential. Yes, it makes sense from a system point of view due to the explosion of renewables. But is it ready for prime time? It appears not; the cost is too high for the vast majority of potential customers.

Then there is the other type of 'political' conference, which resembles a morale-boosting rally. BCI is perhaps the worst offender.

There is more than a hint of North Korean totalitarianism about it's pro-lead, anti-lithium, dissent-will-not-be-tolerated style. The lead-acid industry feels under attack, so a closing of the ranks is perhaps necessary, but this insularity does not augur well for its long-term future.

The best conferences are those that dare to be critical, with delegates quick to question dubious utterances by propagandising and aggrandising speakers. All too often the opposite is true.

Elsewhere in this issue, **BEST** takes a road trip to Austria to visit the European factory of the now independent Microporous and lead-acid machinery maker BM Rosendahl.

If that's not enough to whet your appetite, we profile UK Power Network's flagship energy storage project developed by S&C Electric, as well as the usual technical expertise on lead-acid, lithium-ion and supercaps.

Oh, one more thing. If you will be attending ELBC in Edinburgh, do not forget to download the official show app. You can find it in the App Store and Google Play by searching for '14ELBC' – more information on page 42.

Enjoy the issue.

Tim

Tim Probert
Editor

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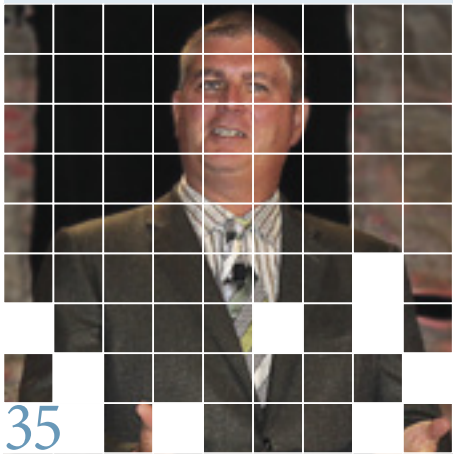
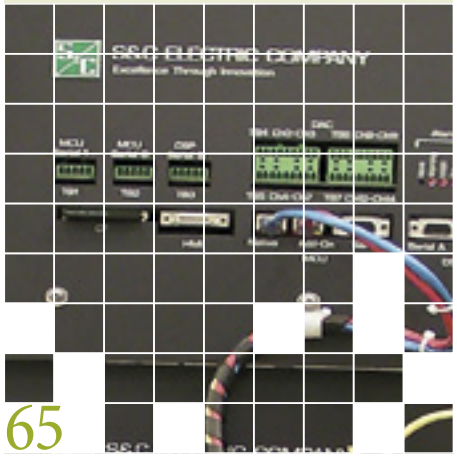
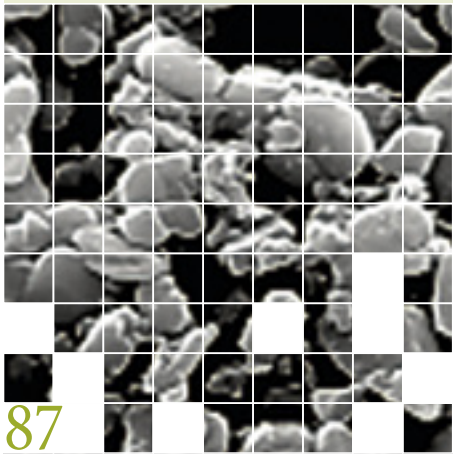
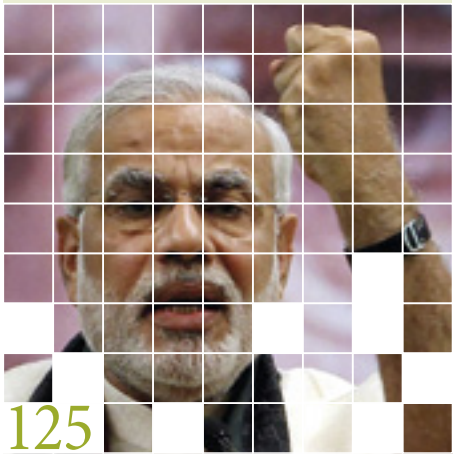
Regulars

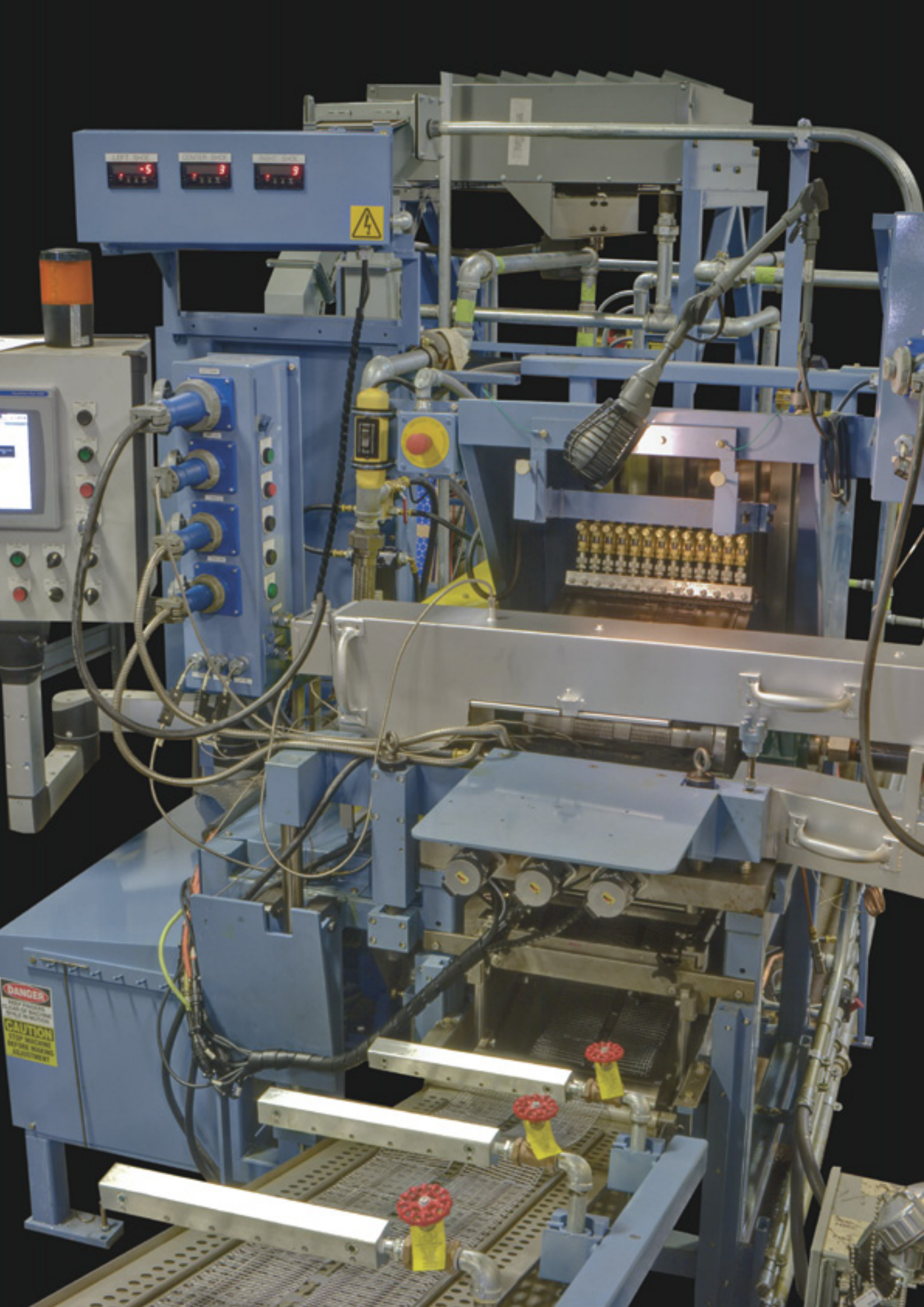
Features







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Chinese growth slowdown: Only anecdotal?

They tell me there's a slowdown here in China. It is hard to see it, if it is happening, but even if growth has slowed to 6-7%, it is a figure politicians in Europe and the US would die for.

You don't see closed malls, boarded up shops and all the other indicators of 'downturn' we have become used to in the West these last seven years.

Most of the evidence is anecdotal. And this writer thinks this is the best kind, because forecasts by trade organisations, consultants and others are notoriously unreliable. From the International Monetary Fund downwards, they get it wrong. Do not buy a report— use your eyes and ears. Battery people have told me inventories are piling up everywhere, from automobiles to starter batteries themselves.

At the CIBF show in China in June, Bravado was the name of the game. Huge stands, video screens and the kind of promotional frippery you only see for automobile shows in Geneva, Paris and Los Angeles. It makes European battery trade fairs look like church fetes.

But was it all bullsh*t? Far from it. Chinese firms can not only make lithium-ion batteries, as they have done for years— they're now offering the machines that make lithium-ion batteries too. Slitters, coaters, calendaring machines and more. This was once the province only of Japan and latterly Korea.

So why should this be? It is only anecdotal, but take a look at the ebike park on any busy junction in any city in China (and try not get killed in the process). Count the bikes with lithium-ion battery packs. They have become more and more common. A good source told me, lithium-ion now has about 10% of the ebike power source market, and it reached that level in under three years from a standing start.

Let's cut all the nonsense about technological superiority of lithium over lead. The no-brainer argument has always been, it is a lot easier to carry a lithium-ion battery pack up ten flights of stairs to charge it than a lead pack. It might have been different in a world of apartment blocks with elevators.

Ebikes and scooters don't have a long life anyway– three years tops– so the chances are market penetration of lithium-ion in the ebike market is due to go exponential in China in the next couple of years. And since lead for the ebike market has been a key driver on the lead price recently, think about the knock that's going to have. You read it here first.

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.

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Key Contacts

Mr. C. Pradeep, Managing Director | 0091-9994388843 | pradeep@jcalloys.com
Mr. C. Prasath, Joint Managing Director | 0091-9994988850 | prasath@jcalloys.com
Mr. A. Shiva Subramanian, Manager-Marketing & Sales | 0091-9500942404 | sales@jcalloys.com

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Question over East Penn successor

Sally Miksiewicz, CEO of East Penn Manufacturing, was killed on June 20 while jogging near her home.

At around 7.27a.m, Miksiewicz, 52, was hit by a pick-up truck in Richmond Township, not far from her home in Pike Township, Pennsylvania.

An autopsy determined that Miksiewicz died of head injuries.

Miksiewicz, who is survived by three sons and a daughter, had three decades' experience in her family's battery manufacturing business.

She was the daughter of chairman and company founder DeLight E. Breidegam.

Miksiewicz took the position of CEO in 2009 having worked there at the time for 25 years. Her brother, Dan D. Breidegam, is currently East Penn's vice president of metals and commodities management.

Commenting on the appointment of a successor to Sally Miksiewicz, Dan D. Breidegam told BEST: "The East Penn family is dedicated to sustaining and growing the company as a family-owned entity for all our employees, customers, and the community. Our conviction is to effectively manage, preserve and protect what we have built together utilising our long-term, talented management team."

Energy Power Systems to produce 'quasi-bipolar' lead battery in Q3 2015

Michigan-based Energy Power Systems (EPS) is to begin production of 'quasi-bipolar' lead-acid battery packs in the third quarter of 2015, BEST understands.

EPS is developing a 'quasi-bipolar' 12V lead-acid battery pack with multiple-stacked, thin plates designed for use in micro- and mild-hybrid cars. EPS will build a 100,000 square feet facility in Auburn Hills, Michigan, a spokesman for EPS told BEST, adding the battery would 'reinvent' lead-acid batteries.

Details are patchy, but the use of a substrate and simplified electrical patterning will mitigate the need for connectors in packs, thus significantly boosting power and energy density.

In 2012, EPS told the Society of Automotive Engineers its first generation of its 'quasi-bipolar' battery would achieve an energy density of 45Wh/kg, and had achieved a power density of 2000W/kg in testing – roughly four times that of current lead-acid batteries.

EPS was founded in 2011 by Subash Dhar, a former president of Ovonic Battery Company, which developed nickel-metal hydride batteries for hybrid vehicles. EPS has secured $25m backing from parent company Townsend Ventures, the venture capital firm that also owns lithium-ion battery manufacturer Dow Kokam.

LG Chem signs battery supply deals with two Chinese carmakers

LG Chem has signed deals with two Chinese carmakers to supply batteries for electric vehicles (EVs).

The Korean lithium-ion battery maker did not disclose the details of the contracts with Shanghai Automotive Industry Corp. and Qoros Automotive Co. Currently, LG Chem provides EV batteries for two Chinese automakers including Changan Automobile Co.

With the latest deals, LG Chem has clinched orders to supply more than 100,000 car batteries to the four Chinese automakers, the company said, adding the release of their EVs will likely to lead to increased battery sales.

LG Chem is to build a factory for the production of lithium-ion batteries for electric vehicles plant in Nanjing.

LG Chem will establish the plant with Nanjing Zijin Technology Incubation Special Park Construction Development and Nanjing New Industrial Investment Group.

The construction for the plant, in which LG will hold a 50% stake, will begin in September, and it will commence production by the end of 2015.

Panasonic to build lead-acid battery plant in India

Panasonic is to set up a lead-acid battery plant in India and plans to make the country a regional hub.

The batteries shall be used mainly in the automotive industry and data centres. The costs for the plant are estimated at Rs200 crores ($36m). Panasonic is currently deciding on a location, which offers either tax concessions or is closer to the company's automotive customers. The target is to start production by 2016.

According to Manish Sharma, managing director at Panasonic India, the company plans to expand in India to make it a regional hub for Asian and African markets. "India will put across a case study for the next at least 10 to 15 years to be replicated at least in African markets and majority of Southeast Asian, South Asia markets," he added.

Samsung SDI completes takeover of Cheil Industries

Samsung SDI finalised its takeover of electronic materials manufacturer Cheil Industries on July 1.

On March 31, Samsung announced it would pay Cheil Industries' shareholders 0.44 shares in Samsung SDI for each Cheil share held.

SDI will internalise battery-related materials techs owned by Cheil. The acquisition is expected to enhance the competitiveness of Samsung's battery business by taking advantage of Cheil's battery separator technologies, while increasing the sales of Cheil's produced materials to automobile manufacturers who are Samsung SDI customers.

Samsung SDI said the new entity is targeting sales of 29 trillion won ($28.7 billion) by 2020, compared with last year's combined sales of 9.42 trillion won. Samsung will double investment in the entity to 1,374.4 billion won.

Samsung Everland, the Korean firm's textile and fashion material division, will be renamed Cheil Industries.

Sony and Hydro-Québec launch energy storage venture

Japan's Sony Corporation and Canadian electricity supplier Hydro-Québec have established Esstalion Technologies, a joint venture to research and develop large-scale energy storage systems for power grids.

The joint venture will use Sony's control technology for olivine-type lithium-ion iron phosphate rechargeable batteries and scalable module systems together with Hydro-Québec's operation and control technologies for electric power supplies and lithium-ion material technology.

Esstalion Technologies is aimed to research safe and reliable systems for large-scale applications and improve battery material technology for electric power systems.

ALABC and partners demonstrate NGHV

The Advanced Lead Acid Battery Consortium (ALABC) and its partners in the Natural Gas Hybrid Vehicle (NGHV) Working Group demonstrated a NHGV start-stop vehicle powered by lead-carbon batteries at the Alternative Clean Transportation (ACT) Expo in California.

The model, a RAM 1500 HFE, works with a start-stop system that operates with compressed natural gas fuel and a 12V lead-carbon battery. The NGHV Working Group plans to build a second vehicle with the same concept later this year operating with "other" technology to reduce more costs than the first model.

The project group stated that NGHV technology will become an alternative for conventional gasoline and diesel engine vehicles due to the combination of compressed natural gas and hybrid-technologies, which lead to lower fuel costs and emissions.

The project aims to create sustainable vehicles with 98% recyclable lead-carbon batteries that use lead, plastic and chemicals from domestic recyclers.

The technical approach was designed by ALABC. The NGHV project is a collaboration of various companies in the naturals gas and lead-acid battery industry and is sponsored by Southern California Gas, AGL Resources, RSR Quemetco and East Penn Manufacturing. The sponsors will test the models in their fleets.

Polypore signs long-term deal with Panasonic for Celgard expander

Polypore has secured a five-year contract to supply Panasonic with its Celgard brand separators for use in large format lithium-ion cells.

This long-term agreement includes guaranteed purchase and supply volume requirements over the five-year term.

In a statement, Polypore CEO Robert Toth said: "After working closely together with Panasonic for many years, we are pleased to formalise our partnership with them. Panasonic is a leader in battery technology and is well positioned to grow as new vehicle models continue to be introduced to the market."

NTSB recommends aircraft-specific lithium-ion battery tests

US authorities have recommended the Federal Aviation Administration (FAA) adopt aircraft-specific lithium-ion battery tests and other measures to evaluate the risk of internal short circuits, following the infamous Boeing Dreamliner incident.

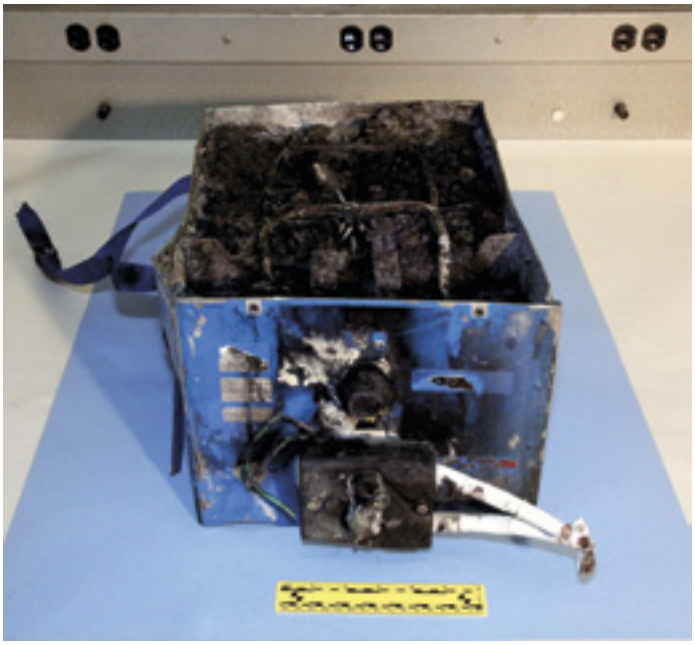
The US National Transportation Safety Board (NTSB) is conducting an ongoing investigation of a fire event that occurred in January 2013 of a lithium-ion battery on a Boeing 787 parked at Boston Logan Airport.

In a letter to the FAA, the National Transportation Safety Board (NTSB) has said that the processes used in 2006 to support the certification of the GS Yuasa lithium-ion battery designed for the Boeing 787 were inadequate, in part, because there is no standardised thermal runaway test conducted in the environment and conditions that would most accurately reflect how the battery would perform when installed and operated.

Investigators found the battery involved showed evidence not just of an internal thermal runaway but that "unintended electrical interactions occurred among the cells, the battery case, and the electrical interfaces between the battery and the airplane."

The NTSB said that including subject matter experts outside of the aviation industry "could further strengthen the aircraft certification process" by ensuring that both the FAA and the aircraft manufacturer have access to the most current research and information related to the developing technology.

In the letter to the FAA, the NTSB recommended five measures including developing an aircraft-level thermal runaway test to demonstrate safety performance in the presence of an internal short circuit failure; requiring the above test as part of certification of future aircraft designs; re-evaluating internal short circuit risk for lithium-ion batteries now in-service; developing guidance for thermal runaway test methods; including a panel of independent expert consultants early in the certification process for new technologies installed on aircraft.



The final report on the January 2013 Boeing 787 battery fire investigation is expected to be completed in the autumn.

New York ultracap manufacturer Paper Battery Company gets $3m financing

Ultracap maker Paper Battery Company has closed $3m Series A private investment financing.

The financing, led in two tranches by Caerus Ventures, will be used to scale from the existing pilot production line to commercial manufacturing and achieve first sales revenues in 2015.

In the last eight months, the company has installed a new pilot line facility, launched a commercial partnership with battery pack manufacturer, TWS Industrial, and signed a test and evaluation contract with one of the largest OEM manufacturers in consumer electronics.

The company's PowerPatch product prototypes have been validated by customers, partners, and strategic investors, and progress towards commercial production is driven by confirmed interest from these parties.

Paper Battery Company's CEO, Shreefal Mehta, said, "This capital round will allow the company to scale production and rapidly bring to market novel pulse-power management solutions building on its ultrathin ultracapacitors."

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Sacred Sun, Furukawa tie-up on extended life battery

Sacred Sun, one of the largest manufacturers of lead-acid batteries in China, has entered into a technical collaboration with Japan-based Furukawa batteries to produce its patented super-long-life deep-cycle FCP series storage battery in Sacred Sun's factory located in Qufu, China.

The product is targeted at the growing Chinese renewable energy and telecom stationary power market. In accordance with the agreement, Sacred Sun will get the full design and manufacturing technology of FCP products from Furukawa battery as well as the use of the "FCP" brand.

Sacred Sun has 6m kVAh annual production capacity and a wide range of product series covering standby, energy storage and motive power markets.

The FCP series storage battery in this technical cooperation has extreme cycle life exceeding 4,000 cycles at 70% DOD, as well as superior reliability and cost advantages compared to current common storage battery types, and will help the further develop the energy storage and renewable energy markets.

Moll and Chaowei Power form stop-start battery partnership

China's Chaowei Power has entered into a strategic partnership with Germany's Moll to manufacture stop-start lead-acid batteries.

Within the next three years, several million euros will be invested in doubling production capacity for state-of-the-art car batteries at Moll's production site in Bad Staffelstein.

Under the agreement, Chaowei Power will subscribe for a 40% limited partnership interest in Moll by way of capital increase for €6.5m ($8.9m) and acquire 40% of the registered capital of Moll Beteiligung at €12,400.

Chaowei Power will acquire all limited partnership interests in Moll G+V at €2.5m all shares in Moll Grundbesitz at €25,000.

It will also acquire from Moll a study report in relation to the establishment of a new battery plant for the production of lead-acid (AGM & EFB) batteries used for micro-hybrid applications for €500,000.

Chaowei Power also agreed to provide a shareholder loan in the amount of €2m to Moll at an interest rate of 4.9% per annum which will mature in 2018, to replace certain existing liabilities of Moll.

In addition, Moll will transfer to Chaowei Power specific technologies and know-how relating to the production of AGM batteries and EFB and a licence right to use the Moll brand, and it is anticipated that Chaowei Power will grant a corresponding sub-licence of the above-mentioned technologies, know-how and licence to the joint venture to be owned 95% and 5% by Chaowei Power and Moll respectively.

Moll and Chaowei are building up large production capacities in China in a joint venture to be able to deliver to customers such as Volkswagen, Audi and others directly in China.

"This partnership creates the preconditions to successfully bear the challenges of a globally acting economy even as a family business", said Gertrud Moll-Möhrstedt, managing partner of Moll GmbH.

Johnson Controls expands in China

American automotive battery supplier Johnson Controls has opened a new battery manufacturing plant in Chongqing City, China.

The facility is expected to produce six million automotive batteries per year. Johnson Controls invested $154m in the plant with a size of 133,000m². "This facility will not only enable us to meet increasing demand from our customers in China, but will also allow us to demonstrate our global leadership in technology and sustainability", said Kenneth Yeng, vice president and general manager of Johnson Control Power Solutions in China. The manufacturer will supply China's rapidly growing demands with its battery technology and services.

The new facility deepens the company's long-term commitment to China. Johnson Controls entered the Chinese market with batteries in 2005. The new facility is estimated to create jobs for more than 500 people. Yeng stated that China is a key strategic market for the company.

Some 22m vehicles are produced annually in China, the biggest vehicle market of the world. A new headquarters of Johnson Controls is planned in Shanghai. Two members of the global executive team will be located there.

"We appreciate the support from the Chongqing and Fuling governments, and we look forward to contributing more to the development of the local economy as well as to the local community," said Yeng. At the opening in Chongqing City, Johnson Controls welcomed the representatives from local governments.

A123 buys technology and staff from Leyden Energy

A123 Systems has acquired lithium-ion cathode and electrolyte technology from Leyden Energy for an undisclosed sum.

The deal includes more than 20 patents covering Leyden's lithium titanate (LTO) and non-flammable electrolyte (Li-imide). In addition, some of Leyden's staff will be relocated from Massachusetts to A123's R&D department in California.

Leyden's technology expands A123's lithium iron phosphate materials portfolio the company commercialised ten years ago. A123 is now a wholly owned subsidiary of the Wanxiang Group after its bankruptcy in 2012. The company recently announced to focus primarily on the automotive market.

Leyden is a recipient of the United States Advanced Battery Consortium (USABC) and designed micro-hybrid applications including a LTO/LMO battery for start-stop engines with longer cycle life for legacy carbon-based materials with development funding from USABC.

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Eurobat defends automotive lead batteries

There would be a significant impact on the overall performance and cost of vehicles if established battery applications were to be replaced with alternative technologies, according to a new study published by European automotive and battery industry trade groups, including Eurobat.

The study concludes that lead-based batteries will by necessity remain the most widespread energy storage system in automotive applications for the foreseeable future. Their low cost and unparalleled ability to start the engine at cold temperatures sets them apart in conventional and basic micro-hybrid vehicles, and as auxiliary batteries in all other automotive applications.

With regard to overall storage capability and potential for further fuel efficiency improvements, the demand for larger battery systems based on lithium, nickel and sodium will continue to grow through the increased market penetration of vehicles with higher levels of hybridisation and electrification.

In any automotive application, regulatory decisions to phase out established battery technologies would impact negatively on overall vehicle performance and cost. The study reaches this conclusion through a detailed analysis of the technical requirements placed on the battery in three different classes of conventional, hybrid and electric vehicles. It also finds that substitution has an effect on targets for fuel efficiency and reduced CO_2 emissions.

Eurobat chairman Johann-Friedrich Dempwolff, said: "Currently all battery technologies have specific performance profiles that serve a well-defined purpose in automotive applications and continue to have an irreplaceable role in reducing CO_2 emissions from transport".

"In particular, this report demonstrates the necessity of maintaining the exemption for lead-based batteries within the EU End of Life Vehicle Directive's wider ban on lead in light-duty vehicles. The EU's legislative and regulatory framework should guarantee a fair and technology-neutral competition between battery technologies."

The study, *A Review of Battery Technologies for Automotive Applications*, also makes clear that a transition towards other battery types would have significant ramifications for development times and would be expensive to implement effectively.

Ford, Samsung join forces to develop 12V lithium packs

Ford and Samsung SDI have unveiled a "near term production" dual 12V lithium-ion/lead-acid battery system and research on a 12V lithium-ion battery to dispense of the lead-acid SLI.

The dual-battery system combines a lithium-ion battery with a 12V lead-acid battery for non-hybrid vehicles with start-stop engines. The new system should enable regenerative braking and fuel savings.

Ford's Energy Storage Strategy and Research Senior Manager Ted Miller said: "That battery system is something we hope to employ in production in a fairly near term. That's a key component in our Start-Stop technology."

Start-stop systems turn off the engine when the vehicle stops, until the driver reveals the brake pedal. The dual system will bring more levels of hybridisation that causes more energy savings and in the end a reduction of carbon dioxide, added Miller.

In the longer term, Ford and Samsung want to replace lead-acid SLI batteries entirely with a lightweight lithium-ion battery. "Battery technology is advancing rapidly and lithium-ion could one day completely replace traditional 12V lead-acid batteries, providing better fuel efficiency for drivers", said Mike O'Sullivan, Vice President of Automotive Battery Systems Samsung SDI North America.

Ford doubled its battery testing capabilities last year and invested $135m in design, engineering and production of key battery components. At last year's Frankfurt motor show, Samsung SDI unveiled a 12V, air-cooled lithium/lead 'Dual Pack', consisting of a BMS and ASIL-B-level functional safety devices.

Johnson Controls and UW-Madison to jointly test battery tech

A partnership based at a new laboratory at the Wisconsin Energy Institute on the University of Wisconsin-Madison campus will strengthen Johnson Controls' ability to research and develop next-generation technology, the company says.

The lab, called the Johnson Controls Advanced Systems Test Lab, will support research focused on vehicular and stationary energy.

The project will team industry scientists with UW professors, graduate students and undergraduate students. It follows a donation which includes state-of-the-art battery testing technology, which will allow students, faculty and engineers to study and optimise energy storage systems.

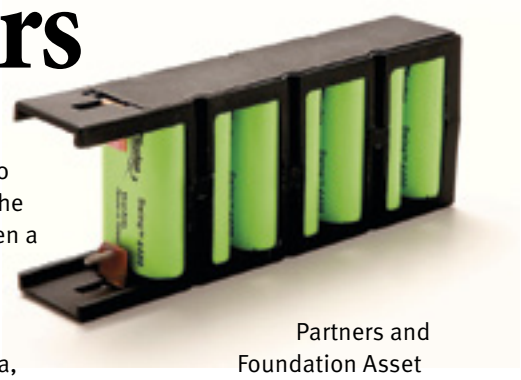
The UW-Madison partnership complements Johnson Controls' existing partnership with UW-Milwaukee where Johnson Controls scientists are working with university research staff and students to develop new energy storage materials.

The lab will be equipped to test batteries both inside and outside of a vehicle.

"This partnership will help advance the energy storage industry by expanding the reach of our university research partnerships," said Christian Rosenkranz, vice president of advanced products for Johnson Controls Power Solutions. Rosenkranz added: "With the help of the UW-Madison, Johnson Controls will test cutting-edge energy storage concepts while training a new generation of engineers."

JCI also has partnerships with Fraunhofer Institute in Germany, Argonne National Lab, Lawrence Technological University, Leibniz University Hannover, HRWTH Aachen, University of Cambridge and University of Science and Technology-Beijing.

Boston Power raises $250m from Chinese investors



Troubled US-cum-Chinese lithium-ion battery manufacturer Boston Power has secured $250m funding from Chinese and global institutional investors.

Boston Power is running its first lithium-ion battery production plant in China and plans to sell roughly $100m worth of product this year. The Massachusetts firm has a foot in the door of the automotive market supplying batteries to the Beijing Electric Vehicle Company.

The annual capacity of Boston Power's factory is about 30MWh and has plans to increase capacity to 1GWh in 2015, according to company chairman Sonny Wu.

Boston Power started in 2005 in Massachusetts based on technology developed by its founder, Christina Lampe-Onnerud, who has since left the company. Unlike Tesla Motors, Boston Power failed to secure funding from the US government to open a domestic large-scale battery factory.

Instead, it sought investment from China, raising more $100m from GSR Ventures, and moved most of its operations to China in 2011. Boston Power's other investors include Oak Investment Partners and Foundation Asset Management.

The company will soon consider a public offering, he said, preferably in the US, according to Wu.

Nexeon opens silicon anode technology plant

Lithium-ion battery technology firm Nexeon has announced the commissioning of a process development and manufacturing facility at its headquarters in Oxfordshire, UK.

At the plant Nexeon will develop silicon anode technology for the next generation of lithium-ion batteries and work to optimise processes that will lead to their commercialisation.

The facility can produce over 20 tonnes of product per year, the company claimed. As well as manufacturing capability, it includes laboratories for process development and material characterisation, and a quality assurance lab.

Planned applications for the technologies produced at the plant include hybrid and electric vehicles and consumer electronic devices.

To facilitate process development the plant was designed with a fully flexible modular process, Nexeon said, including both conventional and novel reactor designs and able to handle a wide range of materials and reagents.

"This first class facility puts us in a very strong position to produce new materials for Li-ion cells, and to optimise the production processes that will be necessary for their commercial adoption", said David Bent, Nexeon's production director.

"We now have the key engineering resources we need on-board, and eagerly look forward to sampling customers with products made in our new facility."

Russ Cummings, CEO of Nexeon's parent company Imperial Innovations, said, "Nexeon's new 20-tonne plant is highly versatile, with end-use applications spanning consumer electronic devices and electric vehicles. We look forward to the company sampling customers with products from this advanced manufacturing facility."

Nexeon has appointed three senior researchers from Sony to work at the facility: Kenta Yamamoto, Kengo Ichimiya and Akifumi Nakamura.

Yamamoto previously worked on anode and Mg-ion cathode systems at Sony's Primary Battery Division. Ichimiya developed polymer battery technology, while Nakamura worked on silicon anodes and cell optimisation.

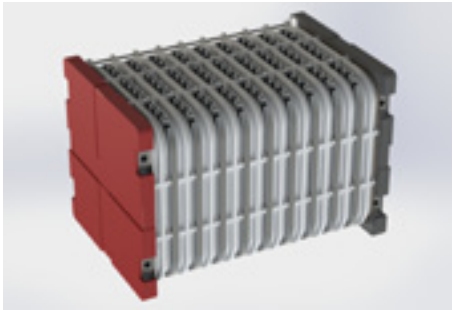
Nexeon recently appointed Sony's former gel electrolytes and polymer Li-ion developer Tsuyonobu Hatazawa as chief technology officer.

G4 launches 'ultra-high power' nickel metal hydride battery

US developer G4 Synergetics has launched an 'ultra-high power' advanced nickel metal hydride (NiMH) secondary battery.

G4's NiMH design is primarily for power-dependent applications, rather than high energy as most commercial cells are designed. The batteries have a low internal resistance, which enables the batteries to deliver extremely high power.

The reduced internal resistance translates into less heat generation during charge and discharge, and allows G4 batteries to be charged quicker– typically five minutes– than conventional battery constructions.



G4 has characterised the rate dependency of their 25Ah 10 cell module at both charge and discharge rates ranging from 25A-1C rate (1 hour charge or discharge) to 400A-16C rate (less than four minutes charge or discharge). Due to the modular nature of the design, stack size can vary to produce batteries with voltages ranging from 1.2V to 24V per module (nominal at C-rate).

G4 has evolved their design since it started with a bi-polar cell some years ago, which it no longer manufactures. Mark Kohler, G4's Project Manager, told BEST: "We have made a completely new high power rechargeable NiMH cell architecture, with a very high rate charge acceptance and superior thermal management."

"The design is truly a disruptive and transformational technology. This is the product we are going to market with." The US company licenses nickel metal hydride technology from Ovonic, the battery materials arm of giant Germany chemicals firm BASF.

G4 puts the cost of the 'G4-NiMH' at $1,500/kWh in volume production.

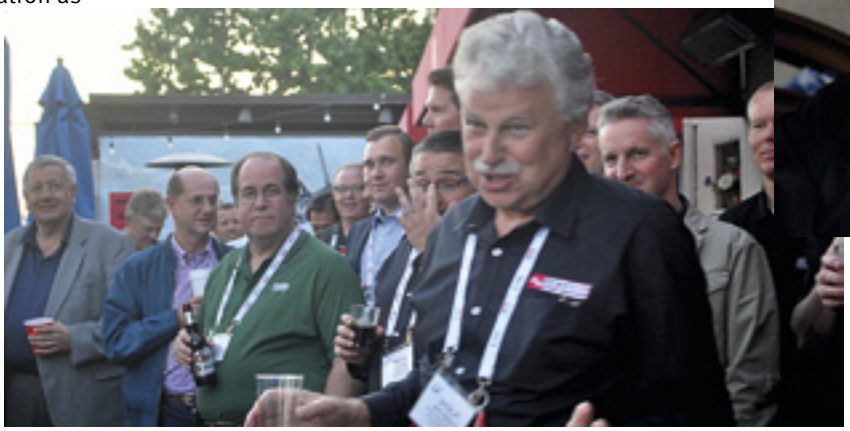
Kevin Campbell takes the helm as Digatron chief

Battery testing equipment maker Digatron's Kevin Campbell assumed the position of CEO on May 1.

Campbell, an engineer by background, held the former position within Digatron as VP International Business Development. He replaces Digatron's founder and owner Rolf Beckers, who turned 65 last year, who continues his role as group chairman.

Over the last 18 months, Beckers has been planning the succession, building up both the North American team, as well as the Chinese and Indian operations.

Campbell will continue to be located at Digatron's Aachen headquarters in Germany, and will continue to have an active role in face to face discussions with clients all around the world as well as the strategic direction for the Digatron global group.



Microporous appoints technology, sales posts

Lead-acid battery separators maker Microporous has hired John Timmons as Vice President of Technology and Parker Sword as Sales Manager, Americas, at its Piney Flats, Tennessee headquarters.

Timmons (below) brings more than 18 years of experience in the lead acid battery industry to the company and plans to be a resource to customers in the technical service area.

Sword served as the international sales manager for a pipe manufacturer where he developed new export markets and says he was drawn to Microporous because it's a customer-focused company.

Microporous was re-established as an independent company in December after previously partnering with one of its competitors.

Entek creates director of engineering position

Battery separator firm Entek has hired John Gillespie to the newly-created position of director of engineering for the company.

In this role, Gillespie will manage, support and provide leadership direction to Entek's mechanical and control engineers. Gillespie joins Entek from Imperium Renewables of Grays Harbor, Washington, where he most recently served as vice president of operations.

Prior to that he worked for Momentive Specialty Chemicals for 18 years in a variety of roles, most recently as Director of North American Production & Project Engineering in Columbus, Ohio. There he was responsible for the production and project activities of 20 plants throughout North America. He holds a Bachelors' in Mechanical Engineering from the University of Dayton.

Samsung SDI expands BMW lithium-ion supply partnership

South Korea's Samsung SDI and German car manufacturer BMW have expanded its partnership with a "multi-billion euro" deal that includes the supply of Samsung's lithium-ion batteries to BMW's future electric vehicles.

Battery maker Samsung currently provides 96-cell, 60Ah battery packs for BMW's i8 plug-in hybrid and i3 electric car models. BMW plans to increase the order by "at least" 20% to 30% in 2016 from its 2014 level.

The assignment also includes technological development of battery cells and next-generation materials.

"The deal is an extension of an agreement clinched in 2009," a communications official from Samsung SDI said and added: "The two models, BMW i3 and i8, are selling very well. It is significant that the deal will continue in future models." The assignment is said to run for several years.

Analysts said the deal would help SDI have greater presence as an electric car battery maker in the US and Europe, where it is relatively less well known compared with other battery suppliers.

BMW aims to challenge Tesla's success with its EV models. Deliveries of the BMW i8 started international markets in June. According to the company, the demand is already significantly higher than the planned production volume for the ramp-up phase.

Samsung recently announced to expand its automotive business after acquiring Cheil Industries and to enter the Chinese market. The company has other contracts with Chrysler, Ford and Mahindra.

Klaus Draeger, managing board member at BMW, said the company will be open to share the battery technology with other car manufacturers to reduce costs of battery cells. "If Mercedes called us, we would be happy to find a way with Samsung SDI to supply them with battery cells," he added.

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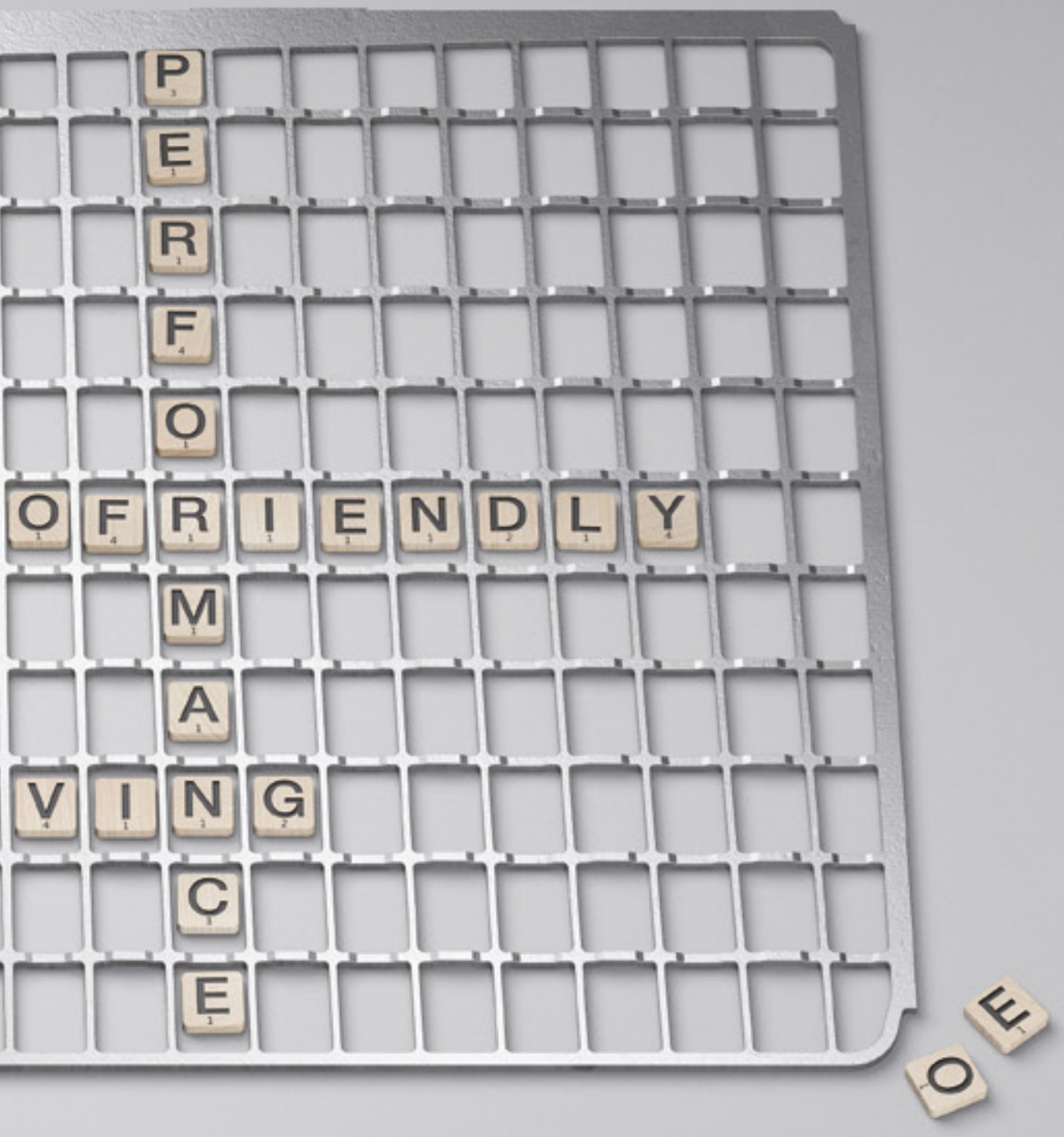

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SolarCity to resume storage programme

SolarCity, the largest US provider of solar photovoltaic (PV) systems, is to resume planned installations of energy storage systems in California after a row over utility fees.

In 2013 the firm began a battery lease programme for its solar customers in California and New England. The programme featured a 10-year contract with zero up-front cost, on the assumption that customers would save more per month on demand charges than the cost of the storage system.

But according to reports, in March 2014 the firm stopped applying to install and connect energy storage systems in California due to time-consuming application processes and the high fees charged by utilities.

The state's Public Utilities Commission now says energy storage systems will be exempt from the charges, which include connection fees of up to $800.

"When we first started it wasn't clear to us that these fees would be charged," said Peter Rive, Solar City's chief commercial officer. "We're happy with the decision."

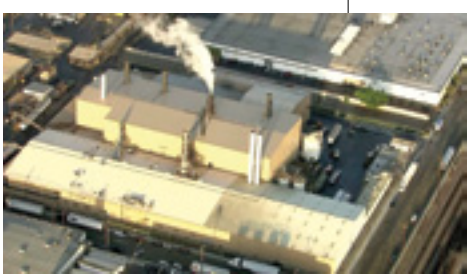
California utilities such as San Diego Gas & Electric (SDG&E) have opposed the exemptions for storage systems. Pacific Gas & Electric (PG&E) said the exemptions should apply only to residential customers and just for a trial period.

SolarCity argues that energy storage will be beneficial to utilities in dealing with renewable energy sources coming onto the grid.

Exide gains permission to reopen Vernon California lead smelter under conditions

California's South Coast Air Quality Management District (AQMD) Hearing Board has given Exide permission to reopen its Vernon lead smelter after the company installed environmental protections.

The protections include air quality control equipment that monitors arsenic emissions and stops lead-contaminated dust from being released during upgrades. Exide is also obliged to submit monthly status reports to the AQMD Hearing Board.



Exide plans to spend $5m to meet the conditions. The facility should reopen by the end of this year, the company stated.

"I'm confident that the equipment we're putting in will allow us to achieve the new air quality standards we're being held to," said Thomas Strang, Exide's vice president for environmental health and safety.

Strang joined Exide in May and is overseeing the enhancements. "Completing this plan will enhance the environmental performance of our Vernon facility and allow us to resume our role as part of California's green economy," he added.

The facility stopped operations in March this year, after the AQMD denied Exide's request to operate while implementing the enhancements.

Exide has provoked environmental concerns since March 2013, when a study by the AQMD found arsenic emissions from the plant. It has been summoned more than 30 times, mostly for emitting lead.

Johnson Controls AGM batteries to power stop-start vehicles in China

Johnson Controls has signed a new long-term automotive battery supply agreement with SAIC Motor Corporation Limited, a further indication of Johnson Controls' bid to expand rapidly in China.

Under the agreement, Johnson Controls will provide its Absorbent Glass Mat (AGM) batteries to power SAIC Motor's stop-start vehicles.

Luke Lu, vice president and general manager of Original Equipment China, Johnson Controls Power Solutions, said: "As the global leader in automotive batteries, we are well-positioned to help the Chinese automotive industry grow by offering a spectrum of solutions to meet increasingly strict fuel efficiency regulations."

Already in Europe, more than half of new vehicles built feature stop-start. Johnson Controls is investing in AGM technology globally to increase production capacity for North America, Europe and China.

Johnson Controls has produced nearly 20m AGM batteries since 2007 and by 2020 the company estimates that 175m vehicles around the globe will include Start-Stop technology.

The company entered the Chinese automotive supply market with batteries in 2005 and continues to invest in it capacity and technical capabilities in China.

10MW battery storage park to be built in Germany

German companies Energiequelle (EQ) and Enercon have announced their plans for a 10MW lithium-ion battery storage park in Feldheim, Germany.

The construction of the biggest battery storage park in Germany will start in June this year at EQ's facility in Feldheim, 30 miles south of Berlin. The facility will have a storage capacity of 5MWh. The plan is to feed the system with the energy surplus of the local 72MW wind farm and participate more efficiently in the weekly tendering for primary control reserve.

Swedish energy supplier Vattenfall will feed the system to cover energy needs in times of high demand that cannot be covered by Feldheim itself and feed its own grid with power from the battery.

The renewable energy companies EQ and Enercon teamed up for the €13m ($17.5m) project co-financed by the European Union and regional funds. "The credit banks were very reluctant, that is why we are our behind our initial schedule", said René Just, EQ business unit manager.

At the moment, the German energy storage market is very unregulated. The amount of money the energy supplier will get per megawatt and week varies between €2,300 and €3,000.

The final aim of EQ is to handle fluctuant of current without relying on brown coal. "You really have to know how the best mix of wind and solar energy looks like", said Just and added: "One rule matches almost everywhere in Germany: either it's sunny or it's windy."

Feldheim, a village of 128 inhabitants, is since 2010 fully energy self-sufficient, generating mostly energy from 43 wind turbines. The village also comprises a heat distribution centre with an installed load of 1,600kW, a biogas plant and a woodchip incineration plant.

Mitsubishi Heavy Industries sells battery manufacturing business

Mitsubishi Heavy Industries (MHI) is to sell its battery manufacturing business and focus instead on grid-tied energy storage.

The purchaser is Taiwanese firm Delta Electronics. The two companies said they have finalised a deal giving Delta Mitsubishi's rechargeable lithium-ion battery manufacturing concern, including machinery. The two companies will continue to work together to further develop the battery business, they said.

Meanwhile, MHI plans to shift its management resources into grid-tied energy storage systems (ESS) that use rechargeable lithium-ion batteries, with the aim of expanding the market for ESS products to sectors such as stationary large-capacity ESSs and electric buses.

"ESS products today are expected to record sustained market growth ahead as core devices for achieving power network stabilisation in tandem with renewables," Mitsubishi said in a statement.

Bitrode partners with Indonesia's IPC

Battery charging and testing equipment maker Bitrode has entered into strategic partnership with Jakarta, Indonesia-based Inter Pacific Cemerlang (IPC).

Since 1989 IPC has been supplying custom measuring and testing instruments to the electrical power and related industries.

John Grimm, director of sales & marketing for Bitrode, said: "Bitrode recognizes the importance of providing local sales and service to existing and potential customers."

Oxis and Schive collaborate on Li-S batteries

Oxis and Hans H. Schive have concluded a new partnership deal that combines Oxis's next generation of cell technology with Schive's design and manufacturing battery pack experience.

Schive will develop lithium sulphur rechargeable battery systems for sub-sea, military and industrial customers using the Oxis cell technology.

UK's National Grid: Battery storage too costly for balancing

Battery energy storage costs need to fall by as much as 99% to be competitive with other grid balancing technologies, according to UK transmission system operator National Grid.

In a report published on 10 July, *Future Energy Scenarios 2014*, National Grid explored the number of years taken to recover the cost of sodium sulphur and lithium-ion batteries through revenue from individual reserve services– Short Term Operating Reserve (STOR) and Fast Reserve– and the decrease in total plant costs that would be necessary in order to recover costs.

The analysis calculated the total plant costs (TPC) for 3MW STOR and 50MW fast reserve plus O&M costs, divided by annual revenue minus annual electricity cost at £36/MWh. National Grid assumed a 15% weighted cost of capital.

Both sodium sulphur and lithium-ion batteries were assumed to have a lifetime of 15 years; and neither battery technology recovered its costs within this period from providing either reserve service, according to the National Grid case study.

For sodium sulphur, National Grid calculated STOR costs outstrip revenue by a roughly 4:1 ratio; with nearly 2:1 for fast reserve. For lithium-ion, the cost-revenue ratio for both STOR and fast reserve is approximately 7:1.

National Grid's analysis suggests sodium sulphur prices need to reduce by 80-85% for STOR and 52-58% for fast reserve. Lithium-ion costs needs to fall by greater than 99% for both services.

By comparison, the report found pumped hydro storage needed to fall 15-17% for STOR and 0-41% for fast reserve; while above-ground compressed air energy storage needs a 51-53% cost reduction for STOR, with no reduction required for fast reserve.

National Grid noted anecdotal evidence suggests the cost of lithium-ion batteries is falling, and that Tesla anticipates the Gigafactory will drive down the per kWh cost of their battery packs by at least 30%.

The report also notes there is value in energy storage helping to improve transmission and distribution network capacities, potentially resulting in deferred or avoided investment, providing storage devices can offer a level of reliability that is similar to or better than that of traditional network assets.

"Stacking revenue streams, so storage owners can access multiple simultaneous revenue streams, can be complex," said National Grid. "It is crucial to understand how the value of flexibility changes over time and what the market will be willing to pay to deliver it. Only once these questions are answered will it become clear if or when the market needs to start turning to storage."

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Top Guns: BCI flies in to San Diego

The Editor loses his BCI virginity and finds it everything it is cracked up to be.

The author's departing flight from San Diego after the 126th Battery Council International (BCI) convention was delayed after a U2 spy plane confused the air traffic control system at LAX. This caused the grounding of hundreds of flights in southwest United States, and many thousands to miss their connecting flights.

Thankfully, there was a mere 90 minutes before the next flight. Thus brought an end to a heavily aeronautically themed BCI, which included an official reception on the USS Midway aircraft carrier and a Digatron party at San Diego's Kansas City Barbeque diner, where Maverick and Goose sang about great balls of fire in Top Gun.

As a BCI virgin, there had been some trepidation about the convention, but armed with an Englishman's ability not to take things too seriously, the 126th convention was a hoot.

If anyone has any doubt about the rather aged nature of the lead-acid battery industry, BCI has an over-60s golf tournament. Arguably, there is a justification for an over-75s competition for the consultants. Still, with 520 delegates (600 including wives)– up approximately 25 up on last year– there is no sign of support for BCI dying away.

This year BCI embraced modernity with a rather nifty smartphone app. BCI executive vice president Mark Thorsby almost sounded apologetic for daring to bring BCI into the 21st century with new-fangled technologies such as 'cell phones', 'the Internet', something called 'lithium' and other technologies which will never amount to a hill of beans.

BCI President Terry Agrelius gave a rather wooden opening presentation including the world's longest joke. The joke went on so long that when the punchline came after around ten minutes, nobody was sure if this was a joke, anecdote, or indeed, relevant.

Whatever it was, it seems doubtful Mr Agrelius will be in great demand as a public speaker when he retires. Suffice to say, after 15 minutes, Gerry Woolf began to snort and was asleep within 30 minutes.

The theme of Agrelius' speech was, with no visible tongue in cheek, that lead-acid batteries were Going Green. It was time to play BCI Bingo and by the end of Agrelius' turn, with all the talk of sustainability, the game was almost over.

What does sustainable actually mean? Can ice cream be sustainable? Sustainable toenail art? Sustainable bestiality?

The Uncruel Sea

After this came inspiration from Michael Abrashoff, the former commanding officer of the USS Benfold and

Michael Abrashoff, captain of the USS 'Big Mac'

author of best-selling leadership book, 'It's Your Ship'. Abrashoff turned the USS Benfold from the worst performing ship in the US Navy's Pacific fleet to the best.

Abrashoff's secret, or so it appears, was having competent staff, don't be too nasty to them and make sure they are well fed. Not rocket science.

Perhaps the key message was do not fear change and ask 'Where's the mist?", referring to how a lowly rating's inquiry as to why the USS Big Mac used rusting iron bolts led to the entire US Navy fleet switching to stainless steel bolts. In other words, just because things have always been done a certain way, does not mean they should forever.

Would a European conference, I asked myself, invite a military man to speak on business leadership? Most probably not. Still, being in the US, where the populace retains a high degree of reverence for its military, it went down very well. At one stage there was a danger of chants of "USA! USA!" going round the hall, but thankfully the audience was restrained.

You couldn't help feeling all this was a touch wasted on a lead-acid battery conference, but it was good fun.

After the obligatory update by David Weinberg on how the lawyers are trying to fight stricter standards on blood lead levels came the "highly anticipated" market reports. JCI's Dale Gospodarek showed various graphs going this way and that, with a small increase of 1.7% in North American shipments of SLI batteries in 2013, with a small drop of 0.7% in aftermarket sales.

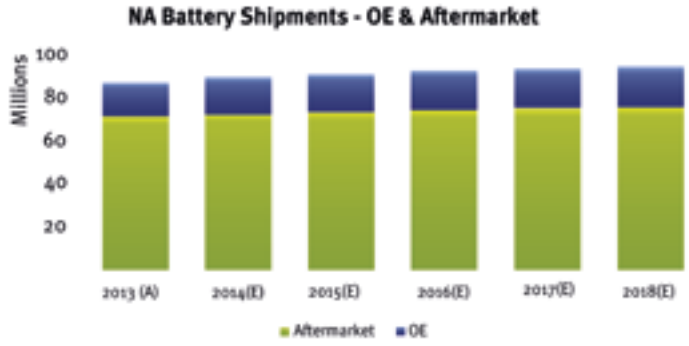
JCI expects annual growth in North America between 0.6% and 1.2% until 2018; although improving OE sales will hinder growth. It also expects experience steady new vehicle sales growth of 1%-3%. Hybrid sales are set to remain a relatively small part of the North American market, reaching 5.5%, or 940,000 of 17m vehicles, by 2018, said Gospodarek.

One slide which caught the eye was the average miles driven by Americans, which is sinking like a stone. Americans drive fewer total miles today than they did eight years ago, caused by a combination of rising gas prices, an aging population and the 'Millennials' generation being less able to afford cars.

North America SLI Battery Shipments

Automotive *Source JCI*

- Total North American shipments of Automotive batteries are expected to grow at a 1.0% compounded growth rate (5.3M units) through 2018)
- OE shipments will continue to show growth rates larger then the Aftermarket growing 2-3% through 2017 at which time the growth rate will slow to 1-2%
- Aftermarket shipments are expected to remain relatively flat, growing at a compound rate of 0.6% over the next 5 years



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Apocalypse Soon

Then came a fascinating crystal ball gazing exercise by economist Alan Beaulieu, "back by popular demand", who also had a book to sell. Beaulieu was so sure of what the future holds he came across as if he had been transported from the future in a time machine, perhaps a Delorean.

Beaulieu's presentation, 'Prosperity in an Age of Decline' was a rather doom-laden missive on how baby boomers can make hay while their kids suffer in penury. Or thereabouts.

Beaulieu served up the bad news gently at first, with a mere slow down expected by the end of 2014 and the first half 2015, not just in the USA but also in South America. Growth in 2014 will be 2.7% falling to 1.9% in 2015.

From here, things got steadily more apocalyptic. Expect a 2001/02 style global recession in 2019, so "sell your business in 2017/18, preferably to someone you don't like!", was the advice. Cheerful stuff.

Skepticism turned to smirks when Beaulieu pronounced that there would be a "1930s style Great Depression in 2030", but don't worry, if you buy his book you can do well out of it. This was a kind of 'get rich slowly' scheme.

To give his thesis some credibility, Beaulieu identified four 'megatrends': 15 years of wage inflation due to skill shortages; 15 years of interest rate rises (with mortgage rates of 7.5% forecast in 2018); inflation back to 1970s levels; and an aging population.

These may or may not be true, but one has to be skeptical about these kind of presentations. After all, with the greatest respect, if he knew all the answers then why was he addressing BCI and not playing golf in Hawaii?

Projections, projections, projections

Hollingsworth & Vose's Mitch Bregman was next. Using data collected from BCI members, Bregman said the North American industrial battery market grew 4.6% in 2013 (motive 3.8%, stationary 5.4%).

Compounded annual growth between 2013-2016 forecast to be 5.6%. Motive power sales are set to rise by 4.2% to $1.07 billion; stationary power sales by 7.3% to $1.21 billion. With the trend towards larger cell sizes, however, sales are rising faster than unit sales.

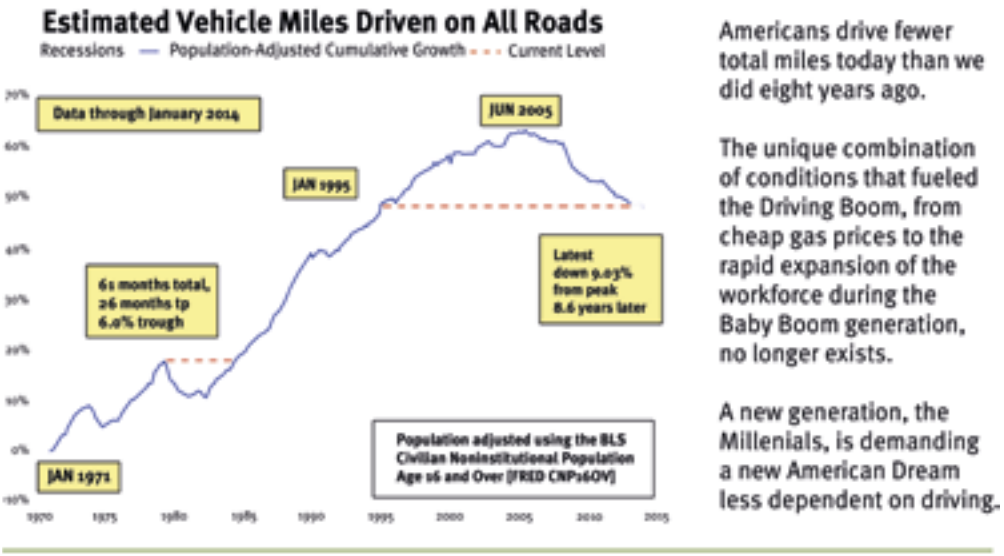
A rather depressed looking Allan Cooper appeared quite downbeat about ALABC's lead carbon battery projects for 48V 'mild hybrid' cars. On the face of it, things are going well.

Working with Controlled Power Technologies (CPT), AVL and academic institutions, the ALABC has taken a 1.4 litre petrol Volkswagen Passat, added an electric supercharger, an ISG, a DC-DC converter and seven 6V Exide Orbital deep cycling lead carbon batteries. With all this kit, the 'LC Super Hybrid' car has reduced carbon emissions by around 13% versus the standard 1.4 litre Passat.

Whether all this gear is worth the expense that would have to be borne by consumers versus, say, a diesel, or a lower displacement, turbocharged petrol engine, is questionable. Indeed, ALABC is working on a Kia diesel with an electric drivetrain that dispenses

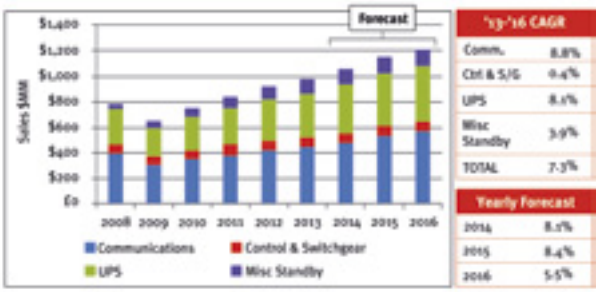
Miles Driven by Americans

Source JCI



Source: Hollingsworth & Vose

NA Stationary Sales Forecast 2014–2016



Fcst Stationary Growth at 7.3% per Year vs. 5.4% Actual in 2013

NA Energy Storage Systems BCI Forecast

Market Still Evaluating Demonstration Sites
BCI Forecasting $29MM in Energy Storage Systems Sales by 2016

with the supercharger, which will be unveiled at the Paris Motor Show in September. The car will use a 6.5kW ISG powered by East Penn Ultrabatteries.

Incidentally, ALABC has put a call out to its members for a new battery for its ADEPT project with Ford, Ricardo and CPT because they need more power and improved charged acceptance for regenerative capability.

The LC Super Hybrid has had problems, says Cooper. During a test, the driver managed to pull off the front of the crankshaft. This did at least prove the batteries had power.

But, accidents aside, Cooper is concerned that the lead-acid versus lithium-ion battle may already be lost.

"We are reaching a tipping point with 48V," he said. " A lot of the German premium manufacturers have already written in lithium-ion. If lithium gets a significant foothold in 48V I see a political threat to lead-acid because the only reason lead is in a car at all is by way of the exemption from the End of Life Vehicle Directive.

"A lot of the technical issues with lithium-ion may go away, at the moment there is no real alternative to the 12V lead-acid battery but things can change. Getting the exemption beyond 2020 may become a lot more difficult.

"The threat is real and near-term. The lead-acid industry has to convince car companies this is the way to go and get them behind us in fighting the End of Life Vehicle legislation."

Of course, this could be read as merely a cry for cash for ALABC coffers. Developing and demonstrating lead-acid 48V cars around the world must be an expensive business, and it is true the ALABC needs new members and new sources of funding.

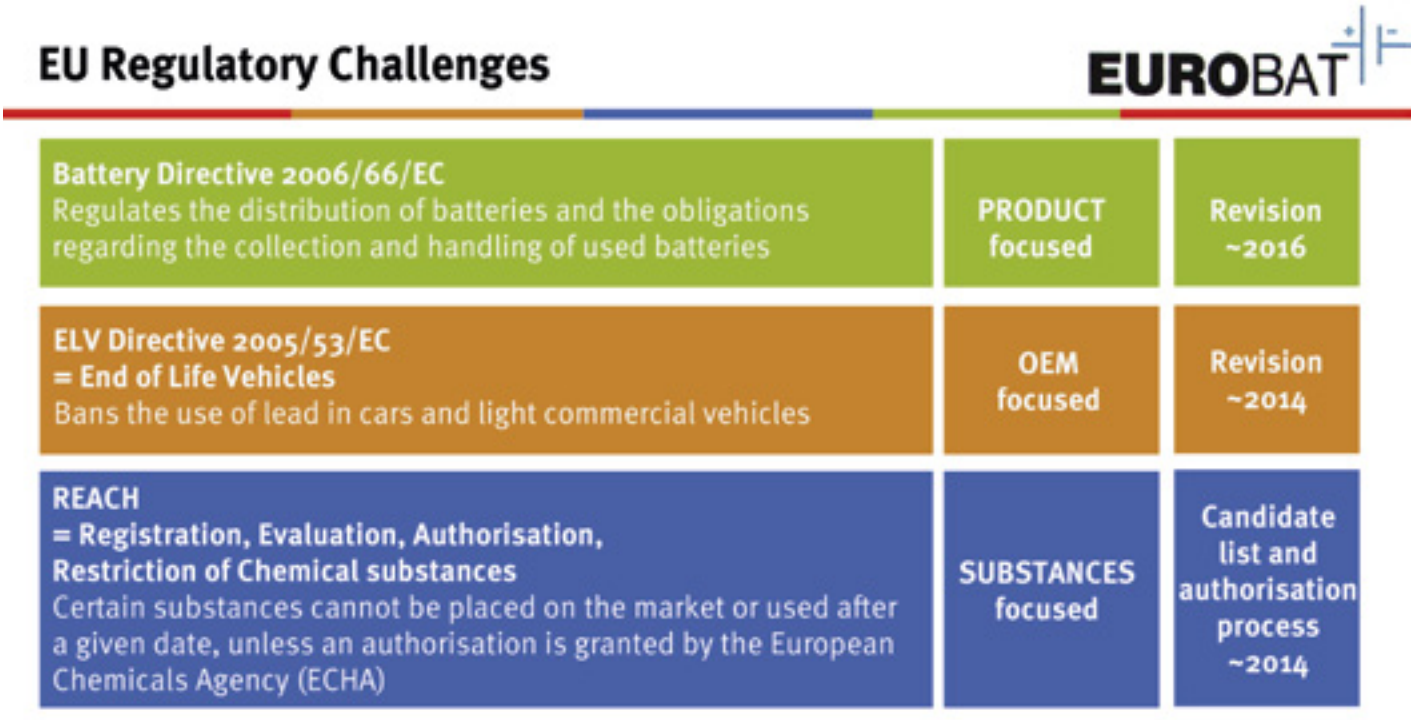
Even so, lead-acid industry faces an uphill battle if it is to succeed if the brave new world of 48V cars materializes. The humble 12V SLI will be around for a good while yet, but, in Europe at least, is the writing on the wall?

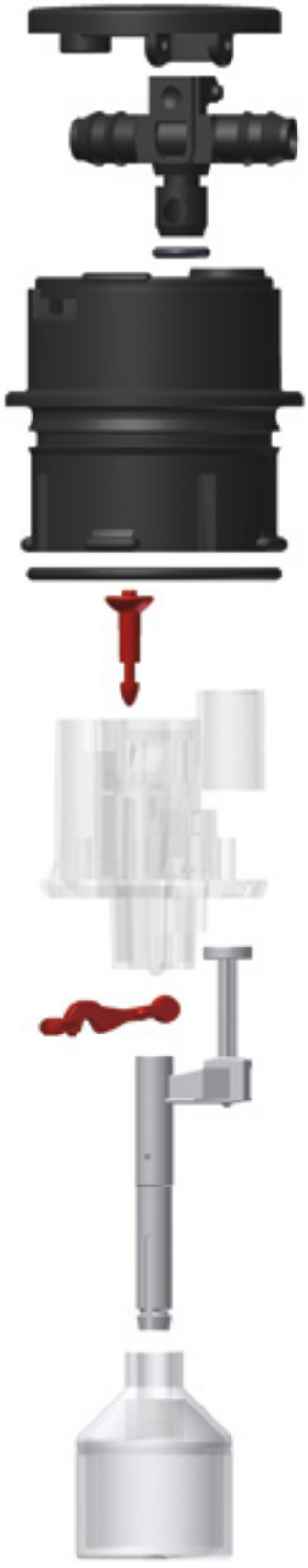
Fighting the good fight

Eurobat president Johann-Friedrich Dempwolff was also rather pessimistic, wondering how long the exemption will last. But, as the audience was reminded, at present there is no real alternative to SLIs, lithium's poor cold cranking temperature performance remains a 'hot button' issue, so to speak.

But the threat is real, and Eurobat is worried enough for Dempwolff to hammer home five key messages about why lead won't be dead:

I. Authorization under REACH would not increase the protection level of health and environment;
II. Contribution to climate and resource efficiency targets endangered;
III. Increasing bureaucracy, cost and competitive disadvantage compared to imports from Non-EU state;
IV. Substitution check given by existing regulations– proven that there is none for lead based batteries;
V. Threat of investment security,





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A taste of things to come from ESPL

BCI President Terry Agrelius (above)

Shawn Peng, Leoch (right)

associated value chain and loss of up to 30,000 jobs.

There was an awkward moment when JCI's Dempwolff flashed up an image of his company's new 48V lithium automotive battery, but the lithium bashing was probably justified, and, when all said and done, Eurobat is confident that lead will get a derogation from REACH.

Ray Kubis took a more mature approach to the lead versus lithium debate, having noticed that the winds of change had become more than a gentle breeze of late, noting it poses a "serious threat". Yet Kubis is mostly concerned with lithium popping up at lead recycling plants, which poses a threat in an entirely different way...

The secret of China's stop-start success

Perhaps the most interesting presentation was saved until last: Shawn Peng of Leoch's 'Present Status of Lead Acid Batteries for Stop-Start Application in China'. It goes without saying China's car industry is experiencing enormous growth.

New car sales broke the 20m barrier for the first time in 2013 (21.9m), and 12-13% growth is expected in 2014. The market leader by some distance is Volkswagen, which sold 2.5m vehicles in 2013, 1m more than its nearest rival, Hyundai.

The downside to these impressive sales figures is, of course, the highly unpleasant fog and hazy weather has occurred more frequently and got worse in big cities like Beijing, Shanghai, and Guangzhou etc as well as the north/east/centre areas in China.

China has made ambitious air cleaning goals: to reduce 25% of emissions in "Metro" areas before 2017; other areas must reduce them by 10%.

Also in these Metro areas, car licenses will not be issued to new cars which do not meet the V standard, adopted by China in 2009 to be consistent with the European Union's emission standard V. All cars must reach standard V from 2018 in China.

As most of cars below the standard can only use start-stop system to reach the V standard, Peng expects thousands of million stop-start cars will be sold from 2015 over the next decade– a colossal market.

China's new vehicle emissions regulations for 2016-2020 were published in January and they will a further boost to AGM and EFB batteries until the end of the decade, with an average fuel consumption 5 litres per 100km demanded in 2020.

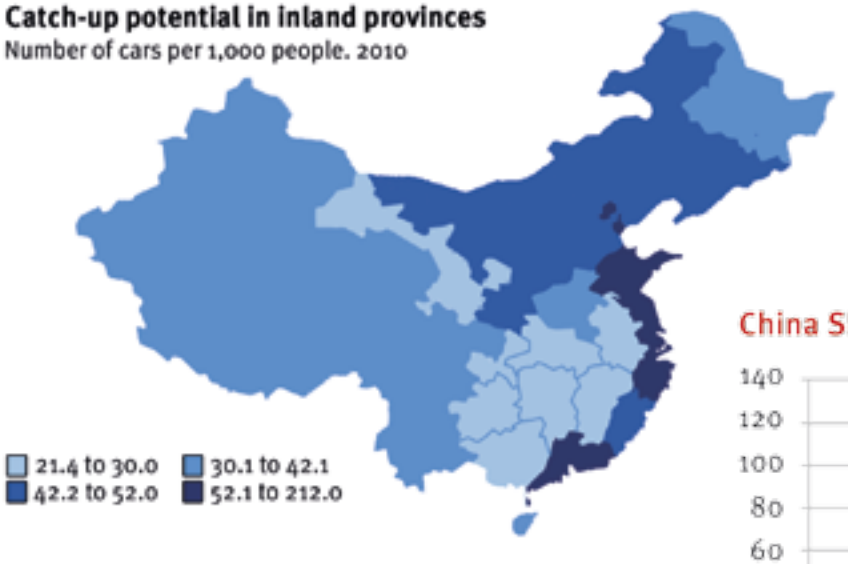
Different OEMs, of course, like different battery technologies. Volkswagen likes EFBs, joined by Ford, Honda and Mazda. Most Chinese manufacturers as well as European brands such as BMW, Mercedes and Audi, says Peng, opt for AGM batteries for stop-start applications.

Peng admits that Chinese battery manufacturers will, for now, struggle to make AGMs to European OEM standards due to high temperature durability issues. The message is China will not have

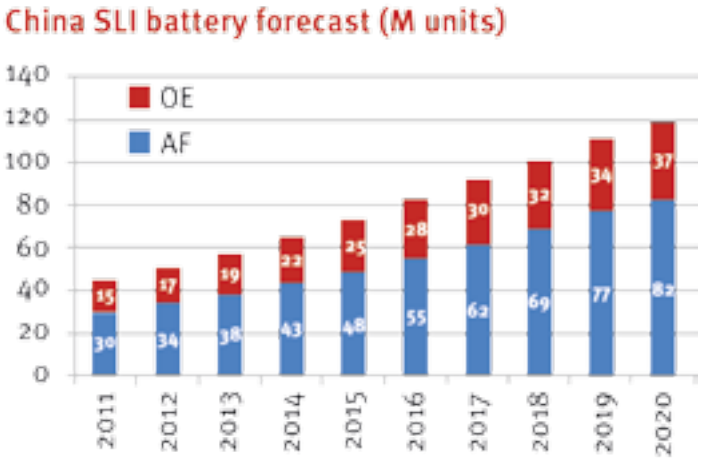
"Chinese Government has proposed, in 2013, the target of production volume for new energy powered vehicles: 2015, 0.5 million accumulated units (EV or PHEV); 2020, production capacity increase to 2 million/ year,~5% of the total produced vehicle."

Courtesy: Leoch

	CHINA	United States
Population	1,361,150,000	317,095,000
Population Density	365 per mile	90 per mile
Miles of Paved Road	979,014	2,734,102
Number of Cars	240m	255m
Number of Drivers	260m	200m



Courtesy: Leoch



the stop-start battery market to itself, it needs a global reach.

The issue of high temperate durability of stop-start batteries is the "top priority" for Chinese makers of AGM batteries, particularly as vehicles built in one region must have a battery suitable for all other regions where it will be sold. Rest assured, they are eagerly eying up different cooling methods....

For EPBs, said Peng, two different design directions will evolve, "heavy duty" and "general duty". Heavy duty needs a battery with almost an equivalent performance of an AGM, with more modest cycle life improvements required for general duty EFBs.

In all, Peng estimates a 25m unit market for OEM batteries in 2015-2020– 15m for AGM, 10m for OEM. For the aftermarket, the expectation is for 45m AGM units and 30m units for EFBs.

Smog hanging over Shanghai, China. | Paul Chesley via Getty Images

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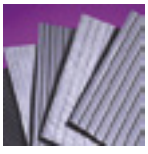

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Microporous: On its way to full fitness

Microporous was re-established as an independent company in December 2013, after former owners Polypore International, which also owns Daramic, were forced by the US Federal Trade Commission to divest the Tennessee-based separator outfit. Tim Probert visited Microporous' European plant in Austria to talk to CEO Jean-Luc Koch.

Jean-Luc Koch, CEO of Microporous

On December 19, Microporous was finally independent from Polypore after a five year saga, having been acquired by Seven Mile Capital Partners. Why did the process take so long?

Jean-Luc Koch: Almost from day one following the acquisition by Polypore in 2008 there were complaints from customers about their lack of alternative, especially for PE separators. Customers were unhappy with a situation where competition was already very limited and that an alternative source of supply had disappeared.

For our American customers practically the only alternative to Daramic left was Entek, which has a very strong connection with giant Johnson Controls. Since customers do not like to buy material from a perceived integrated competitor, there were limited alternatives to Daramic– not a particularly competitive situation.

Microporous process control system

The FTC immediately launched proceedings with a discovery procedure, interviewing Daramic and battery manufacturers. In 2010 the FTC issued its final order requiring full divestiture of both plants; there followed a lengthy legal procedure of appeals, Daramic tried to take the case to the Supreme Court and so on, this is why the whole process took more than five years.

Does there remain ill feeling with Daramic?

Koch: Any bad feelings were just about the way Microporous was integrated, or better said not integrated. It didn't take long for Daramic to realise that there was a strong possibility the FTC would require both plants to be divested in the near future. A full integration of both plants with Daramic, with R&D capability and so on, was therefore never really on the cards.

We have a good R&D centre in Tennessee, but this has been idled over the past five years. Daramic cut R&D funding almost immediately, some of the equipment was moved to Daramic's lab, although as part of the FTC order, Daramic was ordered to refurbish our R&D centre to its original state prior to the acquisition.

Don't get me wrong, there are great people at Daramic, but if you don't know where you stand and been kept in the dark for long particularly regarding aspects like customers, market evolution or company strategy, it can result in some ill feelings, which is fully understandable on both sides. But now we are competing head-to-head with Daramic with our PE and hybrid PE battery separators.

What's it like working with a New York City private Equity Company like Seven Mile Capital Partners?

Koch: I left Daramic in mid-2010 having been with them for 13 years and for the most part as vice president for global operations. In mid-2013 Seven Mile Capital Partners reached out to me and we quickly found an agreement to work

The 'secret sauce': Managing solvent consumption

together and finalize a plan for the $120m acquisition. It's a relatively young firm, only three years old, and it's a very good relationship. One of the managing partners had been previously involved in the separator business as part of Warburg Pincus, which acquired Polypore in 2004. But that was not the major factor, Seven Mile is keen on industrial companies with potential for development, and they have great insights and experience on how to develop industrial businesses.

We had our first board meeting in January just 3 weeks after the divestiture, and they approved multi-million capex funding for debottlenecking and process improvement both in Tennessee and in Austria. We have some work to do at Piney Flats to recover from the low investment rate over the past few years and also cross-fertilse the advanced knowledge of Feistritz for automotive separator manufacturing.

How long before they sell up?

Koch: Seven Mile Capital Partners has launched a new 12 year fund and we were actually the first acquisition of that new fund, so we are not going to be in a situation where they sell on after only a year or two. There is a new management team with a new vision and a new ambitious business plan; in our industry you don't make huge changes in just a few years, so we're fully aligned on a long term plan.

What is the company strategy in the short to medium term?

Koch: In the short to medium term we want to grow where we are. Our strategy is to grow in Europe, where our market share of PE separators is roughly 20-25%, and in North and South America where our share for PE is less than 10%. We will also further promote our rubber separator product lines, which was never really done outside of the US in the past. So, in recent months our focus has been on ensuring a smooth transmission and making sure we keep our existing customer base satisfied and fully secure about where we want to drive the company. This phase is now over and we are looking to medium-term strategy to increase the manufacturing base where we are already. Throughout the transition, Microporous has even gained several new customers.

That's half the battle. Where is Microporous' growth going to come from?

Koch: Customers know that we focus on high-quality products so there is a price premium, but on the other hand our high production efficiency allows us to compete head-to-head with companies and competitors that are bigger than we are.

The market is pleased to finally have an alternative supplier, especially one fully committed to flooded lead-acid batteries. This is our clear commitment; it's not just lead-acid batteries, but also to flooded. We strongly believe that there are further development potentials and are determined to innovate on the separator side.

We are probably the only truly independent supplier in the market. We are not depending on one big customer in particular; we are not owned by a stakeholder in the industry, or subject to other conflict of interest like operating a joint venture with a large battery manufacturer. Neutrality and independence is a key concern to our customers, we are the only ones committed to being fully neutral and fully independent. Our largest account weighs less than 20% on our results and we have no intent to change that.

We are open with all our customers and truly believe in joint development work; however to be effective on the long run– and we're committed to the long term– respecting and valuing confidentiality has to be a given

A drum roll of separator to be cut

John Timmons, VP of technology

and true commitment.

We see a lot of customers who want to work with us as a long-term supplier. They like our products and our quality, our philosophy and commitment to certain values. They like our transparency and openness and value our strong technical expertise. Our customers expect to be able to talk openly and accurately about product development. If you cannot talk cards on the table, if you do not fully trust your supplier then it makes it impossible.

Your plants are in the US and Europe. Are you considering establishing a presence in Asia?

Koch: We're obviously aware of what is going on in Asia that it is the fastest-growing region, but our primary leverage right now is not really geographical growth, its market share penetration, but we also focus on establishing bridges to Asia and secure some customers there. Asia is generally much driven by price, and we see that trend and pressure on the separator market. On the other hand, we also see customers interested and convinced of the value of high quality separators in their batteries. We believe there will always be a portion of the market that will recognise this, and this is where we want to play.

When we have sufficient demand to justify it, we will look to open a factory in Asia. We have not yet defined how we would go about it, i.e. a greenfield site, an acquisition, or potentially a JV with a financial partner. We have several ideas on how we could locally serve our targeted market segment in Asia… but as mentioned, this is further down the road.

Do you have the resources to grow as you wish?

Koch: We are building a new team. We have just signed John Timmons as VP of technology, Parker Sword as sales manager for the Americas and Claudio Moretti as sales manager for EMEA. We have hired new engineers and are in the process of hiring two more.

Timmons comes with nearly 20 years of experience in the lead-acid battery industry, and he will really help to accelerate our product development. He had several responsibilities including R&D, product development and technical service management, as well as extended international exposure.

Timmons does not yet have a strong rubber separator expertise yet, so we have hired back the former R&D guys from Amerace on a consultancy basis, primarily in order to accelerate our new product development plans related to rubber separator technology.

As always people are key, and we're building a great and fully committed expert team. On the capital side we will not be lacking any resource, we just need to make sure we do things step by step and grow at a pace that will not jeopardise in any way our commitment to our customers, our quality and further product development.

Anybody can manufacture a PE separator, but manufacturing a high quality PE separator and profitably is not easy. What's the secret?

Koch: You're absolutely right! PE separator is actually a bit of a misnomer, there's actually much more silica in the formulation. You mix silica with ultra-high molecular weight PE with naphthenic oil to allow it to be extruded as a sheet. The ultimate goal is to manufacture a microporous membrane, which is done by removing the oil and having the membrane pass through a solvent, which dissolves the oil. Typically the porosity is 60 to 65%.

A lot of it is down to consistency and accurate process control at each and every step of the

Hans-Peter Gaugl, VP of operations

manufacturing process. When you are manufacturing drum roll, which are more than a metre wide, there are a lot of potential inconsistencies like thicknesses, temperatures, tensions etc... What we have been able to achieve with the specific equipment that's been engineered here– nobody can buy a PE separator manufacturing line off-the-shelf– is purely through in-house design and engineering associated with the latest and most modern technologies.

The backweb (thickness of the membrane) for example is very important to our customers. If you have a lot of variation, the internal resistance will vary, there will be weak spots where it is either too thick or too thin and offer less resistance to perforation, and generally inconsistencies also translates into poor runability during battery assembly– the ability to run at high speed on envelopers. With our tight process control, we easily reach a backweb consistency Cpk (process capability) of 2, when most of our competitors are stuck at a Cpk of 1 and some even less than that.

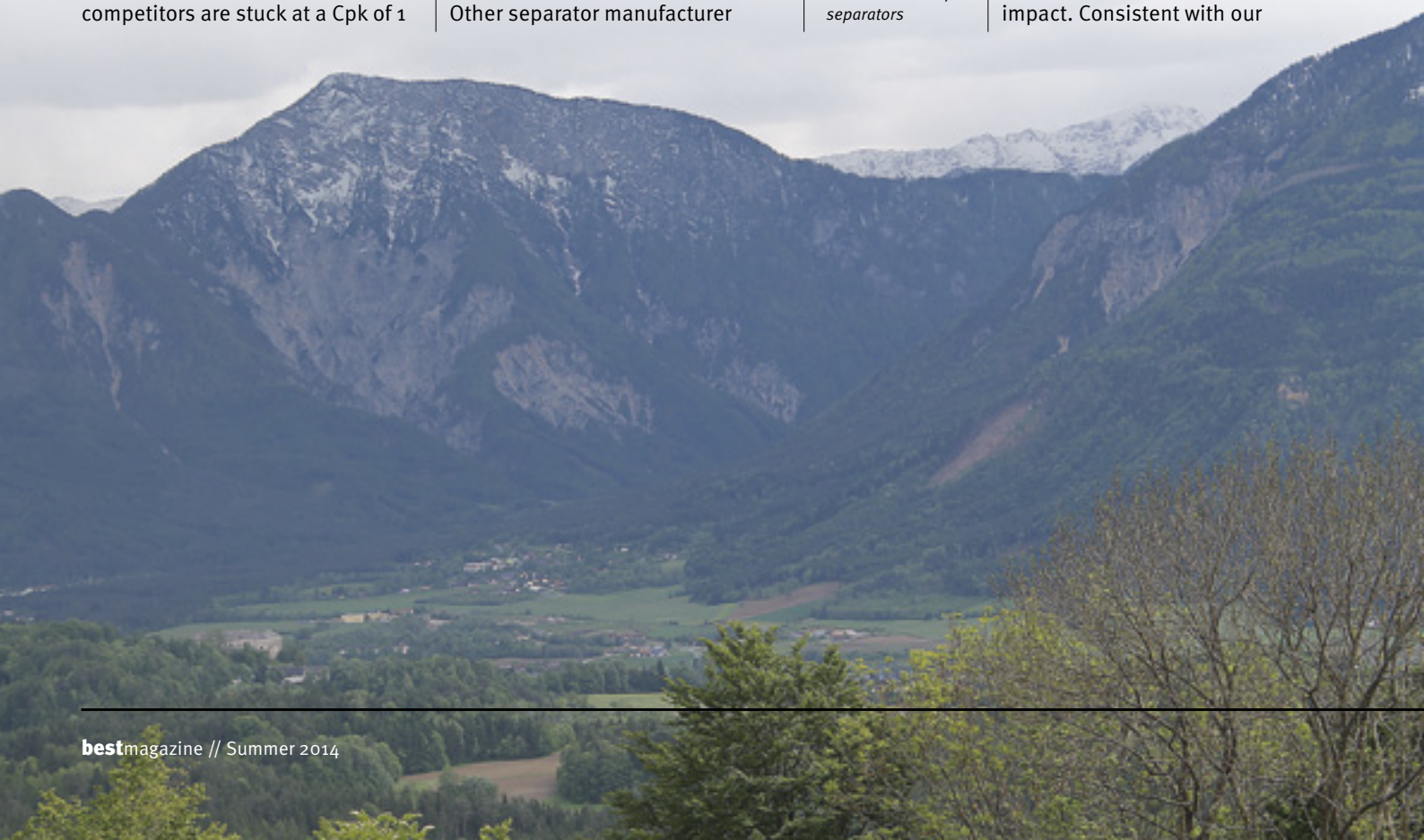
Separators are a mission-critical component of a battery. It represents 3 to 5% of the total cost of the battery but if there is an issue with the separator, it affects the entire battery and its value, warranty etc... As far as product quality is concerned, we believe that our low return rate consistently below 50ppm (0.005%) speaks of itself.

Hans-Peter Gaugl, VP of Operations: Our main focus is process control; our lines are designed to operate within very tight control loops. Controlling each and every production parameter gives us the guarantee of repeatable product quality.

What makes us different from our competitors is we have the equipment and control systems in place that are able to handle very tight tolerances. For example, we have developed a process to produce our automotive separators with backweb thickness down to 0,15mm without losing mechanical strength and puncture resistance. Other separator manufacturer specify their puncture resistance depending on the backweb thickness– normally higher backweb thickness means higher puncture resistance.

In our case we can maintain a constant high value throughout the complete backweb range from 0,25mm down to 0,15mm. This is mainly due to the design of our production equipment. Our major advantage is the experience of our engineering team.

Over the last two decades we installed eight PE-separator production lines worldwide– with every line we implemented the learning from the previous one. With the installation of the Microporous plant in Feistritz we installed our 'masterpiece'. The focus during the design of this line was not to minimise initial investment it was the reduction of daily operation cost by decreasing for example energy and solvent consumption. Solvent is a highly volatile component, in our process we were able to close the loop to minimise the environmental impact. Consistent with our



The hills are alive with the sound of separators

commitment to zero environmental harm we managed year after year to reduce our consumption of solvent and have reached a point unthinkable just a few years ago and around three times lower than our next best competitor.

Will you be releasing any new products in the near future?

Koch: We are investing four times more in R&D than in sales and marketing and we really want to drive the company this way. Right now, we are prioritising the different ideas and concepts we will develop in our R&D centre in Piney Flats.

We are working hard on separator developments for enhanced flooded batteries (EFBs) for stop-start and micro-to-mild hybrid applications and we think we have something good. The initial data is looking very promising but we're not going to make big announcements before we are sure we have something.

With our rubber know-how and access to rubber technology, we think we have some good cards to play. The requirement for EFB batteries to operate at a partial state of charge are pushing for a comeback of antimony in automotive batteries, and our rubber know-how plays a key role because of its relation with delaying antimony poisoning, reducing water loss in the battery and increasing cycling capability.

This would be kind of a hybrid separator similar to our CellForce separator we supply to the industrial market with several other changes to the process and formulation. We are still evaluating. It's not yet final we have several ongoing battery tests. The latest EFBs have a lot of power in them and made huge progress over the last few years; some even outperformed AGM batteries in ISS application testing. We are convinced that the separator will be a further help to be consistently above AGM performance and at a considerably lower cost.

A proud Microporous worker with the (almost) finished product

Feistritz is a beautiful area, but driving here I was wondering whether we'll need a chairlift to get to the factory. Is the location troublesome?

Koch: It is remote and can be a pain to travel to if you don't know the best travel connections. But then I am based in Piney Flats!

Gaugl: It looks remote, but we are only 15km from the Autobahn. We're only 200km from two major ports: Koper in Slovenia and Trieste in Italy. We have a train connection 20km away for containers going north. It's really an ideal location in terms of being central in Europe.

The area has a big battery industry legacy here dating back to the Second World War. Bären Batteries, which was acquired by Fiamm, had a big plant just a mile away. Jungfer was located here before Daramic bought it and closed it.

There are many people with battery experience in the area, making the decision to build a Greenfield site here somewhat easier, as did grants from the national and regional Austrian governments, and the European Union. That is why we are in Austria and not in Poland or Czech Republic.

Koch: Feistritz has been designed to host three production lines, but we currently have only two. A full line like ours cost about €15m, however we already have half of a line ready and stored in boxes between here and Piney Flats; that was part of the acquisition in 2008 and the divestiture order. All together, between our different separator types and dedicated lines we produce the equivalent of 90m square metres of automotive separators per year standardised. Adding a new line will get us beyond 110m; more than many think. We are close to deciding where a new line will be built.

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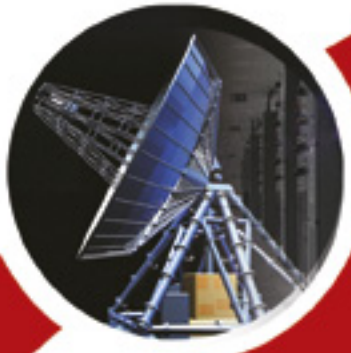

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Add：No.1 Shengyang Road, Qufu City, Shandong Province,China

Tel:+86-537-4422313 Fax:+86-537-4411936 Email: weizengliang@sacredsun.cn

ESA: Now let's not get carried away

Despite the enormous hype at the annual US Energy Storage Association conference in Washington, D.C., there are too many outstanding issues to be truly ready for prime time, finds the Editor.

The first commandment of dealing drugs is "Don't get high on your own supply." At this year's annual Energy Storage Association conference in Washington, D.C. the dealers were higher than a Colombian cocaine cartel with a habit.

Of course, when there's around 700 people congregate for an energy storage event, it's all too easy to believe the hype. But **BEST** is not buying it quite yet.

This publication is a keen supporter of energy storage, for obvious reasons. But it is our role, dear reader, to pick holes in what was a conference hall-sized energy storage hype balloon. By the end of the week at ESA, so much hot air had hissed out of the balloon this author was wondering whether energy storage is EVs all over again– immense promise of imminent sales, but relatively small beans in reality.

Tom Werner, CEO of SunPower

Muchos hype

The hype started with a bang via the keynote address by the CEO of SunPower, Tom Werner, who has seen his company grow from a turnover of $2.5m in 2003 to $2.5bn in 2013, helped by its acquisition by French oil giant Total.

His sermon, entitled 'The Convergence of PV and Storage', was delivered at full volume, but this author was not as convinced as Werner that energy storage is on the cusp of a solar PV-like boom of the kind witnessed over the past decade.

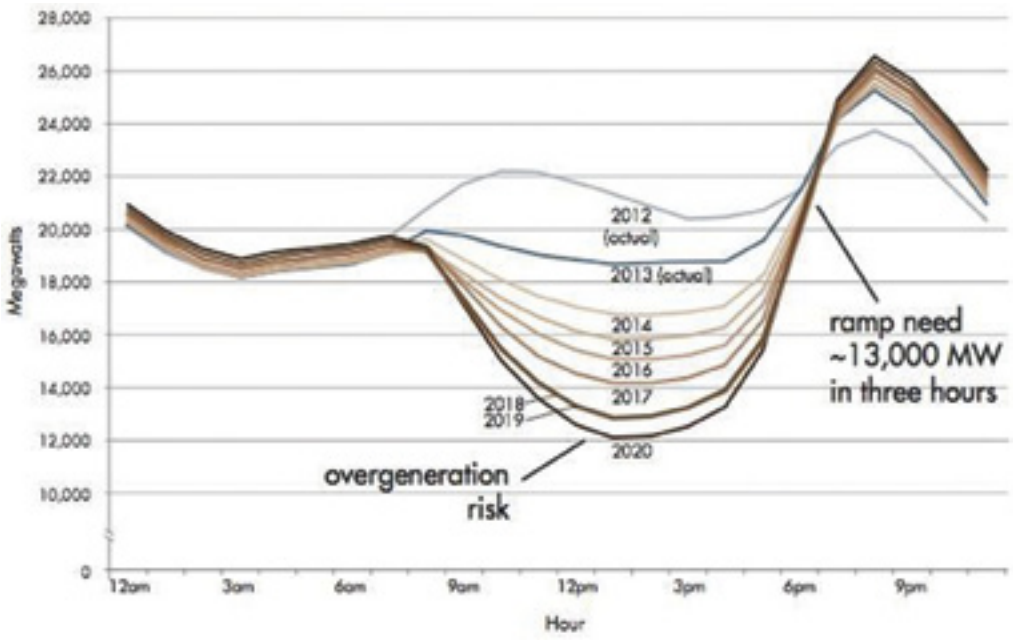
Energy storage, says Werner, is an integral part of SunPower's plans over the coming decade. Having made a bundle on manufacturing and selling PV panels, the Californian company intends to be an "energy service provider", integrating solar and energy storage to steal customers from the likes of PG&E, ConEdison and other utilities.

Their vision is of sexy, "optimised" energy bills, rather than something people just pay and forget about, often not even bothering to look at the bill. SunPower has hired 30-40 people charged with transforming the company to be just that.

On a system level, storage was said to be essential due to the 'duck curve'. The neck of the duck is the increasing ramp rate of peaking power plants as backup for the ever-deeper penetration of variable wind and solar power.

The belly of the duck is renewable generation; the more renewable, the fatter the duck. Energy storage could flatten the curve and make use of some of the excess solar power.

Energy storage, said Werner, would grow 12,000% from 2012-2022. However, virtually in



The 'duck curve': Rising renewable capacity will cause a corresponding spike in backup power requirement

the same breath, Werner proffered battery storage would economic "within 3-5 years"; it was exactly at this point the hype balloon was punctured.

SunPower's ambition is to be commended but it is a big leap to go from manufacturing high quality solar panels to becoming an energy storage/energy service provider via batteries, of which it knows relatively little.

This author questions SunPower's business model; it is basing its future on something out of its control– the cost and performance of battery energy storage. Werner confirmed to **BEST** that SunPower had no intention of becoming a storage technology manufacturer, although parent Total is an investor in liquid metal battery MIT spin-off Ambri and flow battery manufacturer Enervault.

Werner's speech was one of many in a show bursting with optimism, but in truth they were mostly "within five years, this" and "within five years, that". There is no doubt energy storage makes sense from a system point of view, but do the numbers stack up?

Undoubtedly there will be growth in energy storage, but as usual, the hype will not be borne out by reality. As we shall see, there are simply too many issues to be ready for prime time.

EPRI drills through the spin

One of the more hype-free sessions was a pre-conference workshop by Sandia National Laboratory and that respected stalwart of the US electricity industry, EPRI (Electric Power Research Institute). EPRI's Haresh Kamath was a treasure trove of useful nuggets, most of them pretty negative about the prospects for energy storage.

The arbitrage opportunities arising from the duck curve– storing power when cheap to be used at peak times– are much less than anticipated and the difference is too small to finance storage. Where storage does make sense now is on islands with limited grid infrastructure, like Hawaii, or the US Virgin Islands, where the retail electricity price is an astronomical $0.52/kWh.

In mainland USA, storage works for frequency response in markets such as the New York ISO, which rewards the inherent advantages of storage, i.e. response in milliseconds, rather than minutes as for gas-fired peaker plants.

Reality check for grid storage

Kamath warns, however, that the frequency response market for energy storage– which has seen not only batteries but also Beacon Power's flywheel technology installed– is in danger of becoming "saturated" over the next five years. By then, he says, the market will have "collapsed".

Unlike SunPower's Werner, Kamath was generally down on grid energy storage, saying "there is not a market". This, of course, comes down purely to costs.

And the costs are not just down to the battery. Power electronics and the balance-of-plant account for up to 60% of the system cost. Concrete pads to park battery storage systems can be surprisingly expensive, as too can the permitting process.

Moreover, the industry does not yet have the reliability desired by financiers to be bankable. Just because a battery may come with a warranty, developers cannot be 100% sure that the batteries will perform as they should, when they should. Cycle life data of 'real world' energy storage data is very limited for systems deployed in the field.

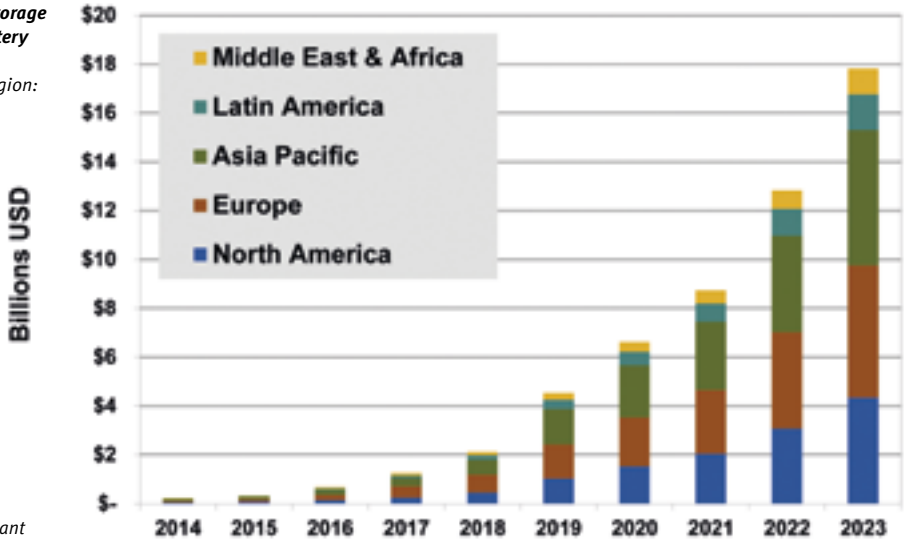
Getting utilities interesting in grid storage will be a challenge. Utilities tend to think in decades of operation, rather than years, when it comes to investing in components. Furthermore, energy storage is seen as having relatively poor ROI and utilities were said to be worried about 'hidden costs'.

In most cases, an energy storage system needs to cost $350/kWh to be in the money said Kamath. The average system cost of $1000/KWh, not to mention an operations & maintenance cost of $200/kWh suggests this may some time away from being viable without subsidies, mandates with regulated returns etc.

Kamath said storage is where computers were 30 years ago. This was damning with faint praise; it meant storage is pre-Windows, not particularly user-friendly, not plug 'n' play, with few standards and codes for utilities to be comfortable with connecting an energy storage system into, for example, a transformer.

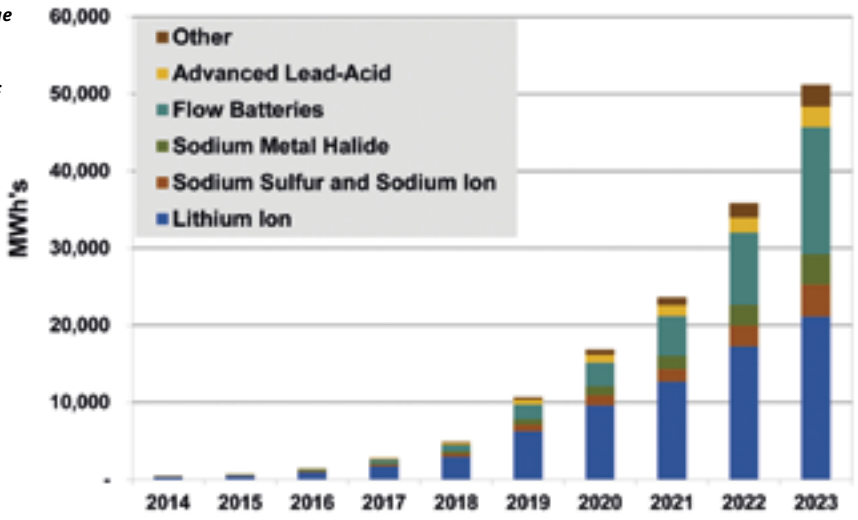
The so-called 'value stack' of energy storage for utilities– frequency response, network investment deferral, arbitrage, voltage regulation, peak shaving and so on– is great in theory, but in practice, no-one yet knows the

Global Grid Storage Advanced Battery Cell Revenue *Forecast by region: 2014-2023*



Source: *Navigant*

Global Grid Storage Advanced Battery Capacity *Forecast by region: 2014-2023*



Source: *Navigant*

capex cost, or indeed, if a battery system is up to the task of such multi-functionality.

Of course, the developers will be armed with performance guarantees, but for 10 years plus? 20 years? Not yet. For developers like S&C Electric, whose real expertise is switchgear and grid connections, their battery knowhow is more or less limited to bolting together other companies' kit.

Raging against the dying of the light?

Jim Rogers, who retired as CEO of giant utility Duke Energy in 2013 after seven years at the helm, used the word 'inevitable' about storage a great deal, albeit in a preachy sort of way that suggested the exact opposite.

Rogers is no mug; he noted Thomas Edison said energy storage was "around in the corner" in the 1890s. Rogers suggested energy storage was still around the corner, but the corner is the 2020s and predicted a 47.3% global compounded growth until 2020, when total installation will reach 11.3GW.

If this sounds a lot, it must be remembered 11.3GW represents just 1% of the total predicted renewable energy capacity in that magic year of 2020.

In this author's opinion, Rogers' speech was rather duplicitous. For all his talk of solar and storage, the ex-Duke man spoke a great deal about the need for coal and nuclear, and seems far more comfortable in extolling the virtues of 'Big Energy' than of distributed generation.

But it was interesting to hear Rogers speak about the clear and present danger posed by solar and storage to utilities, and what they should do about it. Rogers cited Kodak, which, contrary to public belief, actually did work on digital photography, but because it was very much a non-core business, its film division did not invest in it.

In other words, utilities will not cannibalize their core business of generating and distributing electrons via energy storage– Wall Street will not allow it. The challenge for utilities is to see that change is coming and make money from it by accelerating that change. However, as Rogers, said, "Utilities do not control their change".

Regulation, regulation, regulation

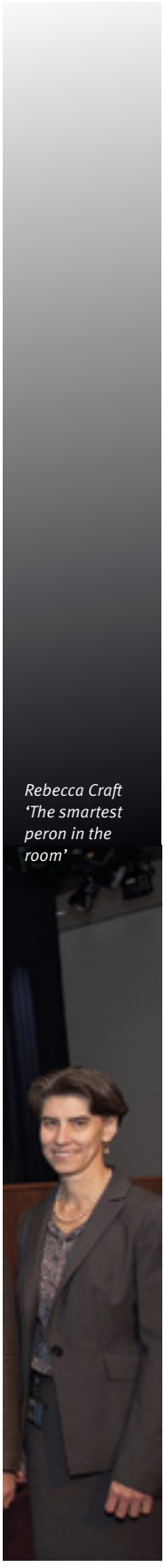
Of course, there are some barriers to change which utilities cannot control, but can be heavily influential– regulation. In many nations, not least the USA, regulations stand in the way between a viable energy storage market and a virtually non-existent market.

Aside from the so-called energy storage mandate by California, there are market mechanisms to encourage frequency regulation and other balancing services in the New York ISO. In the big bit of the US in between the two coasts, there are dozens of states with no measures to encourage energy storage.

How to encourage state regulators to create a market for storage? With great difficulty. Slothful regulators make utilities look fast-moving and getting regulations changed is like pulling teeth.

But utilities are not exactly chomping at the bit to make storage happen. Commissioner Anne Hoskins of Maryland Public Service Commission said she did not know of one utility which had come forward with suggestions for how energy storage could be implemented, saying it is "one for the next generation".

One of the big issues for utilities is the rate and timing of investment recovery; risk-averse utilities like steady investments that pay off over long periods– can they be sure storage is such an investment? No-one really knows.



Rebecca Craft 'The smartest peron in the room'

Commissioner Jeffrey Goltz of Washington Utilities & Transport Commission was highly cautious about the cost burden on consumers, and with very cheap electricity costs thanks to largely hydropower-based generation, with good reason. Goltz cited the example of California PSO that invested $24m in a compressed air energy storage system with no real idea about whether it is in the interests of billpayers for regulated return purposes.

In the short term, the sweetspot appears to be islands– both the Hawaiian/Puerto Rican variety as well as– possibly - islanding capability to ensure security of supply whenever natural disasters like Hurricane Sandy batter the shores.

Utilities uncertain

And what of the utilities themselves? Well, by far and way the most revealing session was a fascinating and genuine debate featuring New York City utility ConEdison, the US Army, developers Convergent Energy and hybrid power technology firm SMA Solar.

The US military is rightly seen as a progressive force in energy technology, but Melanie Johnson of the US Army Engineer Research & Development Centre made it clear it is under no pressure to do energy storage. Army bases are pretty much the same as everyone else; they buy grid power from utilities and back it up with diesel gensets.

The US Army is not about to replace those diesel gensets at bases– there is simply not enough juice to be cost-effective– but it could use batteries to reduce usage of diesel to make fuel savings via peak shaving. Moreover, making

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+49 5522 9010-50

FRÖTEK-Kunststofftechnik GmbH
Ilmenauer Str. 7 k + n
98701 Großbreitenbach

Phone: +49 36781 450-0
Fax: +49 36781 450-30

Hungary

NEMATECH Kft.
Fehér út 10
1106 Budapest X. ker.

Phone: +36 1 431 969-0
Fax: +36 1 262 1613

Ukraine

NEMECTEK TOW
Hvardijszka ul. 122
90400 Huszt

Phone: +380 314 251 554
Fax: +380 314 251 554

China

FRÖTEK Plastic Technology
(Wuxi) Co. Ltd.
No. 11, Xiangnan Road
Shuofang Industrial Park
Jiangsu Province
214142 Wuxi New District

Phone: +86 510 853100-53
Fax: +86 510 853100-63

South Africa

FROETEK SA Ltd.
Hoepoe Street
Fort Jackson
Eastern Cape

Phone: +27 794 980014
Fax: +27 43 763 5835

USA

FROETEK Plastic Technology Corp.
1021 Burke Street
Winston-Salem
North Carolina 27101

Phone: +1 336 723-0059
Fax: +1 336 723-0069

Headquarters:
FRÖTEK-Kunststofftechnik GmbH
An der Unteren Söse 24-30
37520 Osterode / Germany

Phone: +49 5522-9010-0
Fax: +49 5522-9010-50
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the numbers work for the Army, e.g. via participation in balancing services, is problematic because by law it is not allowed to pay the penalties for not being available– it is taxpayer money.

In general, Johnson was underwhelmed by energy storage, particularly after ZBB Energy's vanadium redox flow battery failed to perform in a microgrid demo at, of all places, Pearl Harbor.

The smartest person in the room was Rebecca Craft, director of energy efficiency and demand management at New York City utility ConEdison. If there was once place on the US mainland where grid storage may make sense, it is New York City.

Since Hurricane Sandy, when there were 1.3m outages, resilience is the watchword. Wall Street is technically on a flood plain. Generators are problematic, as storing fuel is not ideal.

There are parts of parts of Manhattan where demand reaches 2GW per square mile. It is also frighteningly expensive to build in the Big Apple; before corpulent New Jersey Governor Chris Christie killed the multi-billion dollar trans-Hudson ARC (Access to the Region's Core) 'Big Tunnel', ConEd estimated the land cost alone for a replacement substation at $1 billion.

So alternatives to digging up roads and sticking in yet more copper wire underground, of which is there is already some 96,000 miles– the world's biggest copper mine?– are attractive. Craft said 10% of ConEdison's system demand peak is fewer than 75 hours/year, so shaving just 150-200 MW would be highly beneficial to ConEdison and ratepayers.

Craft holds the purse strings for ConEdison's new programme to permanently reduce 125MW of demand by June 2016. Naturally, Ms Craft was like a honeypot surrounded by bees.

The programme is political. New York State Governor Andrew Cuomo would prefer to close the 2GW Indian Point nuclear plant in Westchester County, which ConEdison estimates would leave 1.4-1.5GW gap in supply. So ConEd is contracting for permanent demand reduction between 2pm-6pm at a cost of $2100/kW.

Although the programme will consider energy storage, its participation is not mandatory. Judging by her remarks, Craft is not sold on storage. This comes down to, unsurprisingly, cost.

Some peaks, she said, are effectively 10-12 hours long, meaning batteries are not a good solution. "I'd rather dig", she said. For the demand reduction programme, it seems ConEdison would rather go with demand response and energy efficiency measures like low-energy light bulbs.

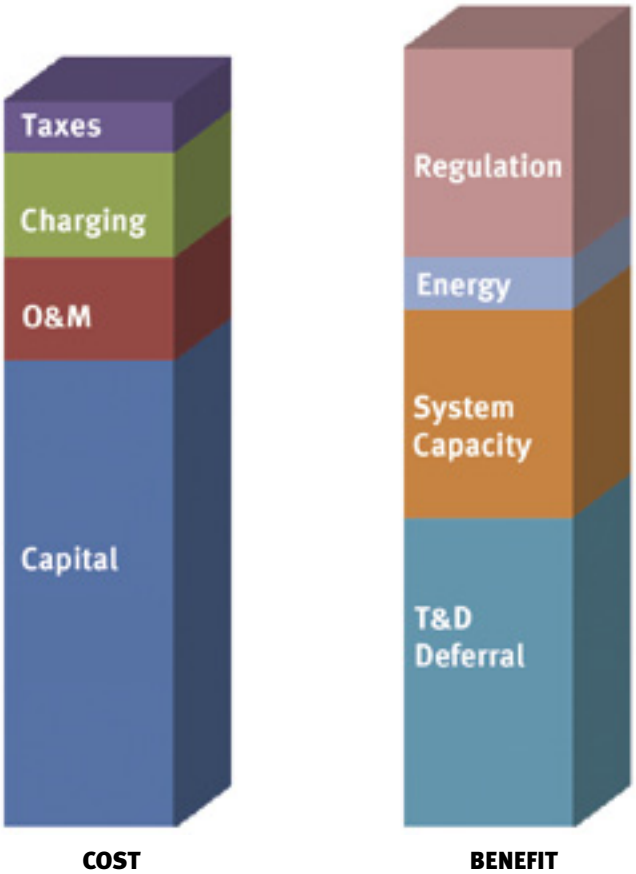
Convergent Energy's Johannes Ritershausen pointed out that demand response is not fully dispatchable, and when push comes to shove people are going to use their aircon– customers can save more money by not going to Starbucks twice a month than turning off aircon at peak times.

Craft replied aggregators may get a contract of 10MW of demand response from utilities, but aggregators will contract for more than 10MW with organisations to be certain of fulfilling their obligations, should there be any "phantom" megawatts... Every year New York City gets 300MW of demand response, it's always there, she said.

The value of storage to ConEd will be "edge of grid" storage to de-bottleneck grid congestion.

Example of energy etorage 'value stack'

Source: *EPRI*



ConEd spends $1billion on upgrades to meet summer peak and "we like batteries for areas of very rapid load growth to defer network upgrades in built-up areas", says Craft.

Permitting problems

The issue of permits threatens to be a show-stopper if authorities are not presented with technical data that can be easily validated. Craft suggested only lead-acid batteries are permitted by the New York City Buildings Department; no permit, no battery, no contract.

And while the New York Fire Department may not know what causes thermal runaway in lithium-ion batteries, they will certainly have heard of the Boeing Dreamliner incident.

It was not all doom and gloom from ConEdison. Utilities are showing more interest in installing storage at network pinchpoints.

Ms Craft believes the Public Services Commissions will start to rethink the market restrictions, allowing utilities to own and operate storage assets. But the question is, will they want to?

SMA Solar's Wes Kennedy reminded the audience that residential and commercial energy storage is not a simple case of whacking in a battery hooked to a PV grid tie inverter; it needs current-source inverter, more than double than grid-tie inverters.

Convergent Energy's Johannes Ritershausen put up a good case for storage. He observed storage increases the number of kilowatt-hours the system uses– good for regulated utilities– and by definition is a net power consumer over a cycle, so it acts as a tool to add load when required, as well as while offsetting losses from PV and renewables.

For behind-the-meter storage, however, Ritershausen admitted that apart from enthusiastic early adopters, most will not be willing to pay upfront for residential/commercial storage. Commercial property firms/tenants lease space; they will not want to buy batteries, so the business model will be for storage customers to enter into 10-15 years electricity supply contract at current market rates, or a little below, and the storage system will be installed with no upfront cost.

Of course, this shared saving model, much like 'free' solar panels, will need some form of government support to enable developers to make a buck. Monthly fees, avoided demand charges and lower bills are unlikely to add up.

The utility always wins

And as more consumers seek to lower their demand charges, utilities will hike their connection fees. It will be a brave/rich/stupid customer who detaches her home from the grid entirely and be solely reliant on PV and/or storage or a genset– utilities are betting few will.

Utilities will remain the backstop, always there, even if millions install storage, so escaping a utility's grubby mitts entirely will be a challenge. This makes a utility death spiral seem unlikely, particularly when it's apparently reliant on subsidised programmes to be implemented by those self same utilities.

More to the point, is storage a friend or a foe? Delgates heard how Southern California Edison recently began disallowing residential and small commercial energy storage units because the nightly float current charge was powered by non-renewable grid electrons. This niggardly ruling soon spread throughout the United States.

Despite wanting to believe the hype, this author cannot swallow it. It's not ready for prime time. Not yet.

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Leighton Buzzard: A market trial, not a technology trial

S&C Electric's flagship energy storage project in Leighton Buzzard, UK is close to completion. The Editor visits S&C Electric Europe's HQ in Swansea, Wales to find out more.

In an unassuming field in a non-descript corner of England sits one of the most exciting energy storage projects in the world. Distribution network operator (DNO) UK Power Networks is putting the finishing touches to Europe's largest battery energy storage project at a substation in Leighton Buzzard, a rapidly growing commuter town north of London.

The project has been funded to tune of more than £19m– no small amount. Of this, £13.2m comes from the UK's Office for Gas and Electricity Markets' (Ofgem) Low Carbon Network Fund, £5m from UK Power Networks, and a further £1m from academic institutions.

Leighton Buzzard is the first project in the world to exploit eight value streams from a single energy storage system, according to S&C Electric Europe, which as EPC contractor has done much of the design and engineering work on the 6MW/10MWh battery farm.

These value streams include providing balancing services for National Grid like fast-response and participating in short-term operating reserve (STOR) market; it will also help regulate voltage, supply reactive power to support the grid, and earn payments under UK government plans for capacity markets, as well as the avoided cost of a new substation.

Commissioning and integration tests will be conducted once the system is fully installed in Q3 2014.

Leighton Buzzard from the inside and outside

By early 2015 the project will be fully participating in the energy market. The project runs until 2018, with progress reports every six months to Ofgem.

Not just containers in a field

UK Power Network's flagship scheme has been a challenge to build. Around 240 tonnes of Samsung SDI lithium-ion LMO batteries are housed in a specially designed building raised two metres above the ground to protect it from flooding by the nearby river. S&C Electric had to work hard with the UK Environment Agency to mitigate water contamination by lithium in case of disaster.

To blend in with the surrounding landscape, the facility has been camouflaged with shrubberies and other flora. It has also had to have a sloping roof, which somewhat counter-intuitively gives a better visual impact than a flat roof; furthermore, it could not be higher than the nearby houses.

One of the biggest challenges for S&C Electric will be ensuring the system operates within its temperature range, which is 18°C-28°C. To keep the system at the optimum 23°C, it will require heating in winter and cooling in summer, with most of heat actually generated by the PCS and transformer.

The battery system, which will be monitored at S&C Electric's HQ in Swansea, consists of 192

cells connected in series to make strings; 264 trays a rack; with 12 racks.

The Leighton Buzzard project will be tested and operated exactly as per the grid code; it will go through the same test as a diesel generator connecting to the grid for STOR. This is one of S&C Electric's strong points, as it regularly performs grid testing for National Grid when it connect wind farms to the grid.

A concern to many energy storage developers is fire risk and getting the necessary paperwork, and Leighton Buzzard is no different. S&C Electric conducted a detailed analysis of fire risk, which will feed into and a UK Electricity Storage Network's best practice guide due out by the end of 2014.

Even though energy storage systems are relatively new, the authorities are fairly comfortable with battery fires, which are seen as common-or-garden chemical fires. If the fire suppression system, which is supplied by data centre specialist Thamesgate, fails, the fire brigade leave it to burn out, as they would with any chemical fire— unless there is a risk to the nearby houses.

A difficult birth

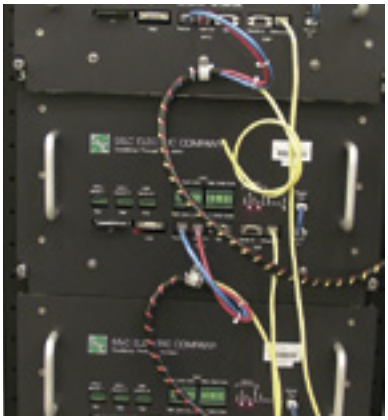
The project was originally intended to be an A123 project; following its bankruptcy, next placed S&C Electric was awarded the contract to build the battery park. S&C Electric's original bid was for the use of Dow Kokam lithium-ion batteries, but the latter's decision to focus on EVs rather than storage meant it could no longer provide the desired commitment or pricing required to fulfil the project.

S&C Electric considered going with A123 batteries but it was decided this would not be appropriate while its rescue from bankruptcy was still on going. It was eventually decided Samsung SDI had the necessary technology, expertise and experience.

S&C Electric's partners in the project include Germany's Younicos, which has developed specialist software for integrating and operating Samsung SDI lithium-ion batteries.

However, this project is much more than just managing the battery's state of charge, it is about managing the batteries to meet market conditions. This requires an interface. The brainpower behind maximising the value streams comes from software developer AMT Sybex and Newcastle University, which have developed a set of algorithms based on 20 years of electricity demand data.

This data gives an historical baseline as to how the batteries will be expected to perform on any given time and date. By anticipating the required state of charge the batteries, UK Power Networks can maximise revenue to market conditions by trading on the right balancing service at the right time, be it frequency



response, STOR or reactive power. However, there will be times when the batteries are unavailable, says Andrew Jones, managing director of S&C Electric Europe.

"It's real-time decision-making and that real-time market decision will filter through to us in terms of the state of the battery. We make sure we manage the battery in that position but we are also managing the battery to ensure we have maximum access to asset life," he says.

"We have set parameters for what you can do to the battery and if it is outside the parameters we won't do it. There will be times we say, sorry you can't do that, you can't make that trading decision because it will impact the long-term battery performance."

UKPN has designed an innovative commercial arrangement in order to avoid direct selling of the services while generating revenue. Under Ofgem's regulations, DNOs are prohibited from trading anything more than 2.5% of turnover.

Although Leighton Buzzard falls below the threshold, UK Power Networks want to demonstrate the market trading activities can be achieved at scale, so experienced demand response aggregator Kiwi Power will be trading in the balancing service market on the behalf of UKPN, while Smartest Energy will be trading electricity. As it is a pilot, AMT Sybex will not be penalised if the market activities do not perform as intended, but Jones says National Grid is not giving it any special favours; the balancing services will be bid into the market. "It will win or lose like anyone else," he says.

"The expectation is it will only bid into a market revenue stream that the battery can handle. Depending where you are on the battery cycle it may suit UKPN, for example, to bid into the STOR market and drain the battery. But the inverter is there so it could also bid into the reactive power market and charge the batteries."

Surely the point of STOR and other balancing contracts is to be relatively inflexible and guarantee National Grid a certain amount of availability when required?

"We could mix storage with other technologies such as diesel generators or gas engines," says Jones. "Kiwi Power will protect its market position by trading demand response instead of storage and not risk the penalties of lost load, which can be as high as a year's revenue."

Will it be worth it?

After two years of operation, UKPN will calculate how much revenue out of theoretical maximum has been captured. This will factor in seasonal changes, weather changes, all of which will build a pattern to determine whether the project is a market success, a partial success with changes required or a waste of time because value has not been captured.

Jones sets the bar at 50% as to whether it has been a commercial success or failure. "This will inform the market design conversation about energy storage," he says. "Storage can do things conventional generation cannot, so the market may need to change to capture all those benefits."

The project will also inform discussions about declassifying energy storage as a generation asset and the ownership model of systems, i.e. DNOs themselves or third party aggregators to which DNOs contract for the services. What S&C Electric needs is for storage to sit in a classification of its own and for it to be owned and operated by any utility, the distribution, generation or supply.

Jones says Leighton Buzzard is critical to this process. "Both Ofgem and DECC recognise the classification of energy storage and trading regulations are major barriers and they want to see the outcome of the project before they change the rules. They will take the learning from this project and implement changes accordingly."

At nearly £20m, Leighton Buzzard is not cheap. UKPN's business case to secure funding, which was £8m positive, said there are 2 GW of substations in the UK with the same characteristics and problems as Leighton Buzzard. But can they afford it?

"They have problems needing to be solved and they can avoid network investments by owning storage," says Jones. S&C Electric is heartened by what it sees a price drop in lithium-ion batteries of one-third in the past two years. Jones says he could buy a lithium-ion battery with BMS (battery management system) from at least three major manufacturers for 2015 delivery at $650/kWh, down from around $1000/kWh two years ago.

On top of this, systems for peak lopping or STOR need an additional 20% for balance-of-plant plus civil costs. For frequency response storage systems, the inverters and other control system equipment put an additional 50% on top of the battery.

To help drive down costs further, S&C Electric wants the UK Government to adopt the Electricity Storage Association's target of 2GW of storage by 2020. "If the Government adopted the target by 2020 or, say, 2025, it would create a £2-3bn market in the UK, and investment would appear very quickly.

"The Government's responsibility is not to put in lots of funding to prove the technology– it's already proven. If it puts in place the right market signals and aspirational targets, the companies will invest."

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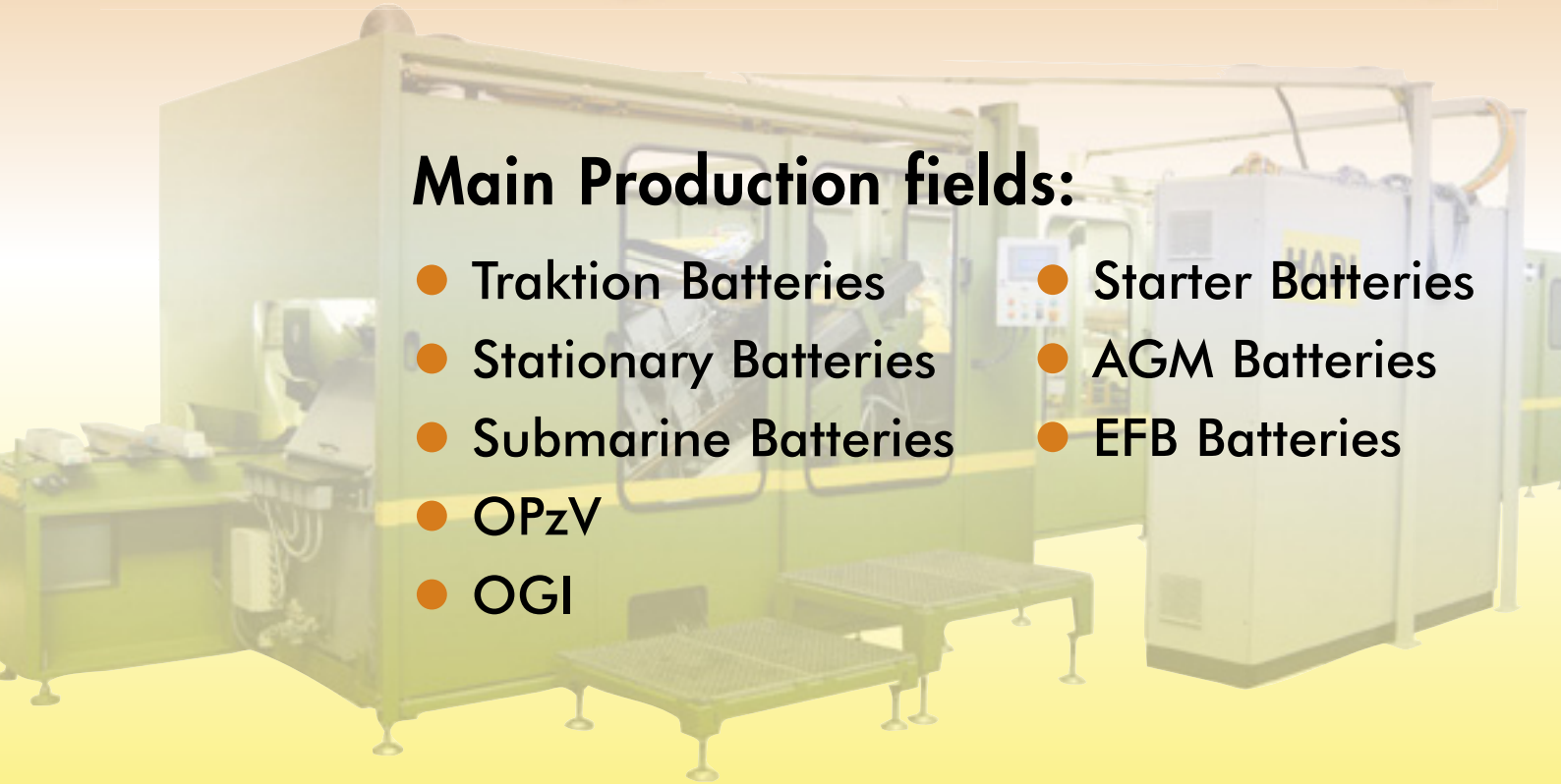

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How to give utilities the finger

Smart consumers and opportunistic PV installers may have found just the products to hit greedy power utilities where it hurts at this year's Intersolar show in Munich, writes Gerry Woolf.

There's no getting away from the fact that energy costs are rising everywhere, and in the UK, it has become something of a political football for next year's General Election campaign. Power utilities are portrayed as "robber barons" and customers are encouraged to "shop around" to find the best deal.

This is a tedious and time-consuming task and does not always yield the best result for the customer. Those with long enough memories can recall state-owned utilities and very simple tariffs.

But it could be worse for Brits. Germans, Scandinavians and Italians are paying even more. Perhaps it is no wonder, then, the vast Intersolar event in Munich in June was so busy and one hall, dedicated entirely to storage called Electrical Energy Storage (EES), was positively heaving with interest.

It is not an easy sell to end-customers. Given that a good many Europeans have already installed PV panels on their roofs– 4000 MW on German roofs alone – and received state subsidies for doing so, in the misguided belief that they were benefitting from the electricity they were generating, why spend more money on a battery?

Why indeed? But with the guaranteed certainty that electric utility costs are only going in one direction, a modest investment of between €4000-8000 ($5445-10,890) might be one way of raising two fingers– or one, depending on where you live– at your power utility, even if the payback might be ten years or more.

For those on a tight budget and a bit of space to hand, the lead-acid merchants were there in force: Enersys, GNB, Trojan and any number of Chinese battery makers were looking for business. But they weren't offering complete systems— a battery yes, but no management system, no tie-in to the solar and/or local wind turbines that you already own or a fancy app-based controller.

The market for these new and complete "residential energy storage systems" is the electrical installer/contractor fraternity or the opportunistic PV purveyor. You need a bit more than lead-acid cells in a box to get to the finish line.

Leclanche: Back in the game

One of the most sophisticated offerings this writer saw came from Swiss-based Leclanche, a battery name with cache, which has completely reinvented itself. Leclanche got out of primary cell manufacture some years ago and invested heavily in a lithium titanate product, which they now make in large-format varieties.

But the company also offers a full modular system– management and renewable tie-in— everything a residential energy storage user needs based around this new cell, which is also available for industrial use. The company calls the system TiBox for the home and TiRack, based on a 19-inch racking system, for industry.

The domestic system is based around a 3.2kW battery block and up to three can be run in parallel. Leclanche were a little guarded about costs, but like everyone else they are recruiting and training installers– the key to bolting this on to pre-existing renewable systems.

But the 'piece de resistance' in end-user focused products, i.e. you and me, came from none other than Samsung, which had the tallest and coolest stand in the exhibition. Proffering a storage system designed for all comers — residential, telecom base stations. UPS and utility—it was all based on the same lithium-ion cells, which it was not going to bore its potential customers with heavy battery detail.

Scarily, a child of five could have followed the simple video presentations which positively urinated on the attributes of lead-acid— bulky, short-lived, limited operation— oh and toxic to boot! It's only a matter of time before Samsung rolls this out to the general public and when it does the fight between chemistry marketing will be a non-contest. Imagine Windows 95 versus Mac's OSX.

The slim and neat 3.2kW home battery storage unit was no more intrusive than an air conditioner and aimed so clearly at that whom we call in the UK, 'Her Indoors'.

Of course, the native Germans were not to be outdone. Sonnenbatterie, another new name to this writer, ticked all the $FePO_4$ cells boxes and battery boxes (between 4kW and 60kW), a compact box and management system and a handy app-based remote controller.

"Sonnenbatterie allows you to freeze electricity prices by 90%!," says the marketing blurb. Good news, but not quite bold enough. "This year, tell your power utility to take a hike," might have been closer to what's really needed.

Hoppecke was there too. But no player had quite the style of Samsung— a major industrial conglomerate, which knows how to sell to ordinary consumers. The electricity energy storage suppliers market, if that is indeed what this part of the Intersolar show reflected, is still very much a 'Wizard of Oz' landscape.

Like lions without courage and scarecrows without brains, there are batteries looking for control systems, control systems looking for batteries and only a few players, some big, some very small, offering a total solutions that makes economic and technical sense to customers — both domestic and industrial.

As I waded through a bag full of brochures and leaflets in my spartan hotel room, close to the Munich Messe, I seriously wondered what confused thinking had gone into some of the literature offerings I had to make sense of. What are you trying to sell? Where does it fit in the value chain of electrical energy storage? And who are your customers?

But this EES hall within Intersolar was a start. Outside of the gargantuan battery shows in China, this was probably the first event in the West that gave big batteries some importance and showed, without the presence of electric and hybrid cars, and if you knew what you were looking for, where the next really big market will be.

And I have been waiting a very long time for it to arrive.

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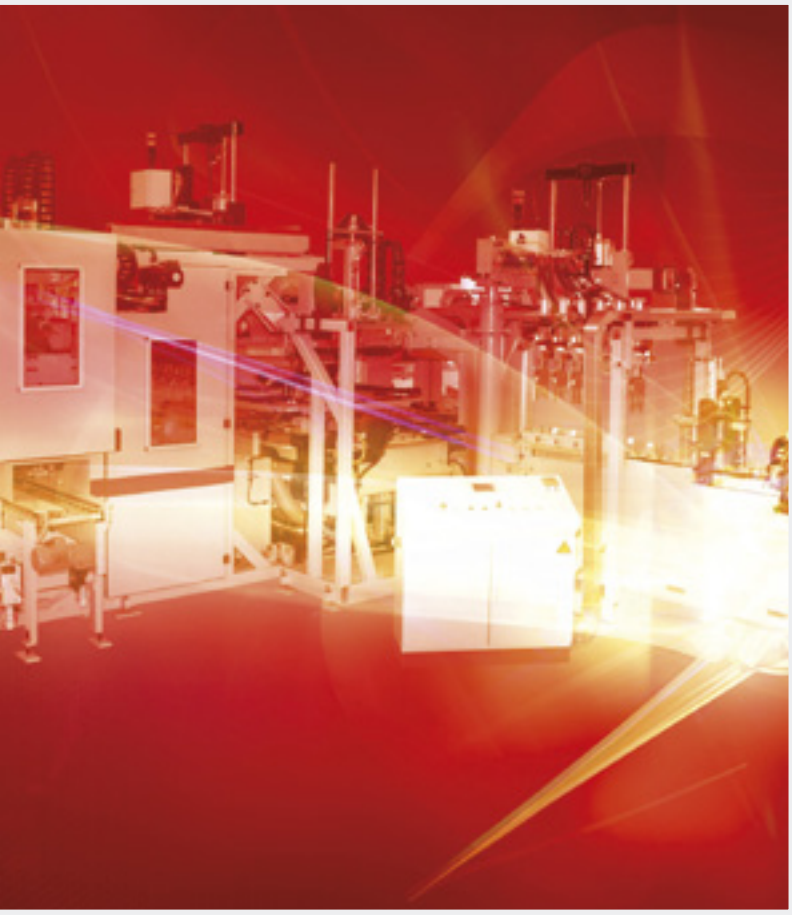

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BM Rosendahl: Pushing the envelope

It is now four years since the Knill Group acquired the assets of BM-Battery Machines from the rubble of Anton Schwetz's bankruptcy and renamed it BM Rosendahl. The Editor visited the company's HQ near Graz to see what the future holds for the Austrian firm.

Austrian battery machinery maker BM Rosendahl and its parent organisation, Knill Gruppe, have a long and fascinating history. BM started life as Elbak Maschinenbau after World War II. Elbak was bought and sold many times during its life; when Exide took over Elbak in the mid-1990s, it sold off Elbak's enveloping and stacking machinery business, BM-Battery Machines, to Anton Schwetz, who became CEO of Elbak Maschinenbau in 1986.

BM-Battery Machines went to the wall in 2010 with debts of €6.4m ($8.7m), brought on by excessive growth and a lack of capital after it had expanded operations to include a technical centre and more staff, leading to a corresponding hike in production costs.

In February 2010 it was acquired by Rosendahl Maschinen, which makes and supplies equipment for industrial wires and cables.

Rosendahl is part of Knill Gruppe's Technology division, which as well as Rosendahl Maschinen and BM Rosendahl, includes the fibre optic cable business Nextrom. On July 1, Knill Technology was renamed Rosendahl Nextrom.

The roots of the Knill Gruppe date back to 1712, when it was known as Mosdorfer. Mosdorfer made mostly sabres, blades and sickles; its customer base included the Habsburgs, and its products were used to slay many an Ottoman in the halcyon days of the Holy Roman Empire.

Fast forward to 1929 and the marriage of Friedrich Knill and the second daughter of Moritz Mosdorfer in the year 1929. As managing director of Mosdorfer, Knill secured an order in 1949 to supply fittings for a 220kV overhead line for Austria's national grid. With the days of sabres, blades and sickles clearly numbered, Mosdorfer thus changed tack to being an energy business with an electrical factory to supercede its forge.

In 1974, Friedrich's son Gunther

Knill took over the management of Mosdorfer, expanding it through a series of acquisitions such as cable machinery business Rosendahl Frisch in 1997 from France's Alcatel. In 2002, Gunther Knill transferred the responsibility to his sons Christian and Georg Knill, who continued the growth strategy of expansion through acquisition.

Being based only 15 miles from its headquarters, a bankrupt BM-Battery Machines was an attractive prospect, says CEO of Knill Technology Georg Knill. "We heard through our bank that BM was going through some financial difficulties and that it might be of interest to us as a specialist machinery maker similar to Rosendahl," he says.

Traditionally, BM's major customers include Varta, Exide, Johnson Controls, East Penn and Banner. It also has a strong presence in terms of exports to Central and South America and East Asia.

"We paid a couple of million Euro at auction at the court of Graz following the insolvency of Anton Schwetz. There was plenty of competition, some within the battery industry and some local businesses not in the industry; Sovema was one such battery industry company."

Richard Jonach, director of BM Rosendahl

With a turnover of €20m a year, this could be seen a bargain, not least because it was an asset deal. Knill acquired the trademark, competence, machines and spare parts, and of course, the team and ongoing orders. "In the end it was a question of price. We had to pay a bit more than we wanted to but we have no regrets. It's a good strategic fit for us."

Knill promptly renamed BM-Battery Machines as BM Rosendahl. BM Rosendahl then set about moving the better machines and other equipment in Ebersdorf to its new home in Pischelsdorf, a mere 10 miles away from its former location.

Since the acquisition, Knill Gruppe's office building was expanded to 5,000m² via two additional storeys. The rather cramped, 100,00m² production area was rearranged to accommodate BM Rosendahl. It has been easy to fulfil orders with the existing machinery, says Richard Jonach, Business Unit Director of BM Rosendahl. "We also took some machines, but we left behind the bad ones!" he says.

EXISTING TECH

BM Rosendahl makes lead-acid battery machinery mostly for the automotive and industrial sectors. BM's expertise is in enveloping and stacking and it claims to be the global market leader in this particular type of machine. BM Rosendahl also makes cast on strap (COS) machines; indeed, it makes machines for all functions after the COS process, but Jonach believes enveloping and stacking is one of the most critical.

"We do everything from single machines to complete-line basis, but from my point of view, we convince our customers about our machinery by the quality of our enveloping and stacking. This is the area where you have to win the customer's hearts and minds."

One particular area of interest is providing equipment to make a

multipurpose automotive battery line. The majority of battery manufacturers do not have the AGM battery volume to justify a dedicated line. So it makes sense to have a single, flexible line, says Jonach.

"The AGM battery is the more delicate in terms of handling material because it is soft and it is easy to break the structure to produce the required recombination effect in the battery. The wrapping process is the most delicate area, how the material is cut and how the plate is wrapped and then stacked at the end of the machine.

"And for industrial batteries, there is a huge variety of different designs, so it's not so easy to make a unique production line to produce different types of 2V cells. Even the sleeving and stacking is a special way of doing industrial cells; it is mainly done with PE separators, but for special applications it's also very common to wrap it with AGM separators; in the US it is a completely different operation."

Fresh people bring fresh ideas

With all the different types of cells, cell designs and materials, how is BM investing in brainpower to keep ahead in development to produce a multi-purpose line that is flexible while maintaining quality control?

"We have the expertise already there, that was part of BM Battery Machines," says Jonach. "And we have hired fresh people into our team– fresh people bring fresh ideas."

For Jonach, fresh people means people not part of the battery industry. "They come to us with little knowledge of batteries, we teach them about the technology and equipment. We work with universities to cream off talent before they graduate."

BM also uses the universities to conduct analytical research, particularly the University of Leoben and the University of Graz."

"We invest 7% to 8% of our turnover on R&D to develop new equipment and further existing equipment to stay ahead of the game, especially when it comes to Asian competitors. We know that they try to copy as much as possible, we cannot stop them from doing that but we can keep ourselves always a step ahead and therefore we are investing in R&D."

In the previous issue of **BEST** [Spring 2014, No. 44] Italian machinery makers Sovema said the trend towards ever thinner lead plates for 'advanced' lead-acid batteries opened up the possibility.

For a new type of machine. Does BM share this view?

"The battery industry has been working on thinner plates for 20 or 30 years or more. All the talk is how we can make the plates thinner and the manufacturing technology has progressed from book casting, continuous strip casting, expanding and now punching as the most common for mass production to make it thinner and lighter. This is the clear direction.

"Of course, there has never been a revolution in lead-acid batteries, it's been a long evolutionary process towards thinner, lighter and (more cost attractive) production while maintaining quality."

Jonach says BM Rosendahl is concentrating its R&D efforts on assembly lines. "Except for one-off special projects– we recently did a special tank formation loading machine project for industrial batteries– all our R&D is concentrated on assembly lines for automotive, motorcycle and industrial lead-acid batteries."

Like other machinery manufacturers, BM Rosendahl is inundated with enquiries for special projects. "Every month, if not every other week, somebody calls me to say that he can lead a revolution in lead-acid batteries.

"We also get visitors showing us their ideas and telling us how they think they can make the revolution

happen. We analyse every single enquiry and we try to follow it as much as possible if we think it makes sense."

Who are these people?

"Some come from the lead-acid industry, others from lithium-ion or other chemistries. It's very hard to judge whether it's a direction we should support or move out of it.

"I'm not sure why, but over the past six months we have experienced a surge in enquiries about 'revolutionary 'batteries. I have no idea who or what drives it."

'New' enveloping & stacking machine

Yet, despite the talk of 'sexy' new technology, BM Rosendahl is concentrating hard on improving its enveloping and stacking machines for standard VRLA batteries. In 2013 it introduced an upgraded machine, of which it sold eight units while it was still on paper.

The key to the BMR10's success is its productivity, speed and efficiency. BM claims this is the fastest single track enveloping machine at 160 envelopes per minute real production speed.

Lead dust removal is factored into the design from the start. "We figured out how we should do the piping to make it as efficient as possible to reduce the volume of dust the customer has to deal with at the end of the process.

"The vacuum transport guarantees a perfect transport of the separator. This unique transport method makes it possible to convey the AGM separator for the production of VRLA batteries without mechanical stress.

"By using a servo drive, the separator cutting length is easily adjustable on the operator panel.

George Knill, CEO of Knill Technology

Enveloping and stacking of formed, unformed, cast and expanded as well as punched plates is handled without difficulty.

The end result is, claims Jonach, the best enveloping and stacking machine on the market. "I do know the way we did this latest machine very, very well and the market has rewarded us by sales. We are sure it is the best on the market. We have now sold approximately 15 of the upgraded machine on a global basis to virtually every continent"

Lithium-ion on the horizon?

Unlike Sovema with its acquisition of So-Lith, arch-rivals TBS has yet to make the leap to lithium-ion battery machinery. Is there something on the cards at BM Rosendahl?

"Lithium-ion is something we observe very closely. In Europe we have production overcapacity so for us it's hard to make a business case right now. But we are learning all the time about the lithium industry in preparation step into the market.

"We have ideas about lithium machines to make battery modules, but as yet we have no designs. We are not in contact with any lithium battery manufacturers at present, nevertheless we have companies such as Magna Steyr and AVL close by in Graz and we work together with them to better understand the market.

"We're spending money on lithium but we're not making any money from it. We're going to conferences and so on but so far are not earning money from it. But it will come, it's just a question of when the big volume arrives and which type of cell technology."

Ah, yes, the type of cell. What is that, exactly?

"There is still no standardization for lithium-ion cells. Everyone

thought the pouch and metal can cells would be the ones to go into mass production but with Tesla going for the 18650 cylindrical cell this has rather put the cat among the pigeons to some extent.

"If Tesla goes ahead and builds the plant it says it will in the United States, it might switch the presumptions about large format cells back to 18650s. You never know!"

And for 48V? "We're talking a lot about 48V, but every other week we hear the OEMs are going in this direction or that direction but I'm still not sure which messages and announcements to trust.

"It's hard to say 48V won't happen, there is a big driver for it, but what it will look like is the million-dollar question; will it be lead-acid or lithium-ion. Ultimately, it's for the OEMs to decide and we try to speak with them directly, but it's very hard."

It also seems unlikely BM will go down the path of developing a power electronics business, as Sovema did in-house before buying Bitrode.

"Power Electronics has never been part of our business and it has not been our interest or knowledge," says Jonach. "We are focused on assembly and we believe there is still a lot to do in that area and there is still a market out there for us to gain shares.

"We are working to our strengths rather than looking to other areas outside our core competence. We try to increase our strengths and competence in our existing products."

BM is set fair to firmly remain in Austria. "We do not see the need to move out of Austria to a country with lower labour costs. We would like to concentrate on our technology in Austria to maintain our reputation as a high-quality supplier, we want to keep that."

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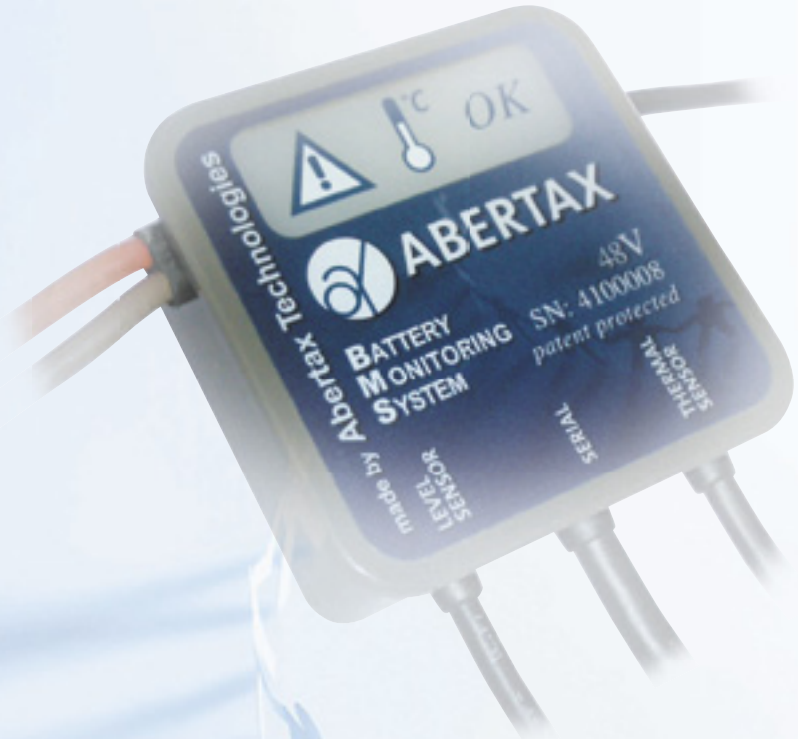

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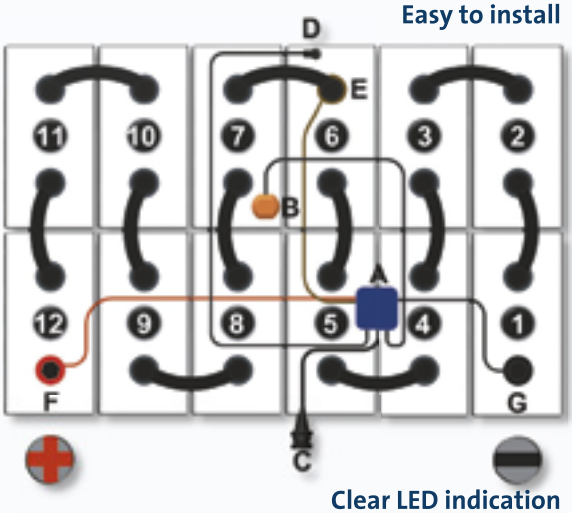

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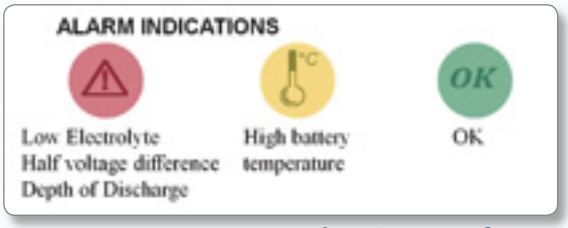

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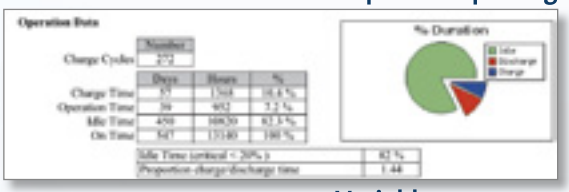

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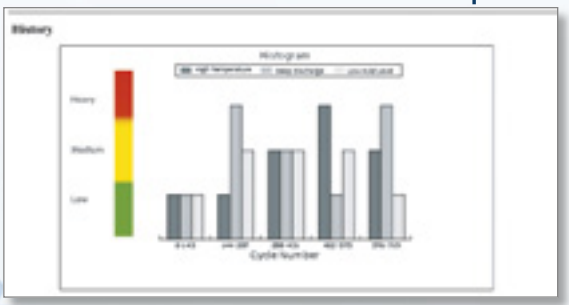

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IMLB 2014:
Lithium breakthroughs struggling to break through

The Editor visits the 17th International Meeting on Lithium Batteries in Alessandro Volta's hometown of Como to find out how 'breakthrough' lithium technologies are coming along. Or not.

This author was recently interviewed by a BBC journalist wanting to know more about all the battery breakthroughs he keeps reading about. Here at **BEST** Towers, we know that while the promise of power from rhubarb, paper, viruses and even urine may make for a good headline– indeed we could fill the news pages with news from MIT, Stanford, Imperial College and the rest– these so-called breakthroughs are far from being a commercial prospect.

So **BEST** put the BBC straight: electrochemical energy development is a slow, often painful process with incremental improvements over long periods. Do not expect quantum leap breakthroughs overnight; Moore's Law does not apply to batteries; we're still using lead-acid batteries, for heaven's sake. And so on.

If the BBC ever sent reporters to battery conferences like the 17th International Meeting on Lithium Batteries (IMLB) on Lake Como, it would be one hell of an eye-opener. IMLB 2014 had a large turnout of 870, which resulted in large queues for everything, like a British passport office or an Italian post office during lunch hour...

Being a highly academic lithium conference this was a younger crowd than most battery conferences, with a large proportion of PhD students, many from East Asia, but also many from Germany, the UK, and, of course, Italy.

Such was the Asian influence it could have been held in China, Japan or Korea, as of course, it sometimes is. Even the nominally American presentations were usually made by Asian nationals.

Lithium air: Like nuclear fusion

The key themes of the conference were lithium air, lithium sulphur, silicon anodes for lithium-ion, and 'lithium rich'. Lithium-air is, of course, like nuclear fusion– always 20 years hence.

That does not stop a great deal of brainpower and taxpayer money pouring into research for both technologies. And, on balance, given the particularly shiny pot at the end of the admittedly lengthy rainbow, it is probably worth the effort.

But there are just so many bloody problems with it, one must wonder if they'll ever get there. Reversible chemistry with a high current efficiency over several cycles and overcoming the deposition of an electrically resistive discharge product limits the capacity of lithium-air remain out of reach.

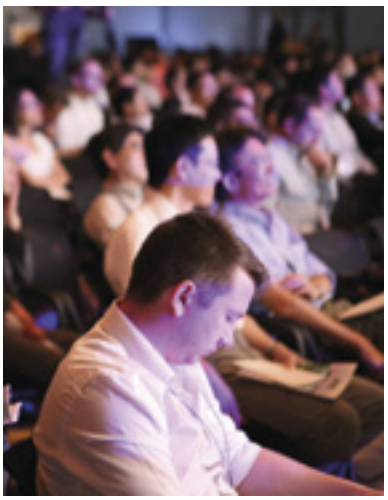
As the University of Oxford's Peter Bruce put it, the best way forward with lithium-air is to eliminate what does not work. Unfortunately, the industry does not know enough about the fundamentals and does not have even the parameters to know, for example, how much H_2O and CO_2 a lithium-air battery could tolerate.

The area least understood, says Bruce, is electrolyte/cathode interface. If the industry cannot get this right there is no hope at all. This is all about creating a balancing act to produce an even amount of LiO_2 on electrode surfaces and the particles.

Easier said than done. MIT's Yang Shao-Horn kicked things off at IMLB with a fairly dry overview of the effect of solvation on lithium-air cells, and measuring solvation to determine superoxide redox potential.

Solvation increases oxygen redox by increasing the acceptor number, thus increasing voltage. However, the potential is affected by the acid content of the solvent.

Somewhat counter-intuitively, enlarging particle size allows higher gravimetric energy gain but makes the charging characteristics worse. There needs to be more understanding how larger cells



could have redox overpotential, says Shao-Horn.

Most work on lithium-air batteries is focused on the cathode. The Chinese Institute of Applied Chemistry's (CIAC) Xin-Bo Zhang gave one such presentation about their research in lithium-air cathode material to improve stability and plug the perceived voltage drop of around 70%.

Aluminium oxide coating of carbon cathodes may or may not work, says Zhang, but generally speaking carbon cathodes have been more or less written off– they are too unstable at high charge. Stable carbon cathodes with nano non-carbon cathodes are preferable but whatever the solution, they are likely to be expensive: gold, ruthenium etc.

CIAC has developed a 'free standing honeycomb-like modified hollow spherical carbon on carbon paper cathode' to maintain stability, which has a theoretical capacity of 3,000 mAh/g and has apparently achieved 200 cycles.

While the US has seemingly thrown in the towel on lithium air– JSCER and MIT have recently cut back on funding– if there is hope, it may lie in the Chinese. But the Chinese propensity to make bold yet opaque claims about capacity and cycling capability of advanced materials irked some of the European delegates. Should we trust the data? Or are these Westerners merely jealous…?

Doron Aurbach of Israel's Bar Han University hinted lithium-air may probably never happen; the decomposition of the electrolyte solution may be just too hard to solve. Aurbach suggested no electrolyte would survive the reactive peroxides and superoxide moieties formed in the solution phase. But what about, some suggested, ionic liquids, some stable to nearly 6V?

Silicon anodes

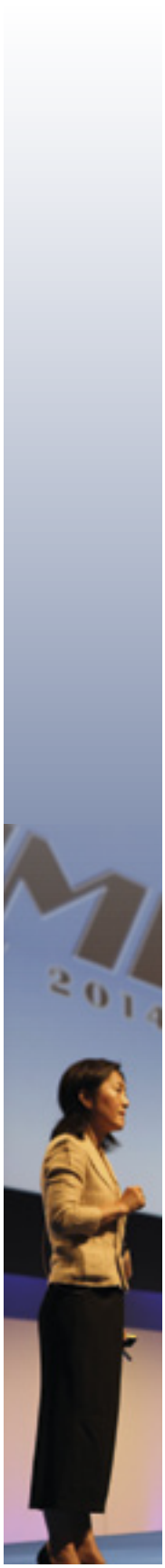
Aurbach was more positive about silicon anodes, with monolithic amorphous silicon nanowires offering a "winning philosophy", but it needs a different, "magic electrolyte" to provide a flexible film to allow volume variation for at least 2,000 cycles.

Another presentation by the Chinese Academy of Sciences (CAS) explored nano-silicon carbon composite anodes, a key part of the "roadmap" of lithium-ion energy density.

Fei Luo shrewdly noted that silicon has been the "most promising anode" since the 1970s, but with a theoretical capacity of 4200mAh/g versus graphite's 372mAh/g, why not? Incidentally, CAS claims it has achieved a real world capacity of 600mAh/g from a silicon anode.

One of the larger issues is cracking of thin film silicon electrodes due to the large volume variation. Cracking peels of active material, increases internal resistance and volume variation further and ultimately destroys the solid electrolyte interphase (SEI) film.

During investigating SEI, CAS found the surface cracked after just 25 cycles. In short, it is a pain in the arse. Vinylene carbonate (VC) additives can improve coverage of SEI but there are just too many unknowns about SEI and its effects on performance to mention.



It seems the trade off for silicon electrode performance is low cycle life at low rate. Nano designs for silicon anodes do not solve SEI problems, it is never stable and dendritic growth does not go away.

Moreover, the high surface area of nano-sized materials leads to low capacity loading and low tap density. Voltage drop of silicon electrodes is also a huge challenge.

Many of these problems are solvable in the lab, but using materials like palladium, platinum and gold may work with white coat and goggles on. If manufacturers are going to raise cell prices by more than a few cents each, they may struggle.

While a nanocomposite silicon anode is certainly possible, at present you will end up with one with low energy density, high cost, low Columbic efficiency battery with very high volume expansion and, in general, one about as appealing as a wet weekend.

If there was one paper to destroy the 'breakthough battery' hype bubble, this was surely it.

Luo said a 300Wh/kg battery with silicon anode may be feasible, but this is only a 10-20% improvement on current lithium technologies. Is it worth it? Well, for a smartphone having ever-increasing processing power, it seems the amount of silicon in lithium electrodes will increase.

Some manufacturers may claim to have already 'cracked' silicon electrodes, but they are typically 95% graphite, and 'pure' silicon is still some way off. In reality, the industry does not need 2000+ mAh/g anodes, 1000 mAh/g will do.

But forget 'pure' silicon, 50% content mixed with carbon will give iPhones a much-needed boost, and it is perhaps only 2-3 years

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from commercial reality, say the optimists.

Voltage fade issue of silicon anodes needs a compromise, i.e. operation at lower voltages, to make use of that additional energy. However, 200Wh/kg energy density for lithium-ion with high silicon content anodes versus 150Wh/kg for lithium NMC is not to be sniffed at.

3M's silicon-carbon alloy could lead the way. The material is being used in a US DOE project to produce pouch cells for consumer electronics. BASF was said to have tested such a cell to the thousands of cycles necessary to be commercially viable.

It took the third day of the conference until delegates heard how the academic theory was being turned into practice, with big boys Samsung SDI and Toyota sharing their research aimed at EV and consumer batteries.

Making as it does 3.3m lithium cells a day, Samsung SDI has more reason than most to stay ahead of the game and its roadmap target is to raise the energy density of lithium polymer batteries to a challenging 800Wh/litre.

Getting there is going to take something different, and again silicon anodes and nickel-rich cathodes are seen as the most realistic option. Sun-Ho Kang noted the theoretical capacity of graphite anodes was 372mAh/g– in practice, 350mAh/g is optimum– means it is impossible to get the required density with the current levels of graphite in the anode.

The benefits of silicon anodes are highly desirable, but the enormous volume change– 280% versus 10% expansion of graphite, said Kang– is a big, big drawback. Mitigating this expansion problem is critical.

This could be done using a "sacrificial cathode", e.g. Li_2NiO_2, in the formation process designed to compensate for the first cycle loss.

Another problem is silicon oxide degradation, which suggests the maximum usage of SiOx in graphite/silicon anodes is 30-40%. In practice, says Kang, less than 10% can be used due to the huge volume expansion.

A silicon-carbon composite anode may offer a solution to the problem, but Kang says nano-silicon clusters become porous, thus loosing electric contact and raising impedance intolerably high. The winner may be a silicon alloy binder, which Samsung has developed to overcome the electrolyte issues with conventional SBR/CMC binders.

The silicon alloy offers a potential density of 500Wh/kg but there are stability issues; Kang notes after 3,000 cycles the binder gets thicker, increasing impedance. Other issues include a low voltage cut off of 3.3V, which calls into question the use of silicon alloy anodes for smartphones. As Kang said, "The lower the current, the

better it works, that is the one issue we have to solve".

To cap it all off, the US DOE then gave a summary of its awardees of 'Applied Battery Research' project funding, which seemed rather heavily weighted towards silicon anodes. Having just heard all the downers on silicon, Dr Tien Duong had the look of a chap who'd bought from a 'genuine Rolex' from a man in the pub for a 'bargain' £1000. "We still want to see how they get on", was the plea.

Lithium sulphur: Slow, slow, slow

If slow but steady progress is being made with silicon anodes, lithium sulphur batteries are looking as challenging as ever.

The big issue with lithium sulphur is poor kinetics, i.e. slow ionic conductivity. There are two choices, said Y.G. Guo of CAS: decrease the active particle size or use nanocarbon networks to separate each particle.

Making cells with smaller sulphur molecules, i.e, S2-4 instead of S8, are a bitch to make. CAS says it has designed a relevant 5-10Ah pouch cell with circa 200mAh/g capacity.

However, the pouch cell is not ideal due to gassing and dendritic growth and, for good measure, says Guo, it would be preferable to develop a new electrolyte and additives, as well as using a lithium alloy instead of lithium metal.

CAS even went as far as researching a lithium cell with a selenium anode with a capacity of 675mAh/g– with polarisation similar to LTO– but selenium is so expensive, and poisonous – this was widely scoffed at. One question accused the CAS of being a "playground with exotic toys"– more jealousy, perhaps?

But it was hard to avoid the conclusion that these toys are rather superfluous. Dr. Aurbach leapt to the defence of CAS, saying such research was essential to keep people in jobs, sorry, er, provides valuable particle analysis.

Aurbach said the well-known 'shuttle' kinetics issue, which hampers the capability of sulphide electrodes so that the cell cannot fully charge, had a "magic solution" of lithium nitrate to protect the anode and offer long-term cycle stability, while carbon-sulphur powder is relatively cheap as active positive material.

More Li-S research came from Sapienza University in Rome, which is exploring the solubility of polysulphide in the electrodes, the low conductivity and high reactivity of lithium metal anodes.

Solid polymer electrolyte is too problematic, so gel is better, according to Jusef Hassoun, and anodes can be improved with tin/carbon anode instead of lithium metal. However, this still results in too high a polarisation and poor low rate stability.

The solutions are to improve the electrolyte to solid/gel polymer, improve the electrodes or take a hybrid solid-solution approach. Dr Hassoun believes a new electrolyte is necessary, as well as hard carbon nanoporous electrodes.

By now, lithium sulphur looked like a harder recipe to follow than Heston Blumenthal's peanut butter and foie gras consommé. It was complication heaped upon complication and given previous presentations about challenges of Li-S one almost felt sorry for Mr Hassoun.

Mr Hassoun proffered that polysulphide added to the electrolyte would create a more stable battery. Yes, said the audience, but this was first proposed 40 years ago for grid storage– where's the beef?

Lithium rich

'Lithium-rich' batteries, being less than a leap of some other lithium 'breakthroughs', are one of the more promising technologies closer to commercial reality. Kuniaki Tatsumi of Tokyo's AIST took a look at 'lithium-rich' NMC cells,

Villa Erba in Cernobbio on Lake Como

with a probable energy density of 250-300Wh/kg, which is possibly pushing the boundaries of lithium-ion batteries.

If 'lithium-rich' batteries are near to commercial reality, this is no cakewalk. It requires active material deposits on the surface of the cathode to improve overpotential performance.

AIST's choice is to use a SolGel method, with aluminium tri-propoxide coating, heptane solvent, dipropylenglycol and ammonia as a catalyst.

The aluminium coating, it was found, suppresses voltage fading, thus having a significant cyclability at a high charge. While the coating increases polarisation of the LiNiCoMn cells, it disperses it– a desirable thing, says AIST. However, due to the SolGel process used, the coating may not be uniform– a concern of several delegates.

The more jaded ears in the audience, who would have heard of the pitfalls of 'breakthrough' electrodes a thousand times, were perked up by Jean-Marie Tarascon and the work by Collège de France on high capacity layered oxide electrodes.

These rock salt layered oxides hexagonal metallic layers, with Li_2MO_3 honeycomb-like superstructures, offer the potential for electrodes of 1000Wh/kg.

However, these 'lithium-rich' high capacity oxide electrodes are not ready for primetime due to voltage drop and oxidation problems, so Collège de France has produced a stripped down, 'simplified' superstructure that uses one cation rather than three, using $LiRu_{0.75}Sno_{.25}O_3$. Precious metals (Ru) sold by the ounce are unlikely to replace transition metals.

Tarascon noted the anodic-cathodic redox process opens the door to cathodic materials with a capacity of 300Ah/g, including previously disregarded heavy metals such as tin to produce more electropositive batteries. Tin suppresses voltage fade by creating free volume to allow fully reversible migration of cations. This reversal migration of cations is integral to lithium-rich NMC cells.

Of course, ruthenium is costly and needs to be replaced, but this research into these techniques, which has the attention of Toyota, is one to watch.

Toyota 'all solid state' batteries

Toyota, of course, is trying to invent essentially a new type of lithium-ion battery altogether– an 'all solid-state' battery with solid electrolyte. The Japanese car giant aims to have an electric vehicle with an all solid-state battery of 400Wh/litre energy density by 2020.

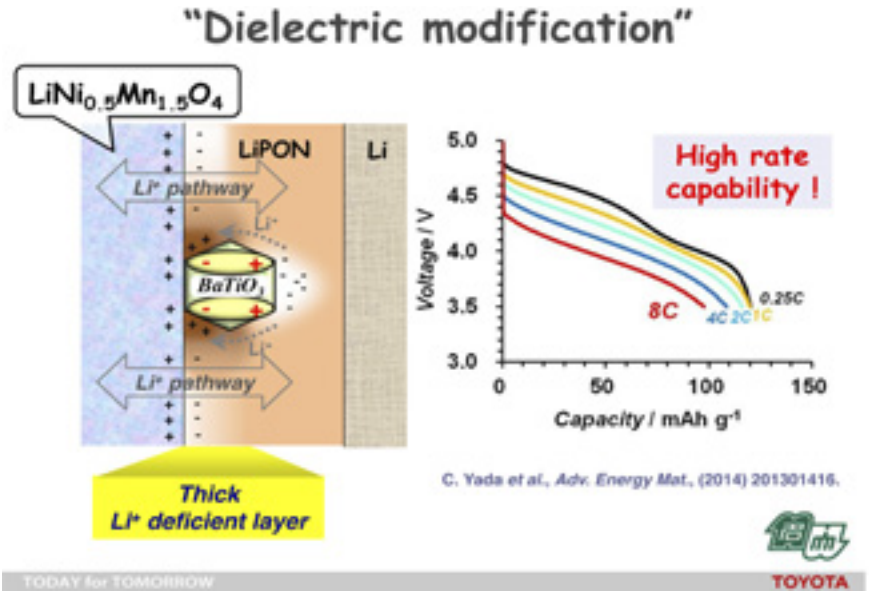
Judging by Chihiro Yada's presentation, this seems unlikely. Yada spoke of Toyota's 5V class prototype cells using inorganic solid electrolyte instead of organic liquids, which offers the potential for non-flammable, chemically stable cells with larger volumetric energy density by removing the dead space between cells in the battery pack.

Toyota has focused on $LiNi_{0.5}Mn_{1.5}O_4$ spinel electrodes with LiPON solid electrolyte. However, preliminary research shows there is a large charge transfer resistance at the interface between the cathode and the electrolyte.

To overcome this, Yada et al have had to work out a method for 'dielectric modification' at the interface to overcome the lithium-ion deficiencies. Toyota found introducing barium titanate ($BaTiO_3$) nano-particles are a good fix to reduce resistance; this required designing an interlayer between the cathode and electrode.

While Toyota looks to have solved cathode problems, delegates were concerned about the manufacturing process of producing such a cell with an interlayer. And what of the anode?

Yada admitted the 2020 target of 400Wh/l was "challenging" and said 400Wh/l was "at the high end of realistic". But given their track record with car batteries and electric vehicles, if there is hope, it must lay with Toyota.



Toyota's 'dielectric modification' technique to overcome lithium-ion interface deficiencies

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Lithium separators: Safety first

1/1000th -of-an-inch thick separators are the only thing standing between you and a lapful of burning computer. Rick Howard explores the latest developments in this vital component in lithium-ion batteries.

First and foremost, separators are designed to physically thwart anode-cathode contact and prevent electrical shorts while permitting relatively unfettered ionic diffusion. These attributes are achieved by the presence of tortuous sub-micron pores throughout the film, which fill with electrolyte and allow ionic conductivity between the electrodes.

To a first approximation, thinner is better, because Li^+ mobility is enhanced during cell operation, but the mechanical strength of these films forces a roughly 7 µm lower limit. Larger, less twisted pores might seem advantageous, but this would facilitate lithium dendrite formation and increase the possibility of an 'event' involving fire and/or explosion. Finally, separators must have adequate puncture resistance, but cannot be too thick (circa 45µm maximum) lest ionic transport, and hence energy output, suffers.

A secondary safety aspect of separators involves thermal stability, specifically the polymer softening point where porosity is lost (see ***Figure 1***), shutting down ionic conductivity and hopefully slowing heat evolution before thermal runaway. Pore closure can be tailored to fit the application: power cells will get warmer than slow-rate energy cells, so a more robust membrane is necessary for rapid discharge usage.

The optimum characteristic of thermal shutdown is a sharp transition temperature where impedance suddenly increases; this is best achieved with very high molecular weight polymers. Softening or melting points vary from about 125°c for low molecular weight polyethylene (PE) and 160-165°c for polypropylene (PP) and polyvinylidene fluoride (PVDF), to over 300°c for aramids, and combinations are used to allow rapid discharge without sacrificing safety. Separators designed for high temperature operations are frequently coated with ceramic nanoparticles for added strength, shrinkage resistance, and heat tolerance (to 200°c and beyond) without substantially reducing porosity.

Separators not only provide much-needed safety attributes, but also affect cell power capability and longevity. Membrane porosity, thickness, and pore size govern the film's contribution to cell performance.

Most separator porosities are 35-45%, generally agreed to meet specifications in cells for energy applications such as hand-held communication devices and laptops. But for power cells, used to accelerate a hybrid EV or work with a portable tool, film porosity must exceed 50%, else the added electrical resistance will heat the cell to higher-than-desired temperatures and shorten its working life by degrading the cathode material and electrolyte.

Intuitively, larger pores should favour power cells, but pore sizes are almost always submicron, as low as 40nm, to minimize the chance of Li dendrite growth through the separator, possibly causing a disastrous electrical short. As SEM photos below will show, porosity and pore size depend on the film processing method, which may be dictated by the polymer composition.

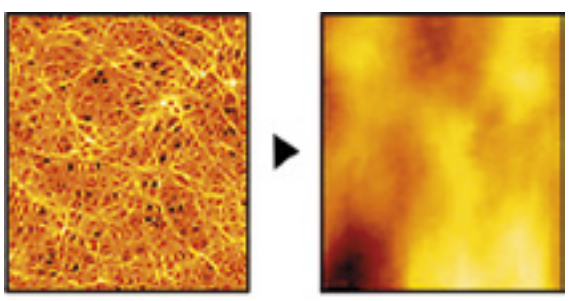

Figure 1. *SEM pictures of Toray's Setela PE film undergoing thermally-induced porosity loss.*

Wet/dry type separators

Process engineering determines separator classifications. Dry-type membrane polymers are formed by extrusion, and then stretched to achieve desired thicknesses and porosities, a difficult production step. Wet-type films start as dissolved polymers, the

solutions are cast or extruded onto a removable template, and the solvent evaporated, a less complex method. Sub-categories include coated and filled separators, typically employing nano-sized ceramic powders.

Coatings require an additional process step, whereas fillers are added to the polymer solution and the resultant slurry is cast as above. Not unexpectedly, there are pros and cons to each type of separator, with many variations on a theme, such as thickness and porosity, and differentiation from one manufacturer to another is not always clear.

Wet-processed separators enjoy roughly two-thirds of the global market, led by Asahi Kasei, Toray, and SK Innovation, while dry-type films account for the remainder, a sector dominated by Celgard and Ube Industries. The Big Three– Asahi Kasei, Toray, and Celgard– each supply about 25% of the market volume. Relative newcomers include Dreamweaver International, DuPont, Entek Membranes, Evonic Industries, LG Chem, Mitsubishi Plastics, Porous Power Technologies, and Sumitomo Chemical, all with a distinguishing technological wrinkle.

Or do they? Celgard sued SK Innovation and LG Chem for patent infringement in April 2013 and January 2014 over ceramic coatings, respectively, and Sumitomo Chemical acquired a license for Celgard's technology as part of a lawsuit settlement in 2013. Meanwhile, in August 2013, SK Innovation won similar litigation brought by LG Chem. Imitation may be the sincerest form of flattery, but it also makes a good living for attorneys.

Figure 2. *Processing schematic of a trilayer separator, with lamination between the extrusion and cooling steps (from Mitsubishi Plastics).*

Table 1 provides a brief description of Li-ion separators available in the global market, hinting at the pluses and minuses of each product line. A better picture of these films' attributes is available by examining the chemical and physical properties of the constituent polymers and their fillers/coatings. From the 'traditional' polyolefin films to innovative membranes of PVDF and

Table 1. *Separator manufacturers and a thumbnail description of their products.*

Company	Process	Separator Composition	Comments/Challenges
Asahi Kasei	Wet-extruded	Polyethylene, also with ceramic fillers	Low melting w/o filler, may oxidise, shrinkage, slow wetting
Celgard; license to Sumitomo	Dry-extruded and wet-cast	Polypropylene, polyethylene, and PP/PE/PP tri-layer	160°C shutoff (PP), oxidation at high voltage, processing difficult, slow wetting
Dreamweaver International	Wet-laid	Cellulosics combined with polyacrylonitrile or polyamides	Must be dried before use; high porosity & rate capability
DuPont	Electrospun	Polyimide	Large pore size, high melting, low production throughput, costly
Entek Membranes	Wet-extruded	Ceramic-filled very high mol. wt. polyethylene	High melting, slow wetting
Evonic Industries	Wet-laid	polyethylene terphthalate composite with ceramic coating	Exceptional wettability and thermal stability, shutdown 220°C, brittle, dusty, costly
LG Chem	Wet-extruded	Polyethylene with ceramic coating	Good puncture resistance; for internal use only
Mitsubishi Plastics	Dry-extruded	Polypropylene and PP/PE/PP tri-layer	160°C shutoff (PP), PE may oxidise, processing difficult, slow wetting
Porous Power Technologies	Wet-laid	Polyvinylidene fluoride with ceramic fillers	Pore closure ca 160°C, 62% porosity
SK Innovation	Wet-extruded	Polyethylene with ceramic filler	Puncture-resistant, thermally stable, oxidises at high V
Toray	Wet-extruded	High molecular weight polyethylene and multi-layer films	Shutdown ca 130°C; multi-layers contain diverse functionalities
Ube Industries	Dry-extruded	Polyethylene, polypro-pylene, multi-layers, all with ceramic coating	Better puncture resistance and thermal stability than uncoated films

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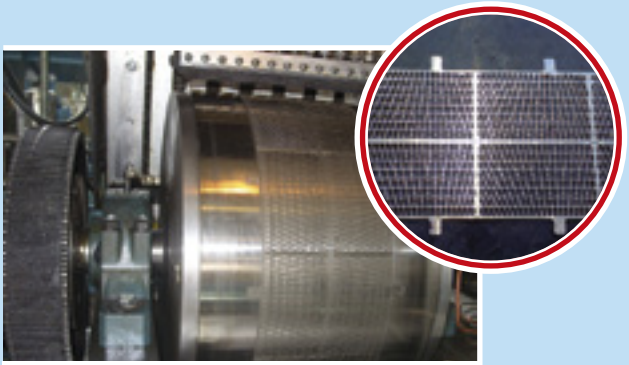

Continuous grid casting mold

HZ vacuum paste mixer

TW no-belt pasting machine

QF oxide mill

ZDX industrial casting machine

TS double-side pasting machine

Automatic lead grains granulating machine

FP plate parting machine

ZHX200 cast-on strap machine

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cellulose/polymer composites, it is clear that the many niche Li-ion applications have different specifications for optimised separators.

Traditional polyolefin separators

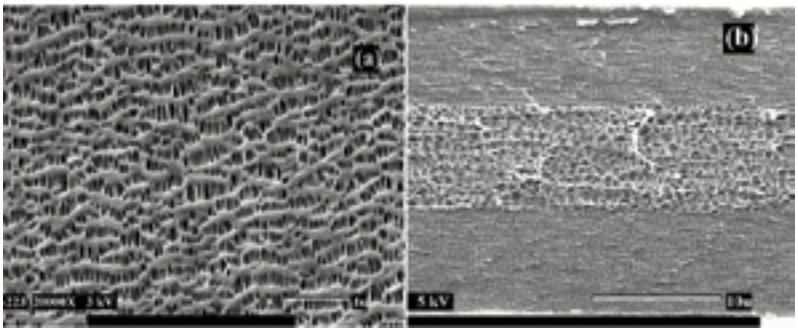
Polyolefin (ethylene, propylene) separators are typically extruded films produced by either the wet or dry process. In the former, polymer pellets are dissolved in a hot, non-reactive solvent or oil, the solution cooled to yield a gel, and extruded. The solvent is then removed by vacuum or heating, yielding a microporous film.

The mechanically more challenging dry process involves extruding the polymer (usually warmed to the softening point), and annealing, which results in partial crystallisation and axial orientation. In both procedures, the film is stretched to enhance porosity and achieve the desired thickness, a difficult and somewhat costly procedure (see ***Figure 2***).

PP membranes undergo about 5% shrinkage when heated to 110°c, while PE films will shrink 10% after 10 minutes at 120°c, raising the possibility of an electrical short with only moderate heating. This is a minor issue for small cells like 18650s (circa 3Ah), which have good thermal dissipation, but can be restrictive for large (›10Ah) cell/battery operation when heat is trapped and builds up in the core, leading to an inhomogeneous thermal pattern across the separator.

Ceramic coatings and fillers of nano-sized Al^2O^3, SiO^2, and similar, provide greater thermal stability and reduced shrinkage, although the coating restricts porosity and may interfere with power capability. Normal cell expansion and contraction during charge/discharge cycles causes

Figure 3.
A: *SEM photo of Celgard monolayer polypropylene film.*
B: *Celgard trilayer PP/PE/PP separator.*



matting of fibrous (wet-laid) structures, reducing porosity with cell usage and resulting in increased impedance. Also, polyolefins oxidise above 4.5V, which disqualifies them from next-generation cells with high voltage/high energy cathodes.

Figure 3 shows two Celgard polyolefin separators manufactured by dry extrusion and stretch-ing. Typical of such films, these are chemically stable at pH extremes, and the sandwiched polyethylene in the trilayer film ensures rapid shutdown if the cell temperature spikes above 125°c, a critical safety feature.

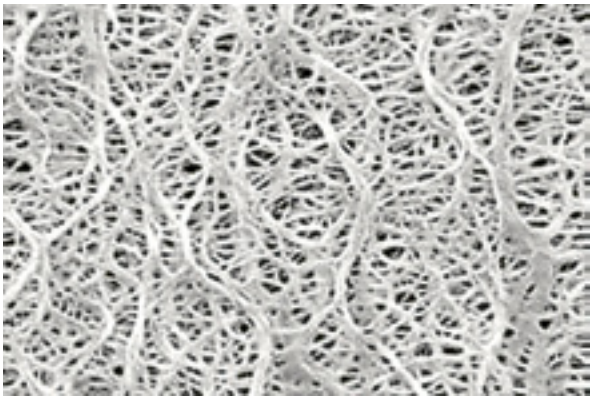
Figure 4 reveals the tangled web configuration of a polyethylene wet-cast film, not as robust as PP separators, but a good option in smaller cells with intense price competition. Celgard manufactures a variety of mono-and trilayer films, some coated with ceramic powder and/or laminated to a non-woven base.

Competing polyolefin separators are shown in several figures below. A discerning eye will note many similarities between these various SEM images (Ube's – ***Figure 5*** - and Celgard's trilayer films appear to differ only by the image orientation and focus), although available data and product descriptions tout the product diversities. For example, Mitsubishi Plastics (***Figure 6***) employs 2D stretching in its dry extrusion process, leading to greater porosity and their claim of 5-9% improvement in power output over cells with "conventional" separators.

Figure 7 shows Asahi Kasei's wet-extruded film, made from a blend of polypropylene (maximum 45%, molecular weight up to 1 million) and polyethylene (10-80% with molecular weight ›1 million). Asahi cites its ability to control uniform pore size up to 0.5µm and thicknesses from 25 to "several hundred" µm.

Both Entek Membranes and TorayBSF (***Figure 8***) utilise PE, although Entek films are a very high molecular weight filled polymer and exhibit 38% porosity with 16-32µm thickness, while TorayBSF offers 30-50% porosity in unfilled sheets as thin as 7µm. In summary, polymer chain length and (proprietary) processing result in obvious performance variations between polyolefin separators, although SEM images show only subtle physical differences.

Figure 4.
Celgard monolayer polyethylene separator membrane, 25µm thick.
This filament structure is less prone to thermal shrinkage than stretched films



Variations on a theme

There are two variations on the polyolefin theme: the use of electrochemically inert nanoparticles, such as ceramic oxides, clay, and other natural products, as fillers or coatings, to raise the heat resistance and film strength. For example, Al^2O^3-coated PE shows only 4% shrinkage after 1 hour at 105°c, while the unprotected film will shrink 14%.

Overcharge studies conducted at Sandia National Labs on related films showed cells with PE membranes short circuited and went into thermal runaway at 135°c, while the composite material remained stable until cathode decomposition occurred at 180°c. Comparative data on film strength (i.e., puncture resistance) are scarce and usually proprietary.

Although technical data were not provided, Asahi Kasei manufactures separators with hydrophilic inorganic fillers, scavenging cell life-shortening water from the electrolyte. Ube Industries' website also does not include a datasheet for their Upore multi-layer PE/PP laminated membrane, which is prepared by proprietary mixing and dispersion technology, then coated with inorganic nanoparticles after extrusion and stretching.

The coating results in improved heat resistance and reduced shrinkage, mitigating the possibility of short circuits. Ube's monolayer PE or PP separators feature relatively straight pores for greater ionic conductivity, useful in power cells, and film thickness and permeability can be engineered according to customers' performance specifications. The coating prevents unhindered Li+ migration between the electrodes, which could be hazardous.

SK Innovation produces an Al^2O^3 dual-coated separator (CCS) that reduces breaching during blunt force short circuit testing. SK's patent application describes trilayer PP/PE/PP films of 9-30µm thickness, where the PP outer layers contain about 40% inorganic filler and the PE middle still gives a 125°C shutdown protection.

Because wet and dry-processes are used to yield micropores and macropores, respectively, depending on the polymer, SK claims increased dimensional stability and film strength with high permeability, relative to other trilayer membranes. Their technological advantage claims are depicted in ***Figure 9***.

As mentioned above, Entek Membranes employs an ultrahigh molecular weight PE in their separators, with several available thicknesses. These films contain up to 69% precipitated submicron SiO^2 filler, allowing Entek to claim additional tensile strength, wettability, and puncture resistance, while also providing lower cell impedance and reduced self-discharge. Further, shrinkage at 200°c was <5% after one hour, far superior to unfilled PE. Entek noted in a 2012 presentation that their filled Teklon films likely require drying for optimum performance but projected the products would be cost-competitive.

New kids on the block

While polyolefin separators have long been the Li-ion industry's standard, several companies have developed electrochemically-robust microporous films to challenge the status quo. These emerging technologies target rapidly growing Li-ion markets that are outside the capabilities of polyolefin separators, such as high power cells and enhanced energy batteries operating above 4.5V.

Common threads in these new entries include greater porosity (permeability), which reduces cell impedance and allows more rapid Li+ transport between electrodes, and generally greater melt and structural integrity.

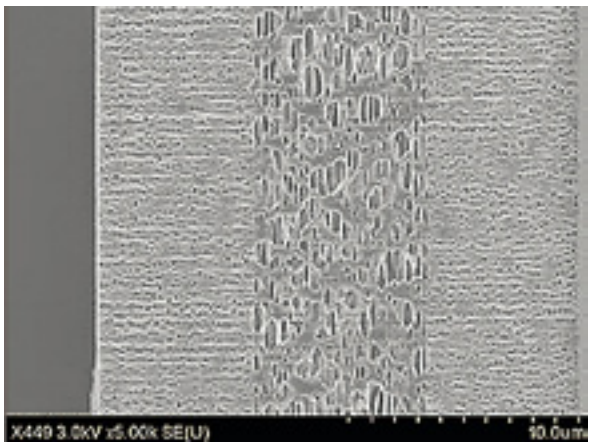


Figure 5. *Cross-section SEM image of Ube Industries' Upore PP/PE/PP trilayer film.*

Dreamweaver films are composites of aramid fibers (Gold) or polyacrylonitrile (Silver) and synthetic cellulosics; the former, designed for high temperature operations, functions to 300°c without significant shrinkage and will survive 500°c spikes, while the latter, a general purpose membrane, has thermal stability above 190°c.

Film processing (wet-cast) involves supporting the synthetic polymer nanofibers on a cellulosic micro-scaffold (depicted in ***Figure 10***), and results in up to 70% porosity with tightly controlled size distribution (median circa 0.22µm). Other claimed characteristics include good wettability and strength with lower ionic resistivity, relative to polyolefin membranes, but cellulose retains residual moisture content, and these separators must be dried before

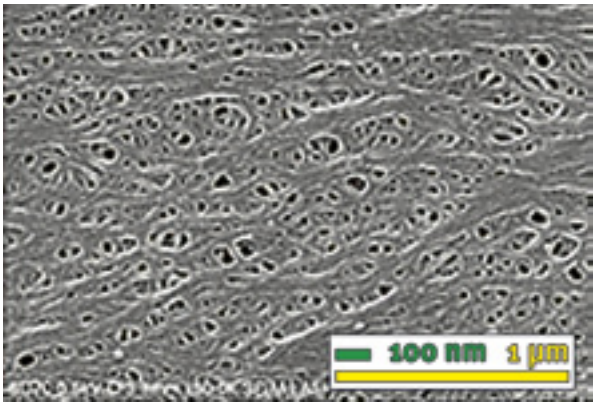


Figure 6. *Mitsubishi Plastics' Sepalent membrane (PE or PP/PE/PP), with porosity around 50% regardless of thickness (15-25µm).*

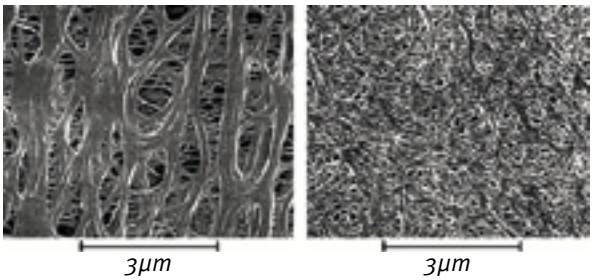


Figure 7. *SEM images of Asahi Kasei's Hipore separators, contrasting large-pore (left) and small-pore versions.*

use.

Dreamweaver further asserts their films promote Li-ion cells with higher capacity, better rate capability, faster charging, and better high voltage stability than polyolefins.

The chemical behemoth DuPont has also entered the Li-ion market with Energain separators comprised of polyimide-based electrospun nanofibers produced by a proprietary process that creates continuous 0.2-1.0µm diameter filaments. These films have an average pore size of about 2.7µm, therefore ionic resistivity is low and cell rate capability is enhanced, although battery producers prefer mean pore sizes ‹1µm to reduce the possibility of Li dendrite formation and a possible "event".

Nonwoven films with large pores are better suited to gel electrolytes, or more commonly, ceramic-coated on both sides, thus controlling ionic diffusion. DuPont's separators allow rapid electrolyte wicking, exhibiting low shrinkage and enhanced thermal stability with softening points ›220°c. Designed for high performing automotive batteries, Energain films are claimed to extend cell working life, facilitate recharging, and permit up to a ⅓ reduction in the number of HEV batteries.

Evonik, a division of Degussa, markets Separion, a wet-laid polyethylene terphthalate (PET) composite with ceramic nanoparticle fillers and coating (see ***Figure 11***) for exceptional control against thermal runaway and shrinkage at elevated temperature (‹1% at 200°c/24 hours). The ceramics, combinations of Al^2O^3, SiO^2, and ZrO^2, create a puncture-resistant separator with a polymer melting point above 220°c.

Other features attributed to these augmented PET films include high porosity and ease of wettability by electrolytes even at low temperatures, boosting ionic conductivity and thus cell power capability, despite its small average pore size (0.24µm).

Porous Power Technologies (PPT) manufactures Symmetrix, a ceramic-filled film of PVDF with 62% porosity to reduce cell impedance. The author interviewed John Shelburne, PPT's Director of Product R&D, to garner more insight into their recently introduced product.

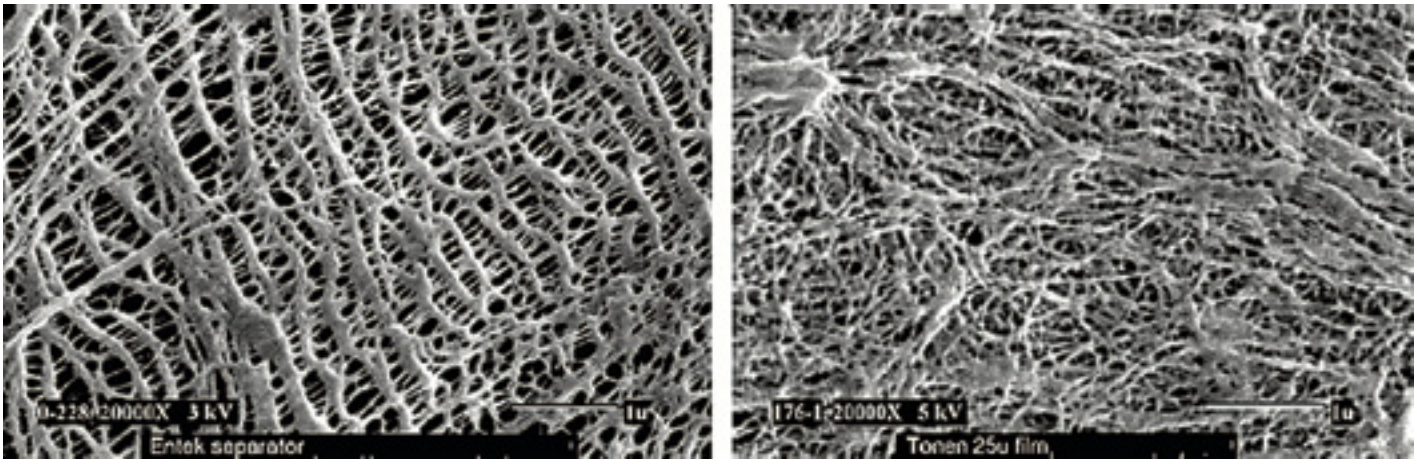
Symmetrix is a very flexible cast film prepared with a fugitive solvent, producing a consistent sponge-like pore structure, as seen in ***figure 12***. Claimed safety aspects include non-flammability, softening point circa 160°c but with low (‹1% at 90°c/1 hour) shrinkage, enhanced flexibility, tensile strength, and abuse resistance, and electrochemical stability above 4.5V.

This separator is designed for long cycle life (minimal porosity loss after 1000 cycles) in EV/HEV batteries and other large cells, and fillers can be varied to scavenge electrolyte impurities (i.e., acids or water), further extending cell working life. Despite a relatively small median pore size (0.3µm), Dr. Shelburne noted Symmetrix' high porosity provides low impedance and excellent rate capability, is easily wetted by electrolyte, and readily laminates to electrodes with PVDF binder.

Although the polymer is more expensive than polyolefins, ceramic fillers substantially reduce PVDF content, ensuring the film is cost-competitive.

Puncture resistance is an important safety property of separators that depends on the polymer chemistry, filling/coating, and film thickness; USABC has set 300 grams-of-force per 25.4µm thickness as the minimum standard, using a 1mm

Figure 8. *Entek's Teklon film (left) is made of biaxially-stretched ultrahigh molecular weight PE, while Toray Battery Separator Film (TorayBSF) produces porosity-controlled Setela™ PE membranes, both by a wet-extrusion method.*



diameter probe. Due to different interpretations of test data, only a few companies release puncture strength measurements.

Puncture resistances of generic membranes are polyethylene at ~750gf, polypropylene (more brittle) at 300gf, and trilayer PP/PE/PP with only 190gf resistance. Specific examples include Dreamweaver Gold (140gf), Dreamweaver Silver (210gf), Celgard PP (335gf), and Teklon (400gf). An alternate, perhaps more relevant, test for puncture strength involves a ~30 µm probe forced through the separator until it reaches the underlying electrode, simulating a short.

Under these conditions, unfilled membranes exhibit roughly the same puncture resistance, while ceramic-filled and coated films are more robust. Fillers offer a modest advantage over coatings, as particles of the former are likely to intercept the probe and prevent shorting, while the latter can flake off on impact and allow perforation.

Another significant separator data point is the Gurley number, a measure of air permeability that is proportional for electrical resistivity for a given composition, and also gives a rough estimate of wettability by the electrolyte. The Gurley number is defined as the time (in seconds) required for 100cc of air to pass through 1.0 square inch of a given material at a 0.188psi pressure differential; the industry standard measurement is from a 25µm film.

Three variables govern the Gurley number– the degree of film porosity, the pore size, and the film thickness. Polyolefin separators are made with 30-50% porosity, most in the 35-45% range, a bit less with a ceramic coating, and exhibit Gurleys of 200-800 seconds: this high range is attributed to the relatively small number of pores, mostly ‹0.5µm.

A side effect is that these films are slow to absorb (wick) electrolyte. Furthermore, porosity can vary across the membrane, which is problematic for large area cells.

The new generation of non-olefin separators offers improved (faster) film permeability, clearly targeting cells for power applications. ***Table 2*** gives a comparison of Gurley numbers. Unless otherwise indicated, values are from 25µm films.

Finally, there is the hot-tip test, simulating a short-induced hot spot in a cell: a fine-tipped probe similar to a soldering iron touches the separator and the resulting burn-hole is analysed. Polyolefins shrink away from the probe and leave a relatively large gap, possibly inducing a more active short leading to thermal runaway. Filled and coated films, as well as the new, high-melting polymers, are much more shrink-resistant, and the scope of the damage is limited to the hot-tip size.

Chinese separators: Not much cop?

This article would be incomplete without mentioning Chinese separator manufacturers. Their films are rarely exported, and unfortunately, cell producers consider the membranes' quality inferior to Japanese, Korean, and US products. Although China's annual lithium battery separator output is approximately 150m square meters, high-end Chinese Li-ion cells incorporate imported films; national companies supply ‹40% of the material used by cell exporters. Roughly 20 companies have instituted separator development or production: an overview of larger firms follows. Datasheets are commonly available only to Chinese battery manufacturers.

Cangzhou Mingzhu Separator Science & Technology manufactures three grades of films: a dry process, uniaxially stretched PP membrane,

Figure 9

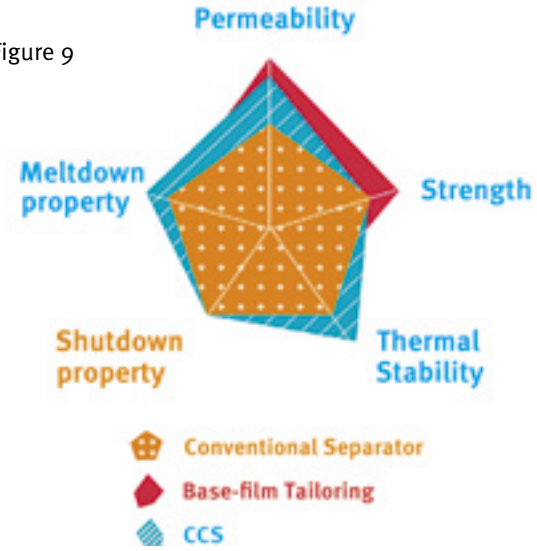


Figure 9. *Schematic showing qualitative properties of SK Innovation's CCS separator. Base-line tailoring refers to a PP/PE/PP trilayer film without filler.*

Table 2: *Comparison of separator porosities and Gurley numbers (permeability); values from manufacturers' datasheets.*

Producer	Polymer	Porosity	Gurley	Comments
Celgard	PP/PE/PP	41, 45%	575, 750 sec	2nd values for 38µm film
Celgard	PP	55%	200 sec	
Dreamweaver	PAN/cellulose	60%	90, 216 sec	2nd value for 40µm film
Dreamweaver	Aramid/cellulose	62, 68%	325, 340 sec	2nd values for 40µm film
Evonik	PET	ca 45%	ca 20 sec	Ceramic-filled and -coated
Mitsubishi	PP/PE/PP	50%	350 sec	
Mitsubishi	PP	51%	240 sec	
Porous Power	PVDF	62%	40 sec	Ceramic-filled, 22µm film
Toray	PE	ca 40%	570 sec	

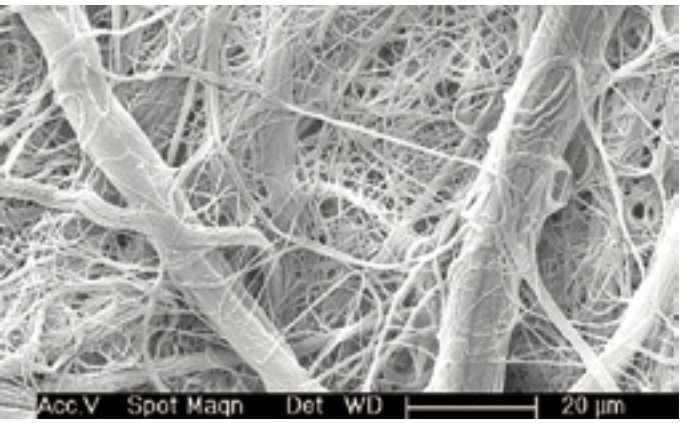


Figure 10. *SEM image of Dreamweaver separator, highlighting the combination of nano and microfibers that provides tight pore size control.*

which also forms the base for their PVDF- and Al^2O^3-coated products. Film thicknesses from 12 to 40µm are available; coatings are 1-2µm, single or double-sided. Donghang Photoelectric is the only other company exclusively utilising the dry-extrusion process, for polyolefin membranes.

Shenzhen Senior Technology Material (SSTM), with more than 30 patent applications, claims two dry-process and one wet-process production lines, outputting 12 to 40µm films. SSTM's biaxially stretched products include PP standard single- and double-layered membranes, as well as PVDF- and Al^2O^3-coated versions.

Foshan Jinhui High-Tech Optoelectronic Material utilises manufacturing technology from FSPG Hi-Tech for their wet-process, 10-25µm extruded polyolefin films. The company has several material patent applications.

Zhejiang Great Southeast Plastic produces a thermally resistant (to 170°c) separator. Shenzhen Hui Cheng Electric manufactures films from nanofibrous polyimides. Jiang-su Jiujiujiu Technology features ultrahigh molecular weight PE membranes made in its 2012-built facility. Zhejiang Nanyang Technology, Yunnan Yuantianhua, and Do-Fluoride Chemicals all have nationally-funded development programs for Li-ion separator production.

The Li-ion separator industry can be summarised as the old guard (polyolefins) versus the young guns (high rate/voltage capability polymers). Historically, PE/PP membranes protect against thermal runaway by losing porosity and restricting ionic conductivity at relatively low shutdown temperatures (125-160°c). Furthermore, convoluted pore structures mitigate the chance of Li dendrite formation, thus lowering the risk of a flash/bang event. This is more than sufficient safety for small cells powering hand-held devices, especially in highly cost-competitive markets.

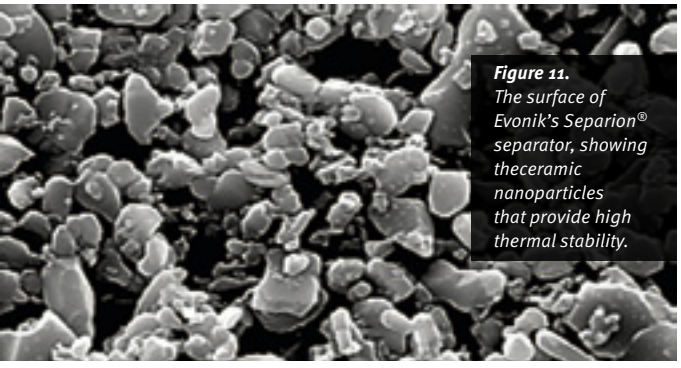


Figure 11. *The surface of Evonik's Separion® separator, showing theceramic nanoparticles that provide high thermal stability.*

Emerging technologies

Li-ion technology is nothing if not dynamic, however, and consumer demands for greater power and energy have changed the separator landscape. This goes hand-in-hand with the emergence of larger cells and packs that are less able to dissipate heat but are necessary for elevated power/energy outputs.

Combined with rapid discharge and (eventually) higher voltage, cells with polyolefin separators do not, and will not, meet safety standards for high performance batteries. An important similarity of the old and advanced membrane types is the controlling porosity that reduces the chance of a dendrite-induced short.

Emerging Li-ion separators, many constructed with ceramic-like fillers/coatings, are more heat and voltage-tolerant than established products, and clearly designed for high energy/power cells targeting transportation and energy storage applications. A small number of large cells or packs in a non-mobile setting are more amenable to active safety circuitry, which is too expensive for a handful of <5Wh cells already with passive safeguards.

Films designed for up-and-coming market segments are unlikely to replace polyolefin mem-branes, due to cost, and are already meeting safety requirements for large systems. The global presence of these advanced non-polyolefin separators will be dictated by the stable performance of next-generation electrode materials and electrolytes.

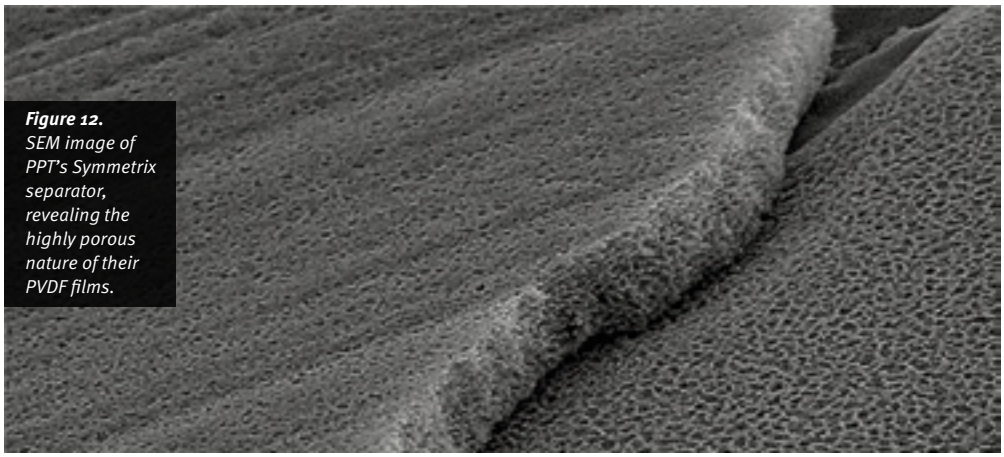


Figure 12. *SEM image of PPT's Symmetrix separator, revealing the highly porous nature of their PVDF films.*

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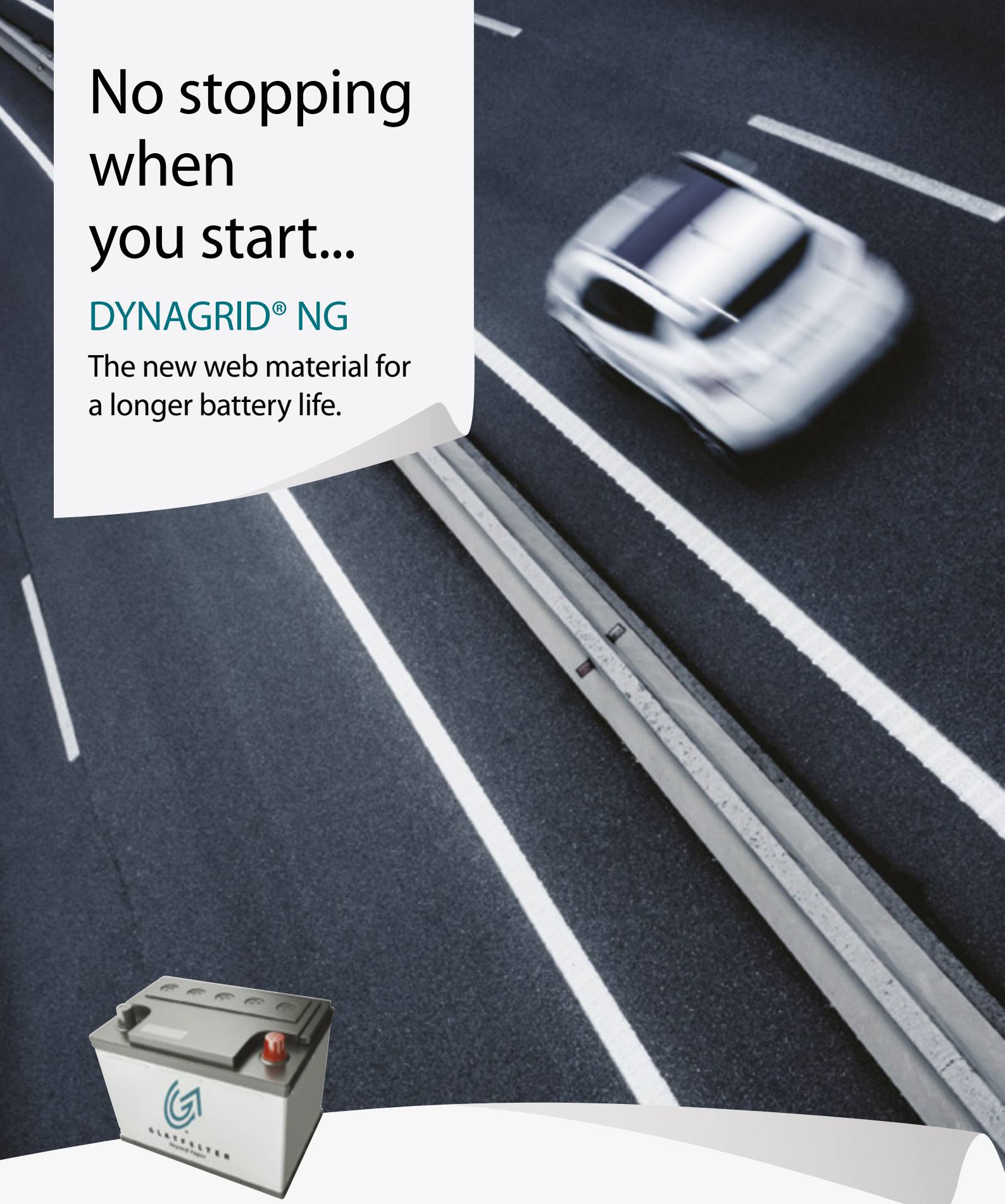

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Dropping in on lead

Lithium-ion is steadily encroaching on traditional lead-acid territory for reserve and industrial power applications. Ruth Williams examines the trend and what it means for the future of lithium.

Lithium-ion has long been established in the personal electronics sector and is starting to make waves in lead-acid strongholds. Lithium-ion companies are targeting industries that need a battery with a longer cycle life as suitable applications for drop-in replacements for lead-acid.

The industrial battery market is worth $15 billion annually, with lithium-ion replacement batteries staking a claim to between 10 and 20% of this total. While it is not ousting lead-acid just yet, the growing use of lithium-ion is not to be sniffed at.

According to a study by Navigant Research lithium-ion's share in the telecom backup power market will grow from 5% to more than 50% within the next four years, albeit on the major assumption that the cost of large format lithium-ion batteries will fall to that of lead-acid by 2020.

The areas being targeted by producers of industrial lithium-ion batteries are motive power, UPS systems, backup needs in the telecom industry, the military and aviation. These industries have previously used lead-acid but now some customers are replacing lithium-ion as a drop-in replacement. So why are people choosing lithium?

Above and below: A 5MW A123 lithium iron nano-phosphate battery, installed in Darlington, UK is one of six battery systems supplied to Northern PowerGrid for peak-load shifting and to manage voltage fluctuations

Well, the cost of lithium is significantly more, true, but with batteries requiring fewer changes over the lifetime of a backup system the total cost of ownership makes lithium-ion an attractive proposal in certain applications.

Lead-acid batteries are typically not as robust against cycling so they will wear out quickly in an environment that requires the battery to be cycled many times. Replacing a battery during the operational life of the system will incur costs not only for the new battery but also the installation cost itself.

Sending a technician to a remote location to change a battery is a drain on time and resources that must be considered by the customer when choosing a system because it can be higher than the cost of the replacement battery itself. Backup power is necessary everywhere, and it becomes more valuable in remote locations where battery power is relied on for telecom base transceiver towers, transmission towers, in UPS systems.

The more remote a location, the higher maintenance costs become so the argument for a 'maintenance-free' battery becomes stronger.

It is this argument that is encouraging companies to get into

this arena. A123 Energy Solutions, the non-automotive slice of A123 Systems that was not acquired by Wanxiang in the bankruptcy proceedings in early 2013, manufactures a 12V cell as a direct replacement for lead-acid batteries. A123's customers buy the 12V7 for use in data centres, backup power systems for the telecom industry and UPS systems.

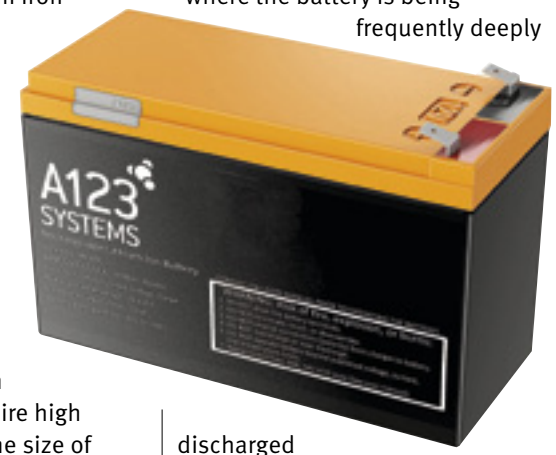
The 12V7 is a lithium iron 'nanophosphate' cell that is well suited to large format batteries due to its higher power capabilities than other lithium chemistries.

Roger Lin, director of product marketing, says A123 has a clear intent for its 12V7 product: "We focus on applications that require high power capability for the size of the battery. So we are looking at applications that need high discharge rates where lead-acid would not be able to provide the energy that lithium-ion would at such a high discharge rate."

The company sees the applications where lithium-ion is best suited to replace lead-acid as those requiring enhanced durability, greater cycle life, weight savings. These include aircraft and aviation for which weight savings are essential; telecom base stations in remote locations that must consider maintenance costs, and micro-telecom transceiver sites that can be located on rooftops where footprint and weight considerations are greater than that of capital expense.

Lin explains that in a scenario such as a rooftop micro-telecom transceiver where the customer requires more batteries to increase runtime, but the building cannot hold the additional weight, lithium-ion is an attractive option to provide the extended runtime while remaining in the overall weight parameter.

Another valuable consideration is the life of the battery. Depending on application, lithium-ion has the potential to last between three to five times as long as lead-acid under the same conditions. Lin says the A123 offering performs particularly well in environments where the battery is being frequently deeply discharged but the lifecycle advantages diminish in a scenario where the battery is not being used in this way.



Left: The 12V7 lithium iron nanophosphate battery

Right: Navitas' 12V lithium iron phosphate commercial version of the 6T military battery

A123 Energy Solutions has significant customers in the IT & data centre space and the telecom industries, both in the US and globally. One recent project saw the installation of six A123 lithium iron phosphate batteries in a number of grid-tied locations in the north of England with utility provider UK Northern Powergrid. The trial to rate the efficacy of energy storage in the grid includes a 5MW battery, which is one of the largest in Europe, and five smaller similar installations.

This is an industry that could be hugely profitable for any player. The UPS backup segment and telecom segment are worth billions per year for replacement batteries. At the moment 10-20% of this segment is lithium-ion but as the services these industries provide grows so will the demand for batteries.

Navitas navigates a route to market

It is this growing share that Navitas Systems, a relatively young US company based in Illinois that acquired the government accounts from the sale of A123 Systems, also wants in on.

While the company is happy to work with any chemistry that suits the needs of a customer, chief marketing officer Mil Ovan explains they focus on lithium iron phosphate and lithium titanate for like-for-like replacement batteries.

"The attractiveness of phosphate is its voltage matches lead-acid making it suitable as a replacement," he says. The voltage means the same charging infrastructure can be used, which would clearly be an attractive selling point.

"The electronics in a lithium-ion battery system mean we make it behave in a good way like lead-acid with respect to charging and accepting charge from a traditional charger, but overcoming the drawbacks."

Both A123 and Navitas use lithium-iron phosphate batteries as drop-in replacements for lead-acid because of the voltage match; typically a lead-acid battery would have six cells in series that matches to lithium-iron phosphate with four cells in series.

Lithium-metal oxide types and non-phosphates can also work

well but the voltage tends to be higher, so using existing charging infrastructure would result in overcharging or significantly under-charging which would result in damage or energy losses.

Navitas is targeting various military customers as well as industrial and commercial applications. The company has developed a drop-in replacement for the currently widely used classic NATO battery for military vehicles. The current model is called the 6T, it is two large lead-acid batteries connected together as a 24V system under the passenger seat of a Humvee.

Navitas' version is a lithium iron phosphate version that fits the same space but offers significantly more capabilities in terms of runtime, calendar life, cycleability and is 18kg lighter than the lead-version.

The Navitas 6T protype is being tested by CalStart, a Californian clean energy company, to evaluate the use of the 12V and 24V battery to replace lead-acid as a starter battery and supporting auxiliary loads in the trucks. But this is not the core of Navitas' business, which is split between military and commercial industries.

For the industrial segment Navitas has a lithium-based UPS system that yields a lightweight and smaller footprint than lead-acid batteries. "Think about a high-rise building in New York where you have space constraints and floor-loading is of greater concern. Of course, the cost is a lot higher but there are other trade-offs you have to consider."

This trade-off is simply that some things cost more than lithium. Physical space in a crowded area or, at the other end of the spectrum, reaching the power supply in a remote area to perform maintenance makes the higher up front cost worthwhile.

At present, A123 Systems is confident there is a substantial market for drop-in lithium-ion batteries. Under optimum conditions, the cells can cycle thousands of times more than lead-acid but the life expectancy guarantees vary between applications from anything from three to five times that of lead-acid.

Above: The XFC-Li from Enersys is a 24V lithium iron phosphate battery for the motive power market

Even companies such as Enersys whose bread and butter is lead-acid are future proofing the business by developing lithium-ion technologies. John Lawton, director of marketing at Enersys UK, spoke to BEST last year about the inclusion of a lithium-ion battery in its Hawker Motive Power range— a traditional stronghold of lead-acid. He said the chemistries could compliment one another and each was suited to its own niche areas.

The XFC-Li is a 24V battery with a 38Ah capacity that incorporates cells with a lithium iron phosphate ($LiFePO_4$) cathode.

The battery pack is intended for use in a niche area of the motive power market, namely low-duty pallet trucks. Unlike heavier duty forklifts, there is less of a weight requirement so a heavier lead-acid battery does not hold such a benefit.

By examining the way the pallet trucks are typically used, Enersys was able to offer a battery to match the needs of the industry. Pallet trucks are used intermittently for a short time then the battery is recharged regardless of the depth of discharge to ensure it would be ready for the next occasion. The lead-acid batteries traditionally powering them work best being discharged to 80% then put on a long recharge, not opportunistically.

Battery health is damaged by this repeated abuse but the operatives had to know the truck would work on-demand so would continue to mistreat them despite the damaging long-term effect.

This is why the company developed the battery to match demand and respond well to opportunistic charging. Lawton said the increased use of lithium-ion in automotive applications makes its use more topical so adapting it for the motive power market was a natural progression.

There are some products for which lead is the only answer. Forklift trucks need weight behind them so load shedding gives no advantage because ballast would be needed to bulk up; but for many applications lithium-ion wins on performance and total cost of ownership as well as weight reductions and smaller footprint.

Development of lithium is not going to go away, its use is too valuable and advancements will continue to be made. While the cost has previously kept lithium unaffordable and ring-fenced lead-acid, as more customers look at total cost of ownership rather than just the capital expense, lithium has found a secure spot in the market.

As the cost gradually comes down, its use in larger format applications will continue to become commonplace. Although it has a higher up front cost the total cost of ownership over the life of a system will make lithium-ion more attractive to customers and gain more ground from lead-acid.

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Battcon:
The nerds take on the novices

The Editor finds Battcon retains its rightful place as the world's premier conference for users of stationary batteries, despite the terrible jokes.

The blurb says Battcon is the world's premiere conference for users of stationary batteries. And it very probably is the world's premiere conference for users of stationary batteries. Then again, the competition to be the world's premiere conference for users of stationary batteries is not particularly fierce.

The first Battcon took place in 1996, organized by Florida's Albercorp to help customers and potential customers choose and operate batteries. A fine idea, and one that has seen Battcon grow to include some of the great and the good of the (mostly lead-acid) US battery industry.

Until 2014, Allen Byrne of Interstate Powercare had been chair of Battcon for all but one of the past 18 years. Byrne, legendary for his 'jokes', said that for this year's show he received more jokes than papers, so he decided to step aside.

Yet despite this loss to the world of comedy, his successor, self-proclaimed "battery nerd" Curtis Ashton of Century Link, renowned for his "legendary" intake of Dr. Pepper, gamely kept the flame burning for terrible gags.

Maintaining Byrne's tradition of keeping awake the audience by introducing each session with a corny quip or three, Ashton regaled Battcon delegates with a full repertoire of lame wisecracks of his own.

These really were dreadful witticisms, told with all of the timing and delivery of a satellite navigation system, such as:

"A proton and a neutron were walking down the street. The proton says, 'Stop, I dropped an electron. Help me look for it.' The neutron asks, 'Are you sure?' The proton replies, 'Yes, I'm positive.'"

You get the general idea. Yet the woeful japes were in keeping with the clubby, friendly, compulsory company-polo-shirt-and-chinos laidback atmosphere of Battcon, which is probably just as well

given the two-and-a-half days of questions and answers about topics such as 'Battery Discharge Testing: Implementing NERC Standards and Field Experiences'.

Battcon is, mostly, a succession of 'Batteries for Dummies' presentations and panel debates, from battery sizing, to commissioning, testing, monitoring and so on. This is back-to-basics stuff, albeit undoubtedly useful to the many battery novices in the audience, of which more than half were first-timers. But revelatory it was not.

Out of place?

The keynote speaker was Matt Roberts, executive director of the Energy Storage Association and, boy, did he look out of place. In fairness, there were several utility guys in attendance, but they were mostly who looked after batteries in substations, or nuclear power plants, not the sort interested in flywheels for frequency regulation.

Roberts' message– and his pitch to utilities/battery companies who may or may not want to join the ESA– was there isn't really much difference between UPS and telecom battery applications from energy storage, so why not get involved? Or, as he put it, "Rather than on standby, this is putting batteries to work". Yes, glib.

The California energy storage mandate of 1.325GW is worth $4 billion– more than the entire US sales of electric vehicles; and the frequency reserve market (which includes FERC Order 755 which rewards the rapid response of batteries/flywheels more than gas-fired plant) is worth $19.5 billion, possibly $27 billion by the end of 2020, said Roberts.

Meanwhile, demand response, which includes batteries for use at peak power times, is a $3 billion/year market, as much as $6 billion/year by that magic year of 2020.

New fangled fruity stuff

After the keynote the opening session featured three papers about lithium-ion safety, GE's sodium nickel chloride and Aquion's aqueous hybrid ion (AHI) energy storage battery. It was if it was a case of 'get the new-fangled fruity stuff out of the way and get on to the manly VLA and VRLA batteries', with the speakers perhaps unwittingly colluding in the deception.

Aquion's Ted Wiley was the pick, describing a solar-diesel microgrid project with a 60kWh AHI battery. The AHI deploys an activated carbon anode with manganese oxide cathode, a synthetic cotton separator and a water-based electrolyte.

Rather like a lithium battery, there is an intercalation reaction.

Michael Powell's responsible for Dominion's nuclear switchyard programme

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When the battery is discharged, sodium ions flow into the MnO^2, and make their way between the manganese and oxygen fatoms.

The AHI suffers from high internal resistance and so is not suited to high power, but is well suited to high cycling energy storage applications. At its Redwood Gate Ranch project in Jenner, California, Aquion has deployed three, 19.2kWh modules stacked with 4V cells in parallel, hooked up to a 10.8kW solar PV array and a generator with a 30kW inverter.

Wiley put the capex of the project, including the solar panels and generator at $80,500, not much more than the cost of a similarly specced "advanced lead-acid" set-up, which was estimated to cost $73,300. The author managed to wangle the cost of a 20kWh module out of Wiley: $10,000 ($500/kWh).

So it was onto the 'dummy's guides'. The aforementioned Curtis Ashton got his turn with an interesting presentation about string testing thermography, primarily for UPS. When not making terrible jokes, Ashton has the ability to engage with the audience.

In general, says Ashton, building a UPS system is not rocket science: it needs good connectors, good airflow and properly sized cables for the current. All too often, however, things can go wrong, and string testing thermography can help. With infrared cameras now available for less than $1000 (even with a very limited definition of 250 pixels), there is no excuse not to have one.

Non-commercial show?

Battcon promises to be non-commercial but at times that claim seemed dubious. If this wasn't hard selling, then it was very much soft selling, particularly by telecoms/UPS firm Century Link, which seemed to be involved in every session.

There was perhaps too much talk of thermal 'walkaway' for lead-acid. A problem, yes, but is the infamous Boeing Dreamliner thermal runaway incident being used as a marketing tool to flock VRLA kit? Undoubtedly.

To some it must have felt like an audience full of suckers, who would believe a battery would perform better if you offered it a sandwich. And from where I was sitting, it appeared very much to be the case.

Take Encell Technology, now trading as Servato Corporation after it acquired the former's battery management services business (and, incidentally, not touching its nickel-iron battery operations with a bargepole).

Encell/Servato's presentation was not helped by the fact that the speaker was a last minute replacement, an engineer by the name of Doug Magnuson, who also works on the nickel-iron battery. Confused? Not as much as the audience who had to swallow this stuff.

Encell's schtick is intermittent charging of VRLA UPS batteries. This is not new, UPS manufacturer Eaton has been offering this since the 1990s. We'll come back to them later.

Encell thinks it is a jolly good idea to take UPS batteries off float current and then top them up once every 24 hours. This not only saves

Test Products' Bill Cantor receives the Battcon Hall of Fame award from fellow inductee Lesley Varga

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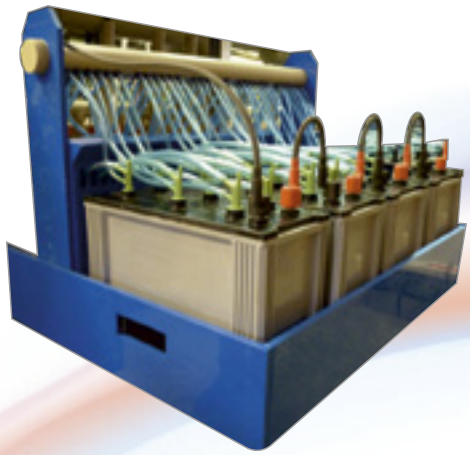

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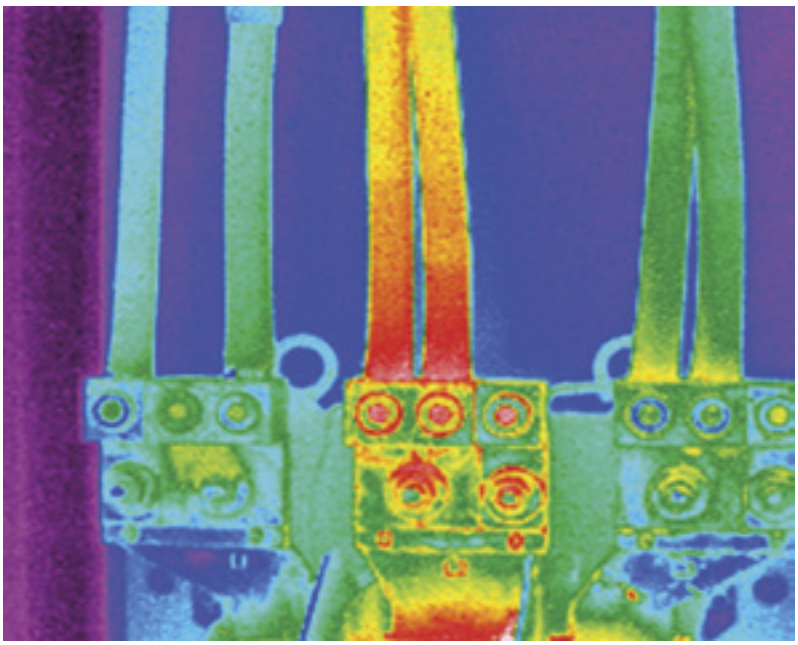


Thermal anomaly detected during inspection of commercial data centre. (excerpt from Proceedings Book 2014)

energy (up to 86%, it is claimed) but will also double or even triple the life of VRLA batteries. Really?

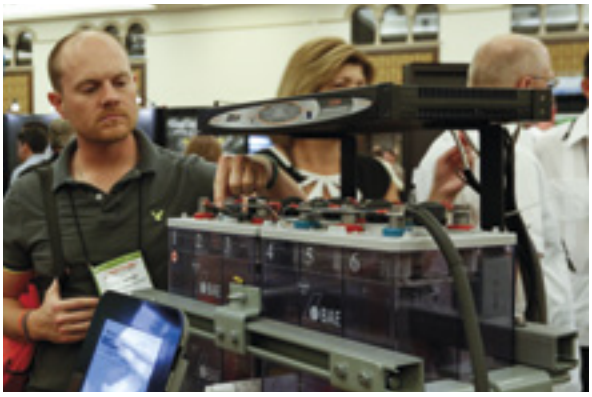
With a little help from this writer, the Encell/Servato paper was the subject of some debate, and little of it was positive. For one thing, any charger can be programmed to charge once every 24 hours. This is not rocket science.

But the whole premise of Encell's offering– that taking batteries off float current enhances battery lifetime– was suspect. Where is the data to back up these claims? Doesn't exist. They've only been testing for a year or so, although battery greybeard David Boden has been working with Encell.

It turns out that Eaton's similar offering caused a spike in voltage when 'topping up', which may overcharge and thus shorten the life of the batteries. So 'cycling' the battery in his way may actually be counterproductive. On top of this, Encell/Servato aims to charge a monitoring service of around $10 a month per string.

It would be very useful to see if Encell's techniques worked with a battery manufacturer to give credence to their system, but no such luck. It may be the real deal, but it reeked and while this writer may be fairly new to all this, even a chronic hay fever sufferer with clogged sinuses could have smelled a rat.

Or take NTM Sensors. By the way, folks, if Battcon is supposed to be a non-commercial conference then what was this pretty blatant advertisement doing in an odds and sods final session which also included a US DoE lab testing whether load shedding of batteries at a nuclear power station could last 72 hours in case of a catastrophic loss AC power? Or Exponent CFD modeling if liquid and forced air cooled lithium-ion battery packs would be cooler than operating with ambient cooling (amazingly enough, they do!)?



NTM Sensors supply ceramic sensors to detect hydrogen gas. Gassing is a problem, but when pressed, Robin Kimbrell said incidents are rare, the sensors may need replacing every three months and besides, mechanical relays are not explosion proof– so would the sensors be any good when the sh*t hits the fan?

VRLA recovery: Game-changer or distraction?

As usual, **BEST** contributor Peter DeMar got very excited by all the talk of the recovery of VRLA batteries left around in a warehouse. Veteran DeMar, who has attended every Battcon, gave a talk about how he recovered 2V VRLA Enersys cells found in a Florida warehouse, which had laid unused for 42 months.

In fact it is quite common for VRLA batteries, which are more forgiving than VLAs, to accept a charge as if straight out of the box even if they have been left alone for some time. Others chipped in with their examples of VRLA batteries being recovered after a long time.

Five years, delegates were told. Eight years, said one. Ten years, dared another. Has the Guinness Book of World Records missed a trick?

This was, of course, diverting stuff, but how useful are recovered batteries in the real world? Yes, old batteries may work as well as new ones if not left on float charge, and, yes, one shouldn't be too quick to replace VRLAs, but does, for example, a data centre want old batteries with no warranty?

Hall of famer

Test Products Inc.'s Bill Cantor won the 2014 Hall of Fame Award for his contribution in the field of DC arc flash hazard relating to batteries.

DC arc flash is a high voltage short circuit event that has the potential to cause severe burns or death.

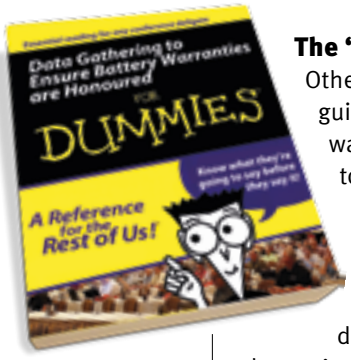
Relatively little is known about arc flash; the industry pretty much has no idea why it occurs. As Michael David Fontaine of the NFPA memorably put it, "We are still at the horse and buggy stage of understanding DC arc flash".

A show of hands to find out how many incidents of DC arc flash had been experienced, but only two hands went up: Curtis Ashton (whose job it is to install UPS systems) and a chap from telecoms firm Mohr Solutions, who it transpired had experienced a short circuit blast, rather than an arc flash.

All the same, the IEEE Stationary Battery Committee wants to hear about it given the lack of incidents reported. However, with the lawyers tending to decline the opportunity of even anonymous reporting of DC arc flash, don't hold your breath.

What the NFPA does know is that workers should not be closer than 18-24 inches to a DC power supply/battery system, and battery cabinets pose a risk up to five times greater than open racks.

The NFPA is introducing new workplace warning signs to warn of thermal hazards and arc flash, as well as risk assessments for arc flash, electrical shock and chemical hazards from batteries.



The "selling of fear"

Other than the dummy's guide to arc flash, there was the dummy's guide to commissioning procedures, the dummy's guide to battery sizing, the dummy's guide to discharge testing, the dummy's guide to data-gathering to ensure battery warranties are honoured and so on.

All good, necessary, worthy stuff. But a trifle heavy going after lunch in the Florida sun, and one could easily forgive the delegates who nodded off in the afternoon.

The audience awoke when a debate broke out about equalizing float current with individual cell voltage equalizer (ICE) devices, dubbed a "fraud" by no less than Enersys' Steve Vechy. For the uninitiated, the vendors of ICE devices claim to solve the problems of 'rogue' cells with lead calcium problems with a uniform float current.

However, in the industry these are perceived to be a joke, which regularly cause undercharging. Despite the claims, it was said that ICE devices they make no difference at all to the negative plate.

If it is done on the positive plate, there is a problem and ICE will only mask it. George Pedersen of BTECH said ICE devices might work for small cells like 12A microbatteries, but not for UPS equipment.

ICE devices were described as products that preyed on the "selling of fear". The same could be said for other products at Battcon.

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Formation of lead-acid batteries: The acid test

In the tenth part of his step-by-step guide, resident lead-acid battery expert Dr. Mike McDonagh gives the lowdown on formation of lead-acid batteries with an excess and a deficit of acid.

In this article, the two processes representing the extremes of acid availability during charging are discussed: tank formation and VRLA container formation. Tank formation is the process in which individual plates are placed into large tanks or vats filled with dilute sulphuric acid and charged with excess electrolyte.

With VRLA container formation, plates are assembled into their cases and formed as green batteries. Here, there is a deficit of acid during the formation process which results in very different conditions and chemistry for the active masses in the battery. The differences in chemistry resulting from these two methods and their subsequent process conditions and methods are examined and compared.

1. Plate formation, dry charge

This process takes the dry, cured individual plates before assembling them into batteries and forming the plates by placing them in vats with very dilute acid (1.05-1.09 specific gravity (SG)). ***Figure 1*** shows a typical tacked line of formation tanks. Each tank may contain 20 to 50 positive and negative plates connected together as individual cells up to the maximum charging voltage, generally 120 to 300V. A current is then passed through the series connected vats to form the positive and negative electrodes.

There are two types of tank formation, tackless and tacked. The original tacked method was to connect the plates by lightly welding a lead bar across each of the positive and negative plates connected in parallel. However, this has been superseded by the use of lead bars in the bottom of the tanks, on to which the plates are dropped, then tapped to provide the connection for the formation current.

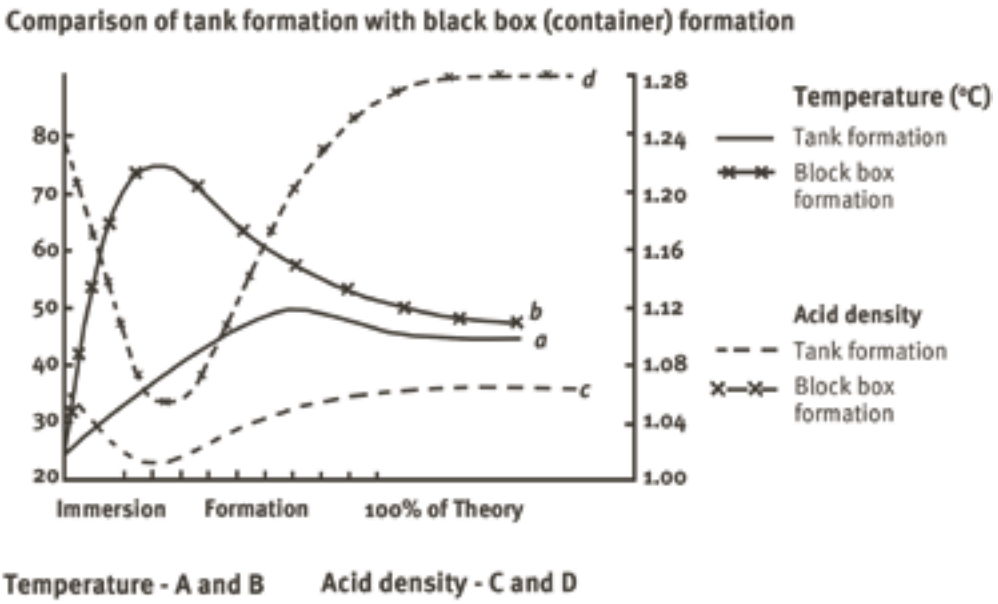
In the latter case, the necessity to ensure good electrical contact has been the subject of attention. To achieve this, the initial current is reversed in order to remove the previous formation layer from the surface of the bars. This is usually a low current for 30 to 60 minutes in order to ensure good contact between the plates and the formation bar.

The process operates using a SG acid, 1.05 to 1.09 as the starting gravity. Because the acid SG is low and the volume of acid is high, the production of sulphuric acid during the formation process has a relatively lower effect on the bulk acid SG than that of the container processes. For this reason, tank formation remains reasonably efficient during the whole process.

Figure 2 shows the changes in acid density and temperature during formation of battery plates experienced during tank formation and compared with the changes experienced during flooded battery formation.

It is evident that there is a great difference in the final SG and maximum temperatures reached between the flooded container method and the open

Figure 1
Tacked tank formation process for traction plates



Source: Lead-acid batteries by Hans Bode

Figure 2 *Comparison of Tank formation with black box (container) formation*

tank system. The lower starting SG of the electrolyte and the large acid volume compared with the active material, ensure that the concentration gradient of sulphuric acid from the plate surface into the bulk electrolyte is only slightly reduced at the end of the process compared with the start. This provides a higher driving force for the reaction:

$$2PbSO_4+2H_2O = Pb+PbO_2+2H_2SO_4$$

As the acid is produced on the electrodes, a concentration gradient is formed from the plate surface into the bulk electrolyte. The diffusion rate can be predicted using Ficks law:

$$J = -\chi \frac{\partial C}{\partial x}$$

The flux J [cm^{-2} s^{-1}] is proportional to the diffusivity [cm^2/s] and the negative gradient of concentration, [cm^{-3} cm^{-1}] or [cm^{-4}]. The negative sign indicates that J is positive when movement is down the gradient.

The lower the bulk concentration of sulphuric acid, the higher the concentration gradient from the surface of the electrode, the greater the rate of diffusion into the bulk of the electrolyte. This results in one of the products being removed more quickly and hence due to the concentration of the products at the reaction site being lower, the sulphuric acid molecules diffuse away from the reaction site. The steeper the slope the faster the diffusion.

Considering the equilibrium constant K for eq. 1:

At equilibrium $\mathbf{K = [H_2SO_4]^2\,[Pb]\,[PbO_2]\,[PbSO_4]\,[H_2O]^2}$

If K>1 then the reaction to form lead and lead dioxide, i.e. form the active materials, will be impeded due to the higher concentration of reactants.

If K<1 the reaction to form the products will be enhanced and the conversion of lead sulphate to the formed positive and negative plates will be more efficient, leaving lower levels of lead sulphate in the finished plates.

However, the efficiency of this process is still impeded by gas evolution from the positive and negative plates resulting from the electrolysis of water. This, and the additional sulphate from the formation reaction, cause a gradual increase in the specific gravity of the electrolyte during the formation process.

The increase is dependent upon the charging rate (current density)

Table 1 *Comparison of main formation techniques*

PARAMETER	TANK FORMATION	FLOODED CONTAINER FORMATION (two shot)	FLOODED CONTAINER FORMATION (single shot)
Intital electrolyte density (Kg/l) 30°C	1.050-1.090	1.070-1.090	1.230-1.250
Final electrolyte density (Kg/l) 30°C	1.070-1.100	1.190-1210	1.270-1.320
Readily achievable Maximum temperature	45°C	55°C	60°C
Average % sulphate remaining in PAM	3-5%	5-10%	10-18%
Formation efficiency, excess capacity factor	2.5-4 x Capacity	4-5 x capacity	4.5-7.5 x capacity
Relative cost measures	Additional washing and dry charge equipment. Extra labour costs and time, the most expensive method	Additional acid removal and recirculation equipment. Extra labour costs and time. More expensive than single shot	Cheapest and quickest method.

and the mass of the active material in each vat compared to the acid volume. Regarding the electrolysis of water, the tanks can be simply topped up to maintain a level slightly above the top of the plates.

Since it is an electrochemically-driven reaction, the calculation of the molar concentrations of reactants and products alone will not provide a true picture of the reaction rate. However, it does give an understanding of the process to demonstrate the higher active material conversion efficiency of this process compared with the box or container process for flooded batteries.

For this reason, tank formation is typically more efficient than box or container formation, where the limited acid volume even in the two-shot process results in a higher acid SG, particularly in the latter stages. As a result of this superior efficiency, formation time and energy can be reduced significantly.

An additional benefit is the lower temperature resulting from tank formation that results from the larger heat sink and open surfaces of the tank compared with the closed system of container formation. The net result is that generally, with the tank method, there is a lower residual sulphate content remaining in the formed active material and less energy and/or time consumed when compared with container formation. Table 1 gives a summary comparison of the two process methods.

Figure 3
Schematic of Tiegel Dry charge apparatus from 1986

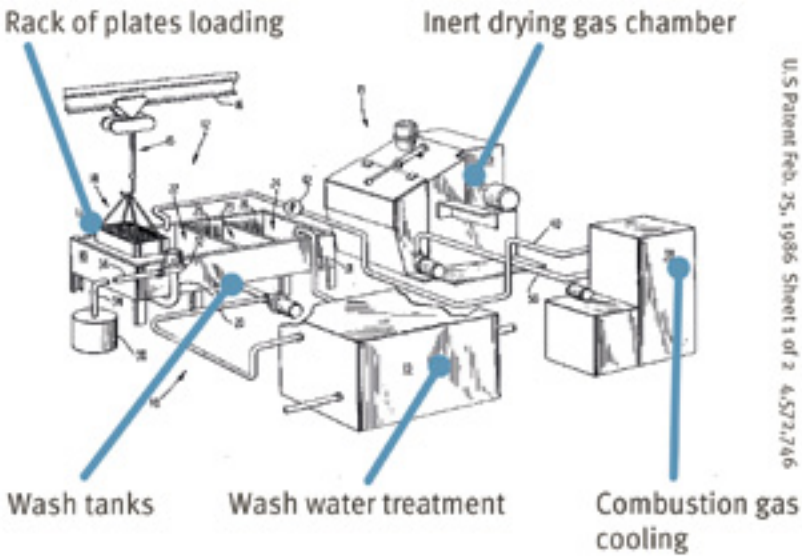


Figure 4
Plate washing method which can only give problems

The main consideration dictating the use of tacked or tackless connection in tank formation is the physical size of the plate. Using tackless formation for large plates such as tubular traction batteries can result in damage to the lug when the plate is dropped upside down onto the bar and then tapped to ensure it makes a good contact.

Additionally, the quality of the contact is critical due to the higher currents used. This would make any deleterious effects due to contact resistance more pronounced and more likely. Generally, companies who produce dry charged traction plates prefer to use the method of connecting the lugs by gas welding lead strip to the tips of the lugs above the level of the electrolyte.

Once charged, the plates are taken from the tanks and washed. The washing removes excess sulphuric acid to prevent surface concentrations from becoming too high on drying. It is not beneficial to remove all traces of acid. However, some residual acid prevents surface oxidation of the positive plate on drying. This helps to ensure that initial electrical properties are not compromised.

The washing process needs to be thorough and ***Figure 3*** is a schematic diagram taken from a patent application for the early Tiegel dry charge process. This shows a normal layout for the washing tanks and inert gas dry charged oven. The wash tanks are generally arranged in tiers of three with running water forming a weir, which overflows from the topmost or tallest tank into the next.

The newly-charged plates are removed from the formation tanks at the end of the process and then stored on pallets or racks prior to drying. For the inert gas dryer a rack of plates is immersed in the lower wash tank and then progressively moved up to the tank which is receiving the incoming water. The wash water is generally recirculated, neutralised and filtered to keep the pH as close to neutral as possible and to minimise the level of impurities to prevent contamination. It is normal to fix a pH value for the wash tank containing the plates before the plates are allowed to be removed. Either this, or fixed wash times with

regular monitoring and adjustment of the recirculating water can be used.

The value of washing the plates is also important in maintaining a consistent electrolyte SG in the battery after the battery is put into service. Variation in SG between cells or batteries can lead to premature battery failure, particularly with voltage limited charging.

Figure 4 is an example of how not to wash battery plates after dry charge. After washing, the plates need to be dried before they can be assembled into a battery. However, there is a fundamental difference in reactivity between the positive plate and the negative charged plate after formation. The positive plate is fully oxidised to PbO_2 and so is relatively inert. This means the positive plate can be air dried, either naturally or with controlled heating.

The negative plate however, is highly reactive and when the moisture content falls to a value of 12% or less, the high surface area of the spongy lead active material will react vigorously with oxygen. For this reason it is necessary to exclude oxygen and moisture from the plate environment whilst drying. Once dried, the plate is relatively unreactive and reasonably resistant to air oxidation. This allows plates to be stored for long periods provided that the ambient conditions have low humidity. Levels of humidity in the plate above 2% can trigger the following exothermic reaction:

$$2Pb + O_2 = 2PbO$$

This is a catalytic process initiated by the presence of moisture, which, due to the finely divided nature of the spongy lead negative is a very vigorous reaction. However, above 12% plate humidity, the reaction is extinguished. The reason for this band has been covered in a previous article on plate curing. It is necessary to ensure plate moisture levels are below 1% to avoid the oxidation reaction, which can be quite spectacular to watch (from a distance). A further processing step is therefore necessary, which requires additional equipment to safely dry the plates.

The most common commercial equipment consists of plate washing tanks and an inert gas chamber which removes moisture from the plates by recirculating hot combustion gases from natural gas burners. The hot gases heat up the plates by a process which evaporates the residual moisture in the active material. The recirculating hot gases containing the moisture from the plates are then cooled in a water spray.

The residual moisture taken from the plates is condensed, which leaves relatively dry gases to continue circulating around the chamber, be heated, and remove further moisture from the plates until they reach low enough moisture levels to be safely removed. This method can process large numbers of plates per shift; typically one tonne of plates can be dried in around 30 to 40 minutes from loading to unloading.

An alternative popular method uses heated vacuum chambers to evaporate the moisture in the plates. The humidity in the chamber is removed by the vacuum pump. The spongy lead in the negative plate is dried but does not oxidise due to the low partial pressure of oxygen remaining in the chamber.

Figure 5 shows a typical vacuum negative plate dry charge chamber with the lid open. Due to the different methods of operation and the difficulty in achieving a reasonable vacuum, loads for these machines tend to have smaller batches, and longer process times than the inert combustion gas method. The use of kerosene or paraffin has largely disappeared due to the hazardous nature of the process.

Figure 5
Example of simple negative vacuum dry charge chamber

2. VRLA charging

There are two main categories of VRLA batteries, those using compressed glass mat, and those adding silica as a gelling agent to produce a non-spillable electrolyte. In both cases the purpose is to provide the right conditions within the electrolyte mass to have some porosity where gases can collect and use the principle of diffusion to ensure the gases undergo further oxidation or reduction to recombine to form water.

It also prevents the loss of gases by simply preventing them from floating to the surface as bubbles, away from the plate surface, as would happen with conventional flooded batteries. The gelling process using silica, provides a gel which contains the dilute sulphuric acid. Initially, the electrolyte is in the saturated state and not in a condition in which gas recombination can occur. At first, water is lost from the gel due to the electrolysis of water and the escape of gaseous hydrogen and oxygen from the battery or cell.

As water is lost the gel dries out to create cracks or fissures adjacent to the electrodes. These voids will fill up with the gas produced at that electrode, either hydrogen or oxygen. These fissures hold the gases and produce a concentration gradient from the gas filled void through the gel or absorbed electrolyte to the next void in a direction away from the gas producing electrode.

By this mechanism, migration to the opposite pole by diffusion down the concentration gradient occurs. Once this condition is reached, recombination of hydrogen and oxygen will occur. A similar process occurs with the AGM battery: initial saturation is achieved from filling with dilute sulphuric acid followed by gradual drying out during the initial cycles or formation process. This drying process is self-regulating; excess water means that recombination will not occur and therefore hydrogen and oxygen will be released through the pressure relief vent and be available to recombine to form water.

With either AGM or gel battery formation, we have the situation

where the formation conditions with these batteries are the furthest removed from those found with tank formation and flooded container formation. There are also some significant differences in the filling procedures and charging chemistry between flooded systems and the starved electrolyte systems. These differences can be listed as follows:

- Quantity of filling acid;
- Filling acid strength;
- Method of filling;
- Available choices of formation method (plates or tank, single shot, two shot, container);
- Current density and ampere hour efficiency;
- SG measurement.

VRLA batteries not only need sufficient acid to provide enough acid at the right SG to achieve the required capacity, they also need to have a saturation level of the separators of around 90-95% to enable gas recombination. The volume and initial SG of the filling acid is therefore a critical factor with container formation for immobilised electrolyte batteries.

The most common method of formation is single shot container formation. The difficulty with acid SG at the end of the process requires that the starting SG, the programme and the temperature are carefully regulated. The starting SG should be chosen so that the water lost during charging will result in the correct SG being attained in the finished battery.

The following is a worked example for a 200Ah cell to calculate the final SGof the VRLA cell after container formation.

The volume available in the cell for acid filling can be estimated as shown in ***Table 2*** on page 117.

This example ignores the water loss due to electrolysis as the precise split of overcharge current between gassing and active material conversion is highly variable and depends upon localised conditions and battery design. It is assumed that the cell is topped up with water during formation and the final water content is similar to the original water content. The final in service SG can be calculated by assuming a 5% by weight water loss as the AGM approaches 95% saturation and gas recombination is facilitated.

The initial quantity of acid is critical to achieve a suitable finishing SG for service. Equally

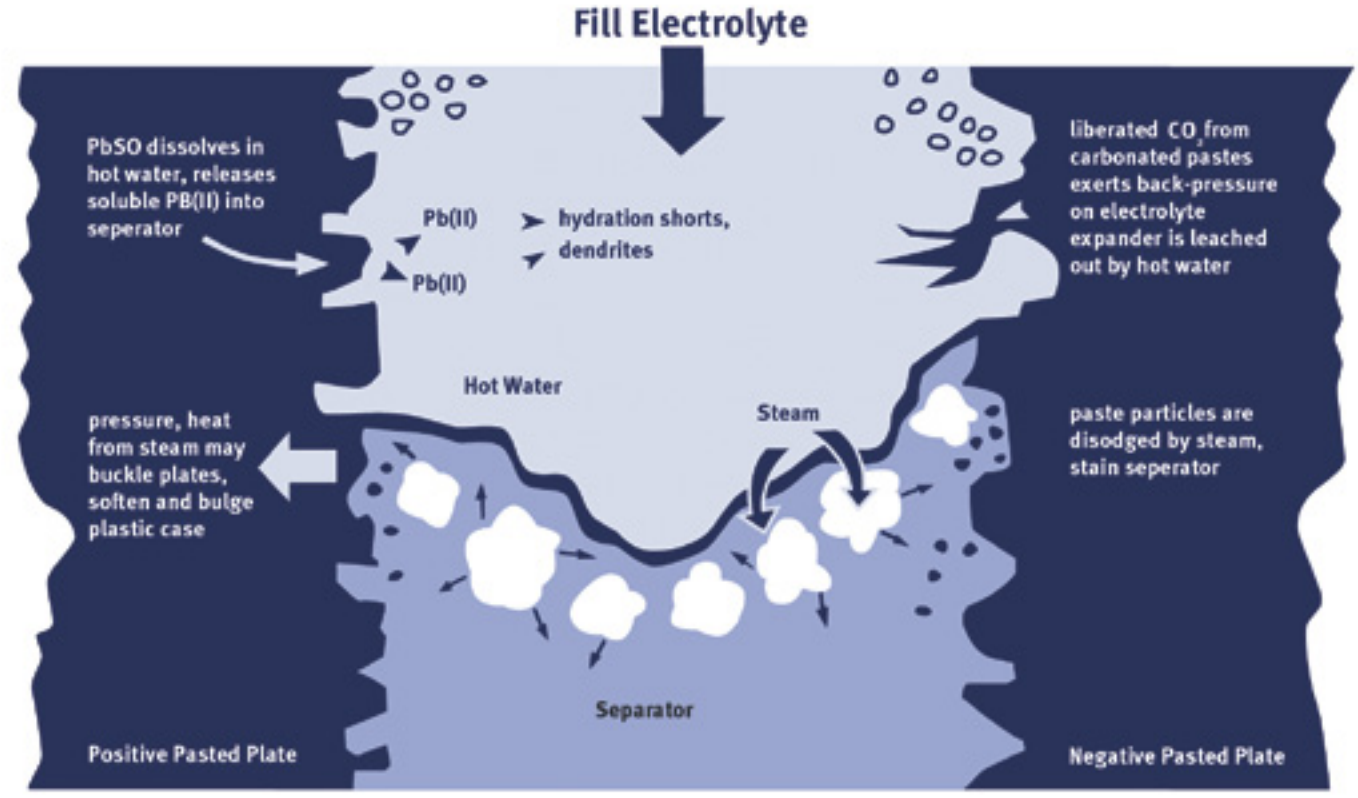


Figure 6
Action on the leading edge of the Electrolyte as it advances in the VRLA acid filling process

Taken from Digatron's 'A guide to VRLA Formation Techniques - *Bob Nelson and Mike Weighall*

critical is how it is delivered. In the case of gelled electrolyte, it is difficult to form the battery in a reasonable time using container formation.

If the plates are green unformed, then a low SG electrolyte is used which will form a gel during the process as the SG of the acid increases and water is consumed via electrolysis. The amount of silica used in the mixture will be sufficient to form a gel between normal SG variations during service, say 1.120 to 1.320 representing the fully discharged and fully charged state. This is dependent upon the grade of silica used and the battery design and operating parameters.

However, many companies find it easier to either, dry charge the plates before assembly or make a two-shot process. The first shot uses a low SG free acid, to form the battery, the battery is then discharged to around 20-50% SOC and emptied. A second shot of low SG acid with silica is added and the battery is recharged.

The problem with this, and with using fully dry charged plates, is the acid strength is at its maximum. This gives a fast gelling reaction and can prevent efficient filling of the battery as gelling occurs, preventing the acid from freely flowing to fill the separator voids and material pores.

One solution is to partially discharge the plates after the formation process is finished, usually to about 50 to 100% of the battery capacity. This then requires a lower filling density of acid and therefore a longer period for the gelling reaction to take effect; this can be pushed a bit further by using a deliberately low acid density for the prepared state of charge.

The gelling reaction is delayed until sufficient overcharge is applied to remove the excess water to the point where the battery has

Table 2
Calculating the estimated volume available in the cell for acid filling

$V_a = V_{ic} - (V_{cm} + V_{am} + V_g)$	
V_a = Volume of acid, V_{ic} = Internal container volume, V_{cm} = volume of compressed mat	
V_{am} = volume of active material, V_g = volume of grids	
For a 200Ah cell:	
Positive wet paste wt	3.10kg (15.5g/Ah)
Negative wet paste wt	2.77kg (13.8g/Ah)
Positive paste = 92kg of 1.400 sp gr in 1100kg paste (including water loss)	
3.1kg of positive paste contains	0.06kg Sulphuric acid
Negative paste = 75kg of 1.400 sp gr acid in 1100kg paste	
2.77kg of negative paste contains	0.09kg sulphuric acid
Total of 1.835 acid in plates	0.16kg
Amount of acid released from the plates	0.14kg (10% sulphate remaining in the plate)
200Ah cell dry weight Final weight before despatch Weight of acid in the cell	9.20kg 12.60kg 3.40kg
1.240 SG acid from cell filling 1.240 SG acid from plates	3.40kg 0.32kg
Total 1.240 acid added to cell	3.72 Kg
1.835 acid content in 1.240 SG acid 1.835 acid in the filled cell	32.6% by wt 1.21kg
Total of acid in cell from plate and addition Weight percentage of acid after formation Specific gravity of 47.6% wt/wt acid from Chart	1.36kg 0.40% 1.31kg
Cell open circuit voltage	2.15V

the correct SG for the design and application. This in fact can be a very accurate method for achieving the correct final SG and state of charge. Both, the two shot flooded/gel method and the pre-charged plate assembly method are suitable for this process.

A great deal has been written on this subject for VRLA batteries, in particular by veteran British battery consultant Mike Weighall and American VRLA guru Bob Nelson. I will just skim over the surface here to illustrate the effectiveness of the various filling methods and their reasons for being used. Briefly, there are several things to consider with VRLA batteries:

- The air spaces in the voids and pores of the separator material and the dry formed paste mass. These provide a back pressure to prevent or restrict the speed of entry of the electrolyte;
- The reduced speed of the acid entry due to interaction with the AGM separator fibres;
- The speed of soaking into the AGM mass resulting from compression factors and wicking speeds;
- The chemistry of the dry paste mass reactions with an electrolyte of lower acid concentration and higher pH at the reactioninterfaces.

The filling process for VRLA

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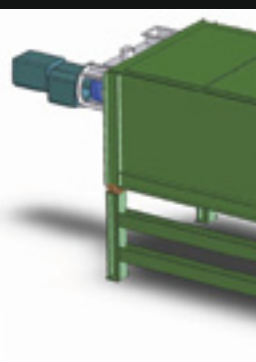

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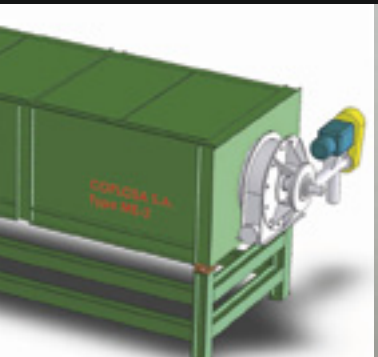

contains some key elements addressing some of the points made above. In particular the use of a vacuum filling method, which removes air trapped in the separator and glass mat. It is evident that situations can be created with reduced acid access to the active material that would not exist in a flooded system.

The key differences are the higher temperatures produced with negligible heat dissipation from excess liquid, higher pH values of the depleted electrolyte, particularly at the advancing reaction interface, and the dissolution of lead in the hot water or steam at the reaction boundaries. This latter reaction is insidious inasmuch as it can often lead to dendrite growth within the separator due to lead compounds being precipitated within the glass mat matrix.

The deposition quite often may be light and not result in a noticeable short circuit. It could however, affect open circuit and discharge voltages, seriously affecting both capacity and shelf life. ***Figure 6*** is a schematic illustration of the effects of a relatively slow filling of an AGM cell with a compressed glass mat separator between the positive and negative electrodes.

There are practical steps required to minimise or avoid these deleterious effects. The following is a summary of measures available:

- Vacuum filling with pulsing after the acid has been introduced. This helps to remove any vapour or steam created and provides mechanical stimulation to force electrolyte into the crevices and pores;
- Water cooling of the batteries during the filling process;
- Chilled electrolyte in the region of 10 to 20°C. Electrolyte which is too cold has a higher thixotropic value and can reduce pore filling ability;
- Shorter fill times by maximising the filling area to allow faster acid ingress. This would require design changes to the battery lid which may not be possible or desirable;

Table 3
Summary of formation process

Formation	Acid filling	Initial treatments	First charge	Pause or discharge	Max bulk charge current	Total time Max temp	Ah input X capacity	% sulphate remaining
Tank tacked	Rapid pour 1.05-1.09 SG	Connect battery lugs with lead bar	0.05xC_{20} for 30min	30min pause middle-end Optional	0.12-0.15 C_{20}/C_5	20-36 hours 55°C	2.5-4.5	3-5
Tank tackless	Rapid pour 1.05-1.09 SG	Reverse charge 30mins	0.05xC_{20} for 30min	30min pause middle-end Optional	0.12-0.20/ C_5	20-36 hours 55°C	2.5-4.5	3-5
Flooded 2 shot	Rapid pour 1st 1.06-1.08 2nd 1.28-1.30	Connection to circuits and water cooling	0.05xC_{20} For 30mins	Normally no pause or discharge	0.25-0.33 xC_{20} A	12-20 hours 60°C	3.5-4.5	8-12
Flooded 1 shot	Rapid pour 1.22-1.26	Connection to circuits and water cooling	0.05xC_{20} For 30min	30 min pause after 8 hours optional	0.25-0.28 xC_{20} A	18-24 hours 65°C	4.0-5.0	12-18
Gel	Vacuum with 2 shot or dry charged plates. Vacuum pulsing after filling can help	Best filled in cooling bath	0.05xC_{20} For 30min	Discharges: 0.5 C10 x1 Pauses: max 1 hour x1	0.08-0. 2 xC_{10}A	24-72 hours 55°C	4.5-7.5	8-12
AGM	Vacuum with 1 shot or dry charged plates chilled acid Vacuum pulsing after filling can help	Best filled in cooling bath	0.05xC_{20} For 30 min	Discharges: 0.5 C_{10} x1 Pauses: max 1 hour x1	0.08-0. 2 xC_{20}A	24-72 hours 55°C	4.5-7.5	8-12

- Longer soak periods before formation starts. This is a relatively simple measure but has limits. Depending upon the acid strength, the reactions between the acid and active material should be completed before the start of formation.

- However, too long a soak period can result in compounds being formed at the grid/active material interface, which can be difficult to shift and due to their non-conductive nature, can create a high internal resistance in the battery;

- Choice of glass mat separator and compression. In-service requirements and battery design have to be considered as major factors in this choice. However, if the surface area and fibre density of the compressed glass mat can be reduced at all, it is beneficial to the more rapid filling of the battery;

- Aspect ratio of the electrolyte space. Again, this is a design feature of the battery. The higher the length compared with the thickness the more difficult it is to fill the glass mat and to avoid dry patches. If possible, gaps around the edges of the cell, between the cell walls and the glass mat separator should be incorporated into the design.

This will allow acid to flow around the edges of the absorbant separator and reach the bottom of the plate group in the container. The wicking effect of the silica fibres in the mat, due to surface tension, can be used as an advantage to draw electrolyte into the bulk of the separator from four sides. This will result in faster, more uniform filling and reduce the likelihood of dry patches in the separator.

With VRLA batteries, there are inherent difficulties with acid filling and adjusting electrolyte densities after formation. The consequences of incorrect processing parameters during formation of VRLA batteries are serious. Variable specific gravities will result in variable

voltages between cells and batteries.

This can seriously affect the performance and life of batteries, particularly in fixed voltage charging which is normal for VRLA batteries. For this reason, control of the formation process is critical to producing a properly performing battery, suitable for the many market applications in which it is currently dominant.

3. Formation schedules

The theoretical coulombic input to convert dry cured paste to active material for the positive and negative plates can be calculated form the electrochemical equivalent. This has been covered in a previous article. Using this, we can calculate that we need 226Ah/kg of active material to shift an oxygen atom on or off a lead or a lead compound.

If we assume the generally accepted 50% efficiency for the positive plate we obtain 339Ah/kg. Depending on the design of the battery and its application, the material utilisation will work out at between 10 and 15g/Ah of dry cured paste. For simplicity, it is convenient to express the coulombic input for formation processes as a factor of their ampere hour capacity. Using the parameters discussed above, and assuming that the negative plate formation is more efficient, we can predict the following minimum requirements for a formation process.

For PAM:
A utilisation of 10g per Ah = 3.39 x Ah capacity (automotive)

A utilisation of 15g per Ah = 5.085 x Ah capacity.(VRLA/ traction)

This is fine if you have sufficient time and sufficient circuits to meet output requirements and if you are using efficient, flooded, formation methods. However, because of the need to have reasonably quick turn-round times, and with normal charging resources, and processes such as single shot VRLA, efficiencies are practically

less than this. A more normal Ah input would be:

Utilisation of 10g per Ah capacity = 4.5 x Ah capacity (automotive)

Utilisation of 15g per Ah capacity = 7.2 x Ah capacity (VRLA/traction)

In order to improve the formation efficiencies and minimise temperature rise during the formation process, programmes have been devised which apply rest periods and/or discharges at particular points in the programme. The effect of these interjections is to provide a period where the acid concentration is relaxed, or reversed in the case of a discharge. The benefits of this are to allow the temperature to drop and the back emf to decrease due to the reducing acid concentration at the active material surface.

This helps to stop unacceptable temperature rises and improves formation efficiency. The various methods described in this, and previous articles, rely on profiles consisting of varying current inputs, expressed as charge factors, including rest periods and discharges during the formation programmes.

Table 3 gives a summary of the processes discussed, with suggestions for suitable charging profiles.

It is evident that the two processes described, despite using the same overall lead-acid chemistry as the basis of operation, have very different requirements needed to produce the same battery performance and quality. The seemingly simple process of tank formation is complicated by the need to effectively wash and dry the plates before they are assembled into batteries.

The simple process of adding acid to a battery container for the container formation of VRLA batteries is more problematical than simple flooded systems. However, the benefits of these technologies and their use in a rapidly expanding, price sensitive market, means that solutions to these problems have to be found.

These solutions must be both cost effective and technically effective. With increasingly complex and price sensitive applications, the challenge is to manufacture under ever tighter constraints of tolerance and cost. The engineering and technical challenges required to achieve this, with a variable, partially understood and increasingly complex technology should not be underestimated.

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India 'Modi'fied!

South Asia correspondent Dipak Sen Choudhury opines on how the new prime minister Narendra Modi could boost India's economy, and takes a look at Amara Raja and fuel cell developments.

The deep-rooted democracy in India triumphs again! Breaking out of the apparent hopeless environment in which the country was taken to, by the previous government, whose long tenure was marked with indecision, corruption, and an absolute inability, of even intent, to check the rampant price increase of essential commodities, the country has decisively voted for a change.

The ultimate outsider, Narendra Damodar Modi, assumed office as the 15th Prime Minister of the country on May 26 after receiving an overwhelming mandate from the Indian electorate.

Considered until only recently as a political untouchable, a pariah in the huge multi-religion, multi-lingual canvas of Indian politics because of his origin and continued association with the hawkish Indian religious majority elements in the country, Modi

hails from the state of Gujarat, the birthplace of the Mahatma Gandhi, the father of non-violence.

Yet not all of Modi's record as an administrator is, allegedly, non-violent! But Narendra Modi, in his unstoppable style, took the bull of Indian democracy by its horns, converted the entire parliamentary election to almost a national referendum on his personal style of governance and came out on top.

The sheer energy of Modi's campaign, his track record of establishing good governance in the state of Gujarat, where he was the state chief minister, together with the revulsion of the Indian electorate towards the incumbent government, has landed him perhaps the most unenviable job in the continent with huge promises to be kept.

The state of Gujarat has prospered during his 15 year's tenure, opening up the economy to investments from both national and international capital, creating infrastructure for social, agricultural and industrial growth. The state has attracted a lot of attention from international observers and activities initiated in taking the development exercise ahead.

Japan, for example, views Gujarat and that part of the country as the focal point of huge industrial and commercial activity in the future and is partnering in many of the initiatives. India as a country hopes Modi to be able to replicate his Gujarat initiatives all over the country and revive the growth rates in all sectors for which India was the envy of the world until a decade ago and restore good governance.

There is another aspect of Narendra Modi that could be of far-reaching consequence. Some call him the Richard Nixon of India– particularly in dealing with Pakistan, the achilles heel of the

country, and of course China. Modi is of the liberal view that countries that trade and invest are less likely to fight and squabble.

His pragmatism could lead to opening more of Indian economy to Chinese investment and the Beijing front could be well managed. With Pakistan it could be easier if both countries start making a lot of money through cooperation, as the two countries share a great degree of emotional bondage regardless of the political posturing. If that happens– China, India and Japan work together harmoniously it could alter the balance of global politics and economics.

Amara Raja Batteries marches on

India's lead-acid giant Amara Raja Batteries Limited (ARBL) has inaugurated the world's largest integrated VRLA plant at Chittoor, in the southern parts of the country. This would be the second manufacturing facility of the company in the country and shall comprise of a number of units, all dedicated to the manufacture of lead-acid batteries only.

The first factory in a total of 500 acres of land, set up with an outlay of Rs3,500m ($60m) will have a workforce of 1500 operators churning out annually 3.5m UPS batteries. The second plant is under construction, presumably dedicated for manufacturing automotive batteries, and a third and two more plants– one for tubular products and other for plastics are in the pipeline.

The company envisages that when all four units are in production, the facility will be providing for direct and indirect employment of close to 20,000 in this economically backward region of the country.

For a company that was born only 20 years ago manufacturing industrial VRLAs– with the automotive division starting operation only in 2000– ARBL has come a long distance and is a company worth to be watched even on the international platform. Johnson Controls (JCI) has been the major technology provider for automotive and also may be providing some support on the VRLA.

Peter Brown, managing director of Essential Energy & Sushil Kumar Chaturvedi, CEO of Ascend Telecom.

The original VRLA technology of ARBL had come from GNB USA, as it was then known, and the industrial product performance is considered to be the benchmark for applications in Indian conditions. ARBL has a sizable presence in the export market too– both in industrial as well as in automotive.

They are one of the preferred suppliers to the Singapore taxi– an application many consider to be nothing short of murder with the best performing brand lasting out for at best a year or so! JCI's presence in the company is significant and they are holders of 26% of the equities and an almost equal or slightly more holding of the original promoters– the Galla family and associates make it a very well run company eager to excel.

There are whispers the company is also quietly trying to build up some lithium-ion capabilities– however, this stands unverified. All in all, it is a company that has a great future with all its fundamentals right.

Fuel cells start to take off

UK fuel cell supplier Intelligent Energy and Ascend Telecom Infrastructure Private Limited, which has been serving most of India's mobile network operators, have signed a landmark multi-year agreement to provide power for telecom towers in India. This is a landmark deal which holds out the prospect of real and significant cost reductions for India's telecoms industry.

Because of its sheer size and the expectation that the number of telecom towers will almost double to 800,000 from the current 400,000 by 2020, India represents huge opportunity. The market size is presently estimated at $2.8 billion per year.

In order to establish the viability of their technology, for the past three years Intelligent

Energy has been setting up pilot demonstration sites and working out the techno-economic viability of the fuel cell-based power generation concept in India. For their upcoming partnerships, Intelligent Energy, through its wholly owned Indian division, Essential Energy, will be integrating effective power management solutions for power installed in telecom towers.

This, depending on a specific site requirement, will include the advanced power solutions including fuel cell power system with a view to reduce both operating cost and carbon footprint related to usage of the traditional diesel generator sets.

Intelligent Energy has also teamed up with Microqual Technologies, a telecom infrastructure provider company of India, to offer tower sites that will come with power generation units that will help telecom operators run their network equipment without depending on the costlier diesel.

In a unique configuration, Microqual, fending off tough competition, has been able to get access to the state-run utility Power Grid Corporation of India's transmission towers for mounting of the telecom equipment. The rentals for these towers would be 20-30% cheaper than the prevailing market rate.

Intelligent Energy will have modules of hydrogen fuel cells on every Microqual tower. Offering towers with built-in power supply should make the tower contracts more acceptable to telecom operators.

A flurry of fuel cell activity in the telecom space has suddenly raised the expectations of the industry, which will be closely watching the performance of this technology. The issue of shipping hydrogen to remote locations of this vast country will itself pose a major logistical challenge. However, unlike diesel, which also has to cross the shipment hurdles, hydrogen is at least pilfer-proof. That itself will be a major relief– the rest will be up to the reliability of the technology to establish its niche in this difficult application.

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A cross between a battery and a dishwasher

Anthony Price, director of the UK Electricity Storage Network, reports from Hamburg, which hosted the fifth International Flow Battery Forum in July.

There is something about boats that make for a good conference. Conference organisers who need to find a way of providing a networking opportunity with a bit of interest and preferably no means of escape can use a good boat trip as a social event, throwing in a few drinks or a dinner to liven things up. Usually the boat trip involves going round in a big circle, talking lots and ending up in exactly the same place that you started from: a mirror for energy storage, perhaps?

There is also something about islands that attracts battery people. Island power systems have a particularly pronounced need for energy storage, as often the local network is either not connected to a larger system or if it is connected, the link is weak and could do with an upgrade.

Such is the system on the island of Pellworm, off the North Sea coast of Germany. Delegates from the International Flow Battery Forum (IFBF) visited Pellworm as their industry tour prior to the annual conference. Pellworm's inhabitants are very much into sustainability, and find themselves in a position where they produce more electricity than they can consume from a range of PV and wind turbines. The undersea link to the mainland is restricted in its capacity, so the island's electricity distribution company has been looking at electricity storage as a means to improve its local electricity network.

Delegates surrounding the Cellstrom VRB at Smart Region Pellworm

The 'hybrid power station' contains a lithium battery supplied by Saft, alongside a vanadium flow battery supplied by Cellstrom. The two batteries are connected by power electronics supplied by GK. The characteristics of the two batteries complement each other; the lithium battery provides capacity to deal with short term fluctuations while the flow battery provides the means to smooth energy over longer time periods.

The conference itself was opened by Ron Mosso of Enervault with a review of the recent commissioning of their iron-chromium flow battery at Turlock in the central valley of California. This is one of the more exciting flow battery developments in recent years, not only a non-vanadium system, but also a configuration which uses their proprietary cascaded flow technology.

Mosso's presentation covered the practical side of flow battery development, with details on engagement with local permitting and consenting agencies and dealing with the critical issues of site management. Enervault has brought the system from lab scale to deployment scale in less than five years and it shows the determination of a start-up company to make the investment

and deliver a project in such a modest timescale.

But outside the technical achievements, Mosso set the scene for the conference by declaring the big change since last year's conference is the arrival of a real market for grid scale energy storage. The Enervault 250kW/1MWh project is part of the landscape for large scale energy storage which now also includes the Californian procurement decision AB2514, Southern Californian Edison's 30MW RFP, Long Island Power Authority's RFP for 150-650MW, Hokkaido Electrics 12MW contract and Terna's 130MW contract in Italy.

There should be real optimism that in many parts of the world, the need for storage is not only recognised, but storage is also being positively developed.

ThyssenKrupp enters the fray

Surprisingly for some, the well-known German engineering company ThyssenKrupp, declared its interest in flow battery development. Already a major supplier in electrochemical cells, their logic is that it should not be difficult to use their expertise to produce large-scale flow batteries.

Niels Bredemeyer explained the issues of large-scale scale-up and stated ThyssenKrupp's ambition to produce a cell with an active membrane area of about 2.5m^2. Such large scale systems, if successful, would help to reduce the specific cost of electricity storage and may be a significant part in changing the role of flow batteries as they are used on the power system.

Although many people associate flow batteries with vanadium chemistry, it is evident there is more than one choice of technology. Professor Huamin Zhang of the Dalian Institute of Chemical Physics (DICP) in China, spoke about their work in developing an aqueous zinc nickel flow battery, as well as an organic lithium bromine flow battery, to complement their successful work vanadium systems.

With partner Rongke Power, DICP has now installed more than 36 vanadium flow batteries, and is moving towards a cost target of $350/kWh. The zinc nickel flow battery, by contrast, is still at the laboratory stage, although promising initial results suggest that in the longer term, it could be a viable alternative to the vanadium system.

Going back to a search of suitable redox couples has led ViZn Energy to a choice of zinc-iron as a flow battery couple. Paul Silberud is targeting 2MW/6MWh containerised units for deployment in microgrid applications as their development route. He displayed his costings for running a microgrid with and without storage and predicts 25% saving in diesel costs when microgeneration is run in conjunction with a flow battery.

More exotic is the work of Harvard University's Michael Marshak. His team has proposed a battery running on quinones instead of metals. He proposes rhein, which is a major constituent of rhubarb. The suggestion is that organics would, in the long term, be a cheaper alternative to metal salts, and although at the early stage certainly gave some food for thought. Harvard University is not the only organisation looking at this; Rebecca Potash of Cornell University has also been looking at organic salts and she reported on their feasibility study to come up with a lower cost solution to the flow battery problem.

While most applications for flow batteries concentrate on large, grid-scale use, Stephan Rudolf from Bozankaya BC&C gave about 30 seconds background on the use of energy storage for electric vehicles. Sadly, flow batteries were not suitable for traction use as the vibration caused disintegration of the stacks, and so BC&C was considering the use of flow batteries as support for charging stations, particularly in areas of weak networks. Their work examined corrosion resistance of vanadium flow batteries and the use of IR sensing to support the control of the battery system.

The IFBF dinner took place on a sailing ship

The IFBF brings together a wide range of developers, researchers and users of flow batteries, and the networking and knowledge sharing potential is significant. Adam Whitehead of Gildemeister, a veteran of the flow battery industry, carries the scars of dealing with bureaucracy; not only in Austria, but around most of Europe and he presented an informative paper on the trials and tribulations of installing and commissioning flow batteries.

Dealing with regulations is a messy business, made even

more so by possibly deliberately confusing legislation and specifications which seem to contradict. Clearly, a flow battery developer is going to need to confidence to navigate their way through the soup of tariffs, regulations and directives covering everything from the supply of electrolytes to the final decommissioning and recycling of the battery systems.

The IFBF covers all topics in the flow battery industry, and Lee Barker of Canada's Van Spar Mining, spoke about a new vanadium mine in China. If you thought all vanadium ores were the same, then Barker had some interesting news about ores with much higher proportions of vanadium, which he hoped would lead to a much lower cost base. A comment from the countered this by saying that although the industry wants low cost vanadium, the price would be driven up by demand. The more important metric is quality of the vanadium salts.

A vision for energy storage

The fact that the industry is still moving forward is testament to the over-riding need for storage. During panel sessions on the methods of funding flow battery development, Professor Hubert Girault of EPFL spoke about Switzerland's need for storage.

Although considered to be the home of pumped storage, Switzerland, stuck in the electrical crossroads of Europe, is caught in an economic trap by not being in the European electricity market. Storage is going to be essential, both short term and long term, and so Switzerland's national strategy is to increase storage capability. The need for governments to have a vision for their energy strategy is critical, explained Hubert.

The contrast with Japan was significant - in Japan, there is a close relationship between the government and private companies, making for a close market– a substantial difference to North America. However in Japan, the dialogue between government and industry tends to support technology developers– as shown by the recent switch back into vanadium technology by Sumitomo.

Beatriz Ruiz of Jofemar explained that with strong development in renewable energy, especially from the larger companies, that there was much interest in energy storage and so private companies were prepared to invest. Yoshiyuki Nagaoka of Sumitomo gave a further insight into Japanese thinking, explaining why a choice away from nuclear power, and a switch into renewables meant that flow batteries were an ideal candidate for storage, because of the higher storage capacity, compared to say lithium ion batteries. This was enough to convince Sumitomo to switch back into the flow battery business, after suspending their flow battery development for several years.

Ron Mosso, speaking for Enervault, commented on the balance of support from the US federal government, state agencies, venture capital and large companies. It seems that support from venture capital is now harder and the balance is leaning more towards support from large companies and industry.

There is a real sense of movement in the flow battery industry. Small and large projects are showing that the technology can be delivered; the flow battery's characteristics of power and high energy are needed by many customers and that flow batteries will be an important part of power system operation in the years to come.

There is still work to be done– Rick Winter, one of the members of UET, a vanadium flow battery producer, sums up the problem as not one of chemistry but of good quality engineering. He describes a flow battery as a cross between an ordinary battery and a dishwasher. Dishwashers need to be designed by a mechanical engineer, and now is the time for flow batteries to come out of the lab and into production.

UET is no stranger to this; it recently released pictures of their 500kW/2MWh unit system which they hope to deploy in Schleswig-Holstein in this summer period– just across the water from Cellstrom's system on the Island of Pellworm. Not quite where we started.

Carole Laine of Amersil explaining membrane technology

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Supercapacitor riddle: Rival or partner?

BEST's supercaps expert IDTechEx's Dr Peter Harrop looks at the relationship between supercaps and lithum-ion batteries and explores whether the two technologies are friends or rivals.

Consider three supercapacitor riddles. ***What takes a lot of space and no space? What has a rival that is a partner? What do fuel cells need next?***

Readers of **BEST** should know the answer to the first one. Structural components replace structures, thus taking no extra space, a neat engineer's workaround for a big component. Supercapacitors are a case in point. They need to be ten times bigger than lithium-ion batteries to store the same energy for relevant applications.

Previously we have reported on structural supercapacitors being developed at Imperial College London partnered with now Chinese-owned Volvo, where the supercapacitor is intended to be a load-bearing structure in, say, a car where it could be the door, the roof and/or their supports. Alternatively it could be 'smart skin' using this technology. Supercapacitors vanish. Then it is the size of the battery alternative that is the problem. The biter bit?

All options are some way from production but there are incremental stages towards the achievement of structural supercapacitors that can compete with lithium-ion by "redefining the battlefield" so that size is no longer a problem. We have previously reported on start-up Printed Battery Company, which, confusingly, develops plastic film supercapacitors that can be transfer printed to form part of a structure. Now let us consider the many other options being prepared.

Need for flexible components

"Thin and flexible energy storage devices are desired in many electronic devices that require flexibility," says George Chen, an expert in electrochemical technology from the UK's University of Nottingham. Flexible phones or other personal electronic devices would make usage convenient and more reliable, he adds. Also, ultrathin supercapacitors can help to reduce the volume of the whole device and allow installation of additional functionalities in place of a bulk battery.

"There are many applications of ultrathin supercapacitors (or batteries). For example imagine just wearing them, instead of carrying them in your shoulder bag, when boarding a flight," he says.

Chen cautions his work is still at the early stages of development and that improvements are needed before commercial ultrathin supercapacitors become a reality.

"For example, the device as reported exhibited negative deviation from theoretical predictions, which means the actual energy capacity was likely lower than reported," he says. "Also, the device suffers from a fast loss of stored energy, known as self-discharge. Reasons for such non-ideal behaviour are still not known and call for further research in terms of fundamental science and practical engineering."

Chen collaborates with Weiya Zhou and his team from the Chinese Academy of Sciences that use what they call a 'skeleton/skin strategy' to address a technical problem that also results in a structural component.

Supercapacitors based on carbon nanotubes and conducting polymers have higher energy densities than pure carbon nanotube-based ones, but they suffer from lower power densities. This is because the polymer layers overlap, leading to poor electrical conductivity. The carbon nanotubes (single-walled carbon nanotubes - SWCNTs) are the skeleton and the polymer layers (polyaniline - PANI) are the skin. The skeleton/skin structure ensures that the films are better conductors than conventional SWCNT/PANI electrodes.

Improved power density

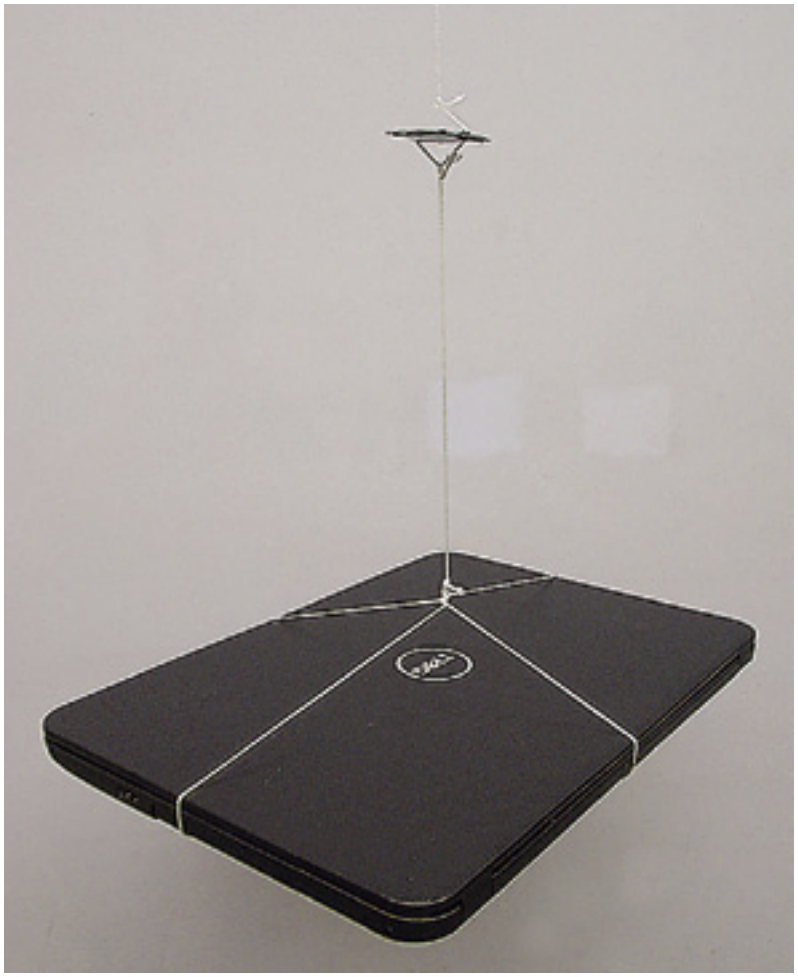
"Electrons can be transported continuously through the skeleton/skin architecture," says Zhou. "In the SWCNT/PANI network, interbundle junctions and continuous connections with SWCNT-SWCNT contacts ensure low

resistance." The film's conductivity was higher than that of SWCNT/PANI electrodes with overlapped PANI-PANI contact, which led to improved power density.

There are completely different approaches. IDTechEx's Supercapacitors Europe 2014 event in Berlin in April had an update on the progress of Cambridge University in collaboration with the Nokia Research Centre of Microsoft to develop a circuit-integrated supercapacitor for smartphones. Dr Pritesh Hiralal opened the conference with his presentation about the integration of supercapacitors into the fabric of flexible printed circuits. This is a supercapacitor that fully integrates with the flexible printed circuit (FPC) production process and can be easily manufactured by any FPC producer.

However, others are going straight to load-bearing structures such as, initially, small wafers the size of a postage stamp. Graduate student Andrew Westover and Assistant Professor of Mechanical Engineering Cary Pint recently made in Vanderbilt's Nanomaterials and Energy Devices Laboratory in the USA.

"These devices demonstrate for the first time as far as we can tell that it is possible to create materials that can store and discharge significant amounts of electricity while they are subject to realistic static loads and dynamic forces, such as vibrations or impacts," says Pint. "Andrew has managed to make our dream of structural energy storage materials into a reality."



Laptop suspended from a thin structural supercapacitor Source: Vanderbilt University

Game-changer?

Structural energy storage will change the way in which a wide variety of technologies are developed in the future. "When you can integrate energy into the components used to build systems, it opens the door to a whole new world of technological possibilities, says Pint "All of a sudden, the ability to design technologies at the basis of health, entertainment, travel and social communication will not be limited by plugs and external power sources."

In a paper that appeared May 19 in the journal 'Nano Letters', Pint and Westover report their new structural supercapacitor operates flawlessly in storing and releasing electrical charge while subject to stresses or pressures up to 44psi and vibrational accelerations over 80G, which are significantly greater than those acting on turbine blades in a jet engine. Pleasingly, the mechanical robustness of the device does not compromise its energy storage capability.

"In an unpackaged, structurally integrated state, our supercapacitor can store more energy and operate at higher voltages than a packaged, off-the-shelf commercial supercapacitor, even under intense dynamic and static forces." Pint has inserted a neat picture of his flake of supercapacitor supporting a large laptop. Yes, it is Young's modulus and shear strength that matters now!

"Battery performance metrics change when you're putting energy storage into heavy materials needed for structural integrity," he says. "Supercapacitors store ten times less energy than current lithium-ion batteries, but they can last a thousand times longer. That means they are better suited for structural applications. It doesn't make sense to develop materials to build a home, car chassis, or aerospace vehicle if you have

to replace them every few years because they go dead."

O graphene where art thou?

Graphene in supercapacitors has yet to offer major increases in energy density despite some professors calculating that 200 Wh/kg should be possible, leapfrogging today's lithium-ion batteries by about a factor of two and today's supercapacitors by about a factor of 40. In a novel approach, Pint and Westover's wafers involve electrodes made from silicon that have been chemically treated so they have nanoscale pores on their inner surfaces and they are then coated with a protective ultra-thin graphene-like layer of carbon.

Sandwiched between the two electrodes is a polymer film– a reservoir of charged ions, similar to the role of the electrolyte paste in a battery. When the electrodes are pressed together, the polymer oozes into the tiny pores. When it cools and solidifies, it forms an extremely strong mechanical bond.

"The biggest problem with designing load-bearing supercaps is preventing them from delaminating," said Westover. "Combining nanoporous material with the polymer electrolyte bonds the layers together tighter than superglue."

Lithium: Another riddle

Time for another riddle. What has a rival that is a partner? No prizes for saying supercapacitor, but an explanation is needed.

Supercapacitors compete with lithium-ion batteries by sometimes replacing them, say, across a fuel cell where the fuel cell cannot manage load variations or even accept electricity from say, regenerative braking, poor thing.

More on fuel cells later. For now, consider the fact supercapacitors work wonders when placed across a lithium-ion battery. Rivals and friends because sometimes the supercapacitor completely replaces the battery.

There is much more to this pairing than meets the eye. The reasons are more compelling that at first seems the case. It is little wonder Maxwell signed an agreement with South Korea's SK Innovation in December 2013 to jointly exploit use of Maxwell's

supercapacitors connected to SK's lithium-ion's batteries.

It is popularly accepted that putting a supercapacitor in parallel with a Li-ion battery creates higher power density. For a vehicle, that means improving charging time and acceleration. Additionally, it protects the battery so it lasts longer– important because all too many of them expensively expire well within the life of the vehicle. At the IDTechEx Supercapacitors USA 2013 show, Dr Priya Bendale from Maxwell Technologies revealed a study that confirms the impact of using supercapacitors on battery performance: for instance, cycle battery capacity degradation was decreased by a factor of two and the impedance degradation reduced by a factor of six.

Supercapacitors permit simpler batteries

Look closer at supercapacitor battery pairing and it is clear that a battery so protected no longer has to be a compromise of construction necessary for high power density, with many thin electrodes and a large area of separator wasting space and cost. It can be suitable just for high energy density. The resulting simpler design is lower cost, so not only is less battery needed, what remains is a cheaper battery type.

Another largely ignored factor is, if the battery tolerates deep discharge, the supercapacitor releases this. It results in 10% more energy being made available from the battery. That directly translates into at least 10% greater range for a pure electric car, as has been demonstrated in Japan. This confers huge competitive advantage. Although cycle life typically decreases with increased depth of discharge, progress can be made in improving batteries in harmony with supercapacitors.

Special cell constructions and chemical mixes maximise the potential of deep cycle batteries whereas many other cell chemistries will not tolerate deep discharge and cells may be permanently damaged if fully discharged. If you have developed a lithium-ion battery tolerant of deep discharge, it is time you talked to a supercapacitor manufacturer.

More evidence of fastest improvement

Finally, more people are confirming supercapacitors are improving faster than lithium-ion batteries in most respects. Maxwell Technologies recently pointed to 30% annual increase in power density.

As a purchaser, train manufacturer Bombardier points to unrivalled cost reduction over ten years. Jeff Colton, VP North American Sales of Ioxus says: "Pricing of ultracapacitors has declined by more than 90%. By comparison, battery pricing has declined by less than 40%, and ultracapacitor prices will likely continue to decline at a faster rate than batteries."

Ioxus had no difficulty in raising $21m from investors in April for a bigger push into China, already its main sales territory. With all this extra evidence this year, one has to conclude that a gradual increase in the supercapacitor component and decrease of the battery component in many pairings is in prospect.

Some research programmes are achieving increase in performance partly as a result of change in shape. That may make it practicable to have high capacity supercapacitors across batteries in everything from tablets to electric aircraft.

'Supercabatteries' advance

Supercabatteries (asymmetric electrochemical double layer capacitors, AEDLC) have long been available that compromise the benefits and challenges in one package. However, as one supercapacitor materials company that we recently visited pointed out, compromise is locked in at manufacture, so many designers prefer the versatility of the discrete component approach.

Clearly any designer of a product incorporating lithium-ion batteries should consider the option of putting a supercapacitor across it and, in so doing, go through the many potential benefits, most of which leverage each other, before making a decision.

However, there is a different view. We previously reported on our visit to JM Energy in Japan, which has been making 'supercabatteries' since 1999, and we were delighted to see them again at our

Supercapacitors Europe event in Berlin in April where they presented some very interesting test results of the implementation of their ULTIMO Lithium Capacitor (supercabattery) as an energy storage solution in hybrid buses.

This system comprises 180 prismatic ULTIMO lithium-ion capacitors, delivering 0.55kWh and 135kW. This system allows a reduction in weight of approximately 200kg, using less volume (150dm^3 less) as compared with a standard symmetric supercapacitor system, allowing both energy delivery and recovery during the bus operation.

In other words, just as supercapacitors have been replacing batteries in hybrid buses, now it seems that supercabatteries could do a better job. If that is true, they may sometimes do a better job across batteries.

Healthily broad range of research

It is greatly to the benefit of the industry that research and development reported this year takes very different directions and seeks very different benefits. Some is shown below.

Table: *Examples of supercapacitor research and development reported in 2014. Source: IDTechEx*

Organisation	Objective	Approach
Hutchinson (Total Group)	*Non-flammable device not using toxic or flammable materials such as acetonitrile and NMP*	Aqueous electrolyte and appropriate electrodes
International Center for Materials Nanoarchitectonics (MANA) of the National Institute for Materials Science	*High energy density*	Ultrathin graphene (monolayer or fewlayer) is glued to a 3D strutted framework. This has been achieved by a novel and unique method inspired by the blown sugar art, which can be called the "*chemical blowing method*"
Nayang Technological University	*Weavable supercapacitor fiber with high energy density*	396m^2/g from a solution containing acid-oxidized single-wall nanotubes, graphene oxide and ethylenediamine, which promotes synthesis and dopes graphene with nitrogen, is pumped through a flexible narrow reinforced tube called a capillary column and heated in an oven for six hours. Result: graphene + carbon nanotube supercapacitor electrode that with polyvinyl alcohol/phosphoric acid gel as an electrolyte, achieved energy density of 6.3Wh/L
Oregon State University	*Low cost, high energy density*	Natural cellulose heated with ammonia to make nitrogen doped electrode materials 2000m^2/g, comparable to expensive graphene
Poznan University of Technology	*-4ºC performance with non-flammable device not using toxic or flammable materials such as acetonitrile and NMP*	Salt aqueous electrolyte with additives
University of California, Riverside	*High energy density*	Nanometer scale ruthenium oxide anchored nanocarbon graphene foam architecture doubles energy density
VTT	*Low cost*	Printing
WWU Münster	*Low cost*	Expensive non-active electrode materials such as PVDF and PTFE replaced with cellulose combined with ionic liquid eg. as binders

Supercapacitors across fuel cells

What do fuel cells need next? A key finding at Berlin was that, in the future, electric vehicle propulsion systems, whether based on hydrogen fuel cells or batteries, will have longer lifetimes and perform better with supercapacitors. In Berlin, there was an update on the topic from Imperial College's Dr Billy Wu. He talked about supercapacitors as fuel cell life extenders.

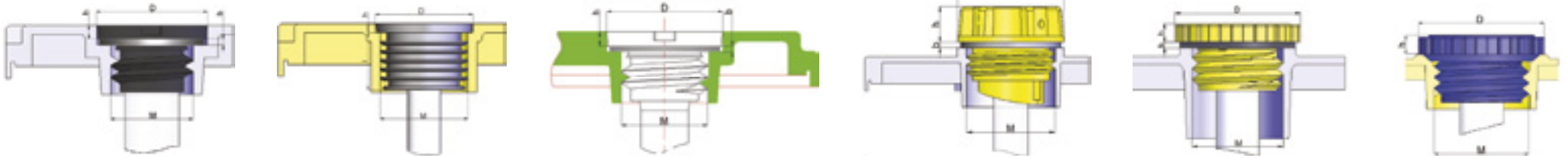
According to Dr Wu, supercapacitors on fuel cell (FC) cars can:

- Increase 17% efficiency over a pure FC system;
- Allow removal of the DC-DC converter to reduce the cost of the overall system;
- Allow down-sising of the FC, therefore potentially reducing the cost of the car;
- Act as a low pass filter to the FC reducing highly dynamic loads on the FC;
- Address the issue of PEMFC (Proton Exchange Membrane Fuel Cell) degradation in automotive applications: rapid load cycling and no load idling. By addressing the degradation of the PEMFC, the supercapacitor is effectively increasing its lifetime.

To these we must add accepting electricity from energy harvesting such as regenerative braking.

We would conclude, with Toyota, Tata Motors, Hyundai and Daimler promising major launches of fuel cell cars and larger vehicles around 2015, and BMW promising to follow around 2020, fuel cells are likely to be a major new market for supercapacitors. Land-based uses of fuel cells are already buoyant.

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 S1-A2 Φ20×M15×P1.5 S1-B1 Φ23×M16×P2.0 S1-B2 Φ23×M15×P1.5 S1-C1 Φ24×M18×P2.5 S1-D1 Φ20×M16×P2.0 S1-D2 Φ20×M15×P1.5 S1-E1 Φ23×M16×P2.0 S1-E2 Φ23×M15×P1.5	S2-A1 D21.30/M19.16 S2-A2 D22.90/M20.77 S2-B1 D21.30/M19.16 S2-B2 D22.90/M20.77 S2-C1 D21.30/M19.16 S2-C2 D22.90/M20.77 S2-D1 D21.30/M19.16 S2-D2 D22.90/M20.77	S3-A1 Φ20×M16×P2.0 S3-A2 Φ20×M15×P1.5 S3-A3 Φ20.5×M16×P2.0 S3-B1 Φ23×M16×P2.0 S3-B2 Φ23×M15×P1.5 S3-C1 Φ24×M18×P2.5 S3-D1 Φ27×M20×P2.0 S3-E1 Φ20×M16×P2.0 S3-E2 Φ20×M15×P1.5 S3-F1 Φ23×M16×P2.0 S3-F2 Φ23×M15×P1.5	S4-A1 Φ20.5×M16×P2.0 S4-B1 Φ20.5×M16×P2.0 S4-B2 Φ20.5×M15×P1.5 S4-C1 Φ23×M16×P2.0 S4-C2 Φ23×M15×P1.5 S4-D1 Φ23×M16×P2.0 S4-D2 Φ25×M16×P2.0 S4-E1 Φ23×M15×P1.5 S4-F1 Φ20.5×M16×P2.0 S4-F2 Φ20.5×M15×P1.5 S4-G1 Φ20.5×M15×P1.5 S4-G2 Φ23×M16×P2.0	S5-A1 Φ24×M18×P2.5 S5-B1 Φ25.5×M18×P2.5 S5-B2 Φ25.5×M18×P2.5 S5-C1 Φ28×M22×P2.5 S5-C2 Φ28×M22×P2.5 S5-D1 Φ36×M28×P2.5 S5-D2 Φ36×M30×P2.5 S5-E1 Φ34.5×M25×P3.0 S5-E2 Φ34.5×M25×P3.0 S5-F1 Φ34.5×M26×P3.0 S5-F2 Φ37.5×M26×P3.0 S5-H1 Φ25×M20×P2.5
Assembly Instruction					

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	● - 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		

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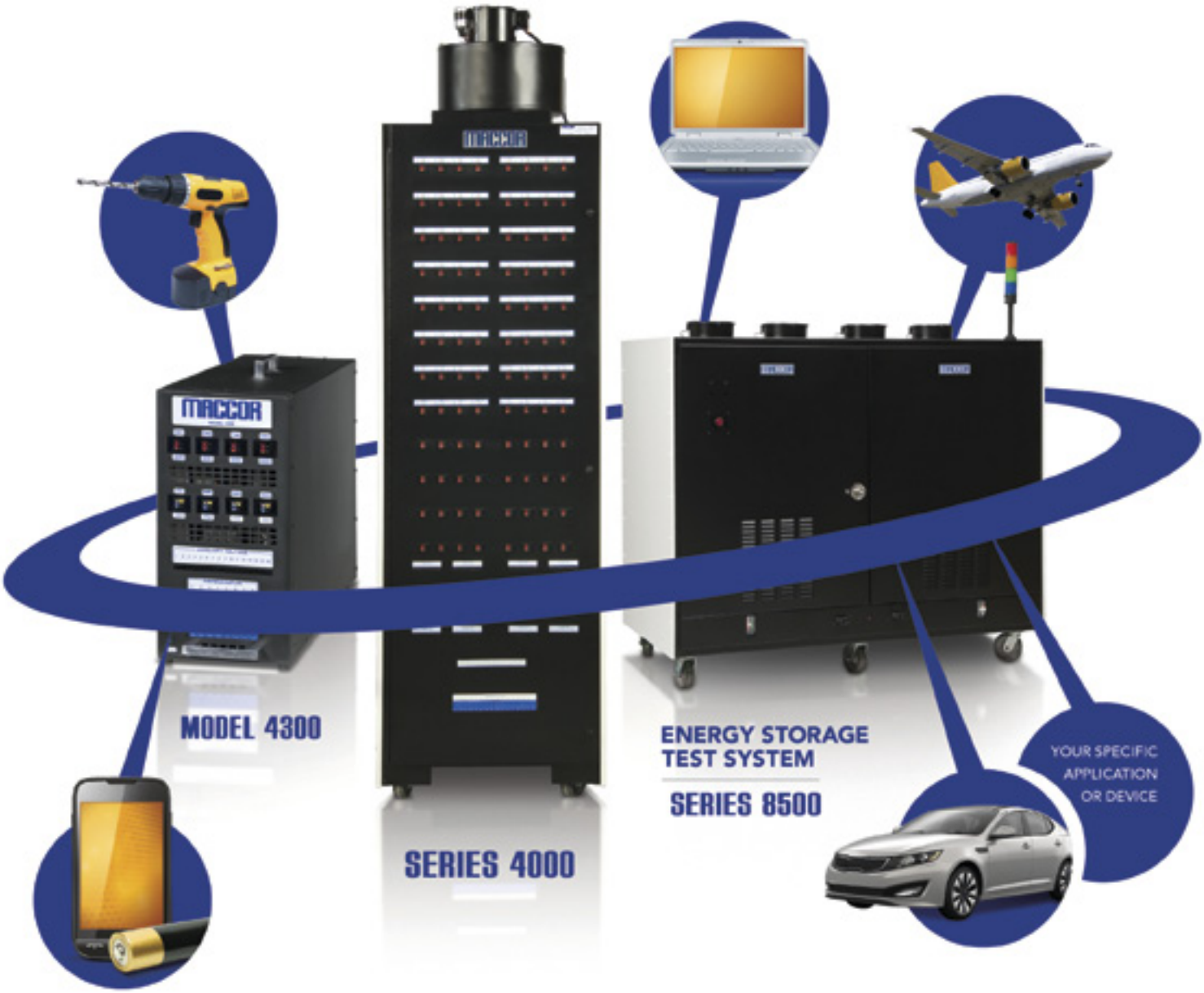

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Supercapacitors: How to determine voltage ratings

Supercap expert John Miller takes a detailed look at how the voltage rating of supercapacitors is determined. As Miller explores, it is a complicated business.

Electrochemical capacitors, also known as supercapacitors and ultracapacitors, share with batteries the characteristic of being low voltage devices. Like batteries, capacitor cells may need to be connected in series to reach the voltage required in an application. To meet the energy necessary for an application, parallel strings of these series-connected cells will likewise need to be combined.

Simple economics suggests that real benefits would result if those cells were of higher voltage than is presently the case. Fewer of them, for instance, would need to be combined in series to reach a required voltage. Again, a cell on which there is higher voltage will hold more energy, given the voltage-squared factor for energy on any capacitor. And, of course, a system comprised of higher voltage cells will have the total number of piece parts reduced, meaning there are fewer interconnects between cells, the voltage balance system is simpler, and so on.

Any of these factors tends to increase reliability and reduce cost. Further, having higher voltage cells containing higher energy makes it possible for the resulting system to be physically smaller. Such potential advantages gained by increasing the voltage on electrochemical capacitor cells are responsible for the considerable attention this area of research and development has received in recent years.

Let us look for a moment at how the voltage rating of an electrochemical capacitor cell is set. By no means is this voltage set thermodynamically by nature, as is the case with a battery cell. A capacitor operates over a voltage range from oV up to a maximum value, and it is this maximum value that is known as the 'voltage rating' of the capacitor. The voltage rating is set by the life desired for the capacitor. Electrochemical capacitors do not catastrophically fail if taken above their voltage rating.

Today's popular commercial 2.7V rated capacitors can operate for short times with 3.5V applied, e.g. hours to tens of hours at 65°C; for longer times with 3V applied, e.g. tens to hundreds of hours at 65°C; for still longer times with 2.7 V applied, e.g. ›1,000 hours at 65°C. At still lower voltage and/or

Some examples of commerical supercapacitor technologies

temperature, these products can generally operate reliably for many tens to several hundreds of thousands of hours.

Improving performance of supercapacitors

Generally capacitors do not wear out by cycling, as is typically seen with batteries, but rather capacitors wear out from the cumulative stress associated with being held at a high charge state. Minimum stress occurs in the uncharged state, i.e. 0V, and maximum stress in the fully charged state (at the voltage rating). Thus, the voltage rating is ultimately set by the life expected from the capacitor.

Electrochemical capacitor life performance standards have increased significantly since these types of products were first introduced 36 years ago. Today life standards ultimately establish the voltage rating. The typical allowed maximum performance change of an electrochemical capacitor when held for 1,000 hours at the rated temperature and rated voltage is a 30% capacitance decline and a doubling of the series resistance. Some manufacturers specify this same level of performance change after the more strenuous 2,000 hours of aging at 65°C at rated voltage.

Symmetric electrochemical capacitors, the most popular type now commercially available, have two identical electrodes that are each nearly 'ideally polarizable'. To be ideally polarizable means here that there is absolutely no electron transfer across the electrode/electrolyte interface at any applied voltage. And because of this, charge storage is strictly physical; there is absolutely no chemistry in the device to store charge.

In practice, ideal polarizability is limited to a rather narrow potential window near the 'rest potential' of an electrode, which is the potential of the electrode in the electrolyte with no applied charge. With a potential across the interface, either positive or negative, electron transfer is more likely to occur than with no potential. Higher potential produces more electron transfers.

The exact potential at which an electrode loses its ideally polarizable nature is difficult to predict since a typical system

is comprised of many different materials including unknown trace impurities, all of which can strongly influence that exact potential. Every material in the system must be stable within the range of applied interface potentials and that includes the electrode, most often activated carbon; the electrolyte, often a non-aqueous solvent with a quaternary ammonium salt; as well as the separator, current collector, binder, conductivity enhancer, and packaging materials.

Trace impurities may include water, transition metals, and oxygen, not to mention chlorine or other similar elements inadvertently added during manufacturing. Impurities may also be reactants of the primary materials created by either chemical or electrochemical reactions, alerting us to the fact that certain impurities need not be there from the start but are formed over the life of the capacitor. HF (hydrogen fluoride), for example, is one such impurity formed during electrochemical capacitor operation that is reported in the literature, which is from residual water reacting with the usual electrolyte negative ion BF_4.

Everything in the capacitor in contact with the electrolyte should be considered part of the material system and capable of causing chemistry. This in general happens as the potential across the electric double layer approaches the decomposition potential of the electrolyte.

Electron transfer, measured by leakage current, will increase as the capacitor voltage increases until, at some applied voltage, the electron transfer rate begins to grow at a much more rapid rate, which indicates that another process or a second mechanism has kicked in, which then begins to dominate the electron transfer process. This second mechanism is nothing more than chemistry, occurring in a device designed for physical rather than chemical charge storage.

One example of such chemistry might be the onset of corrosion of some material at a specific potential. Once the device is charged to that potential, corrosion begins with an associated leakage current. And of course, corrosion is

an irreversible process that does not store charge.

These sorts of chemical reactions impose a practical limit on the potential that can be applied across an electric double layer. Ultimately, they are what often establish the voltage rating of an electrochemical capacitor.

Determining voltage rating

Increases in temperature also generally decreases the voltage rating of an electrochemical capacitor, which occurs through reduction of the ideal polarizability of the electrode/electrolyte interface. All practical electrochemical capacitors operate under slight non-ideal conditions meaning charge storage is nearly but not precisely 100% reversible. Some very small amount of the current is consumed by chemical reactions, which may generate gas.

In a sealed package, the generated gas creates the problem of pressure build-up, and if gas generation continues long enough, this may lead to package rupture. Thus at a given temperature, the time to package rupture is set by the voltage, i.e rate of gas-generating chemical reactions, the purity of the materials, and the package 'dead volume', i.e. void available to hold generated gas.

This brings us to the question of how to determine the voltage rating. How does one go about establishing the voltage rating of a new electric double-layer capacitor material, for instance a new ionic liquid electrolyte?

First, keep in mind that multiple materials within the system demand our concern. The electrolyte is not used, after all, in isolation but in combination with the material of the electrode and with that of other components like binders, conductivity enhancers, separators, current collectors, and trace impurities.

Often an electrolyte measured by itself in a laboratory will show stable operation over a very wide potential window, say 4.5V.

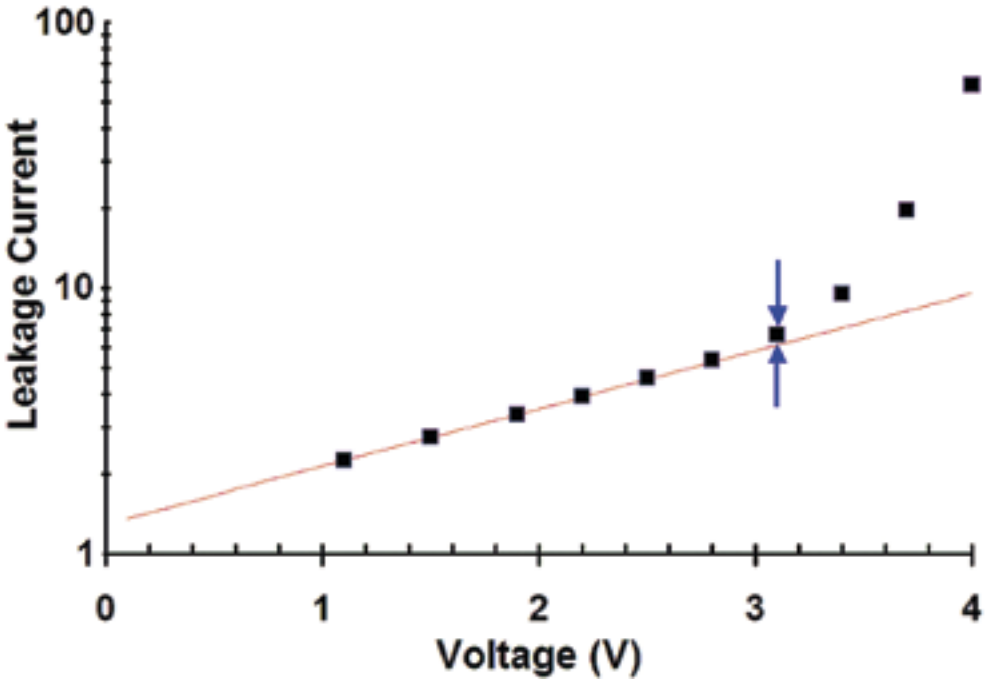

Figure 1 *Hypothetical leakage current versus applied voltage, low voltage data is represented by the red line*

But once carbon is added to the system, the stable potential window decreases to, say 3.3V. Because the rest potential of the carbon in the electrolyte is not at the exact centre of the potential window for stable operation, the voltage often needs to be reduced even more, say to 3V.

Further, to meet life expectations an additional voltage reduction may be required, say to 2.7V. The bottom line is that an electrolyte that first appears to show the promise for 4.5V operation may actually prove to be able to provide only very pedestrian 2.7V operation.

Is there, then, a reliable way to establish the voltage rating of a particular material system? The literature, unfortunately, is full of well-intentioned but poorly thought-through answers. Cycle test results, for instance, are often reported as demonstrating voltage rating, but this is perhaps one of the least sensitive approaches possible.

A publication might report performance fade after 100 charge/discharge cycles or, for that matter, after 1,000, or even after 10,000 such cycles. When the performance fade is small, say 5%, the conclusion is often drawn that the material system is stable at the upper level of the cycle voltage. But this is not correct.

Consider, for example, an electric double-layer capacitor cell that is cycled at room temperature between 0V and 3.5V for 10,000 cycles using a one-minute period. Assume that this device experience only the small capacitance fade of 5% as result of the cycling.

A simple calculation yields the total test time for the 10,000 cycles as 167 hours. So the time spent in the upper 20% of the voltage range during cycling (above 2.8V) would be 20% of this time, or 33 hours. The industry standard

requires 1,000 or 2,000 hours of continuous operation at the rated voltage while at 65°C. This example with a 5% capacitance loss at room temperature after only a few tens of hours in the 2.8 to 3.5V range hardly compares with the industry standard that requires aging with the rated voltage applied for at least 1,000 hours.

The cycling that one sees so often in the literature does not demonstrate a voltage rating at all. One needs to impose 1,000 or 2,000 hours of ageing at the rated voltage with a loss in capacitance of less than 30% to demonstrate that voltage rating. This means that one must be very patient, since such ageing takes a very long time, either 42 or 84 days.

Is there anything that can be done to accelerate this? Accelerated aging is, of course, possible, which involves ageing at a higher level of stress (higher voltage and/or higher temperature) to reduce the ageing time below the normal 1,000 to 2,000 hours. But great care must be exercised so as to not introduce new failure mechanisms and their concomitant misleading results. Accelerating ageing works, but only under the condition that unwanted new failure mechanisms can be rigorously excluded.

Quicker, faster?

Are there other ways to determine the voltage rating more quickly? Yes. Rather than a month or more of aging, one can in a single day examine the leakage current as a function of applied voltage. Although this is an indirect measurement of the voltage stability range rather than a demonstration of operating performance, it can help to substantially reduce the test time (single day versus 42 or 84 days of aging).

However, in place of determining a definitive voltage rating value, this approach provides an estimate of the upper value for this parameter. A strong feature of this approach is that it allows comparisons to be made and rankings among many different material systems, for instance a group of electrolytes or a group of electrode materials. Long-term ageing will still be required to demonstrate compliance with

industry standards.

In considering leakage current as a function of applied voltage, remember that for a polarizable electrode the logarithm of the leakage current increases linearly with voltage, but only up to a point where it then starts to increase at a more rapid rate. This behavior is well founded in electric double-layer capacitor theory, and it is observed in all symmetric electrochemical capacitor devices regardless of size, design, or materials of construction.

Deviations from straight-line behavior in this semi-log plot begin at a voltage at which some second mechanism becomes active that creates leakage current, for instance a Faradaic process. The second mechanism suggests the onset of irreversible processes. These must be avoided in order to have long life so the 'onset voltage' will generally be above the voltage rating of the capacitor.

Figure 1 shows hypothetical leakage current data plotted in this exact form, a semi-log plot of the leakage current versus applied voltage. Low-voltage data is well represented by a straight line shown in red.

In the figure a red straight line is drawn over the low-voltage data points. Notice the data fall on the line up to about 2.5V and then begin to deviate above the line as voltage is increased. This is a semi-log plot and as such any deviation from the line is significant in terms of absolute percentage. Looking at the figure, stable operation, i.e., long life, is only possible when capacitor operation is restricted to the linear region. The arrows in the figure are set at a voltage where the leakage current value is 7% above the straight line, a very substantial amount and well above the value necessary for stable, long-term operation.

The leakage current approach is fast and most useful for comparing the performance of groups of materials. Data to create the plot is simple to obtain. A fixed voltage is applied to the capacitor for a period of time, e.g., two hours, and the current is recorded. The voltage is then increased to a new value for the

same period of time, two hours, and the current recorded again.

This is repeated again and again until the leakage current versus voltage behavior is recorded. The resulting data, when presented in a semi-log format, will resemble data in the figure, with a linear low voltage region and an upward trending high voltage region. Capacitor voltage rating will be in the linear region.

One final comment needs to be made about electrochemical capacitor voltage rating. As initially mentioned, higher voltage cells are certainly something we want, for all the reasons cited. But higher voltage does require higher purity materials. We cannot, however, turn a blind eye to the fact that there are practical limits to the voltage rating given that even using materials with the highest possible purity, there will always be trace quantities of water present in any high-surface-area electrode material as is commonly found in electrochemical capacitors. Although a material system may be found to have a voltage rating well above 3V, the 3V value may turn out to be a practical upper limit based on electrode drying time.

In summary, the voltage rating of an electrochemical capacitor is not set by a fundamental property of the materials but rather by meeting established life performance standards. The capacitor industry life standard requires continuous application of the rated voltage at 65°C for 1,000 or 2,000 hours. Allowed capacitance fade is 30% and the series resistance increase two-fold.

Periodic short-term excursion to some high voltage level, as seen with cycling, does not demonstrate a rating at that upper voltage level. Continuous and steady application of voltage is mandatory. Finally, a quick approach based on leakage current measurement was described that can be used to compare potential voltage ratings of different materials. Nevertheless, 42 or 84 days of aging is still needed to demonstrate the voltage rating per industry standards.

26 – 28 August

The 6th China International Battery Industry

Shanghai, China

The China International Battery Industry Fair is the premier showcase of advanced battery and ultra-capacitor technology. With around 500 exhibitors networking with the vendors and professionals in the huge exhibition hall, this is a great experience to meet and greet representatives of the Asian and worldwide battery industry.

Info: www.chinaexhibition.com

16 – 18 September

The Battery Show

Detroit, US

The event showcases the latest advanced battery technology in the exhibition hall and technical speakers in the conference. This event will display the latest in advanced battery solutions for electric & hybrid vehicles, utility & renewable energy support, portable electronics, medical technology, military and telecommunications. It is co-located with the Electric & Hybrid Expo.

Info: www.thebatteryshow.com

24 – 26 September

Batteries 2014

Nice, France

The three-day conference and exhibition will address issues relating to all battery chemistry types. Topics will include market issues and trends; raw materials; stationary storage; R&D; safety and regulations; automotive applications; battery management and testing; and manufacturing issues, which affect the industry.

Info: www.batteriesevent.com

30 September – 2 October

Energy Storage North America

San Jose, US

During this conference and expo, the visitors will hear from leaders at the forefront of energy storage deployment and planning. The 2014 programme focuses on the convergence of transportation, distributed, and utility-scale applications. The concurrent tracks will offer attendees a deep dive into the market structures, the policies powering them, and the opportunities to integrate projects of all sizes on the grid.

Info: www.esnaexpo.com

9 – 12 September

European Lead Battery Conference

Edinburgh, Scotland

The 14th European Lead Battery Conference will provide an opportunity to meet colleagues from the global industry to hear the latest developments and technical advances in lead-acid batteries with a heavy focus on emerging automotive technologies and renewable energy systems. Featuring technical presentations and an extensive exhibition of more than 100 suppliers of materials, equipment, technology and machinery. ELBC is a first-class conference in the lead-acid battery industry.

Info: www.ila-lead.org/conferences

24 – 26 September

19th International Congress for Battery Recycling

Hamburg, Germany

The three day event provides delegates with an update of battery legislation in EU and worldwide. Topics will include safety issues & transportation regulations; recycling efficiency; the future of LEV, EHV, PEHV and EV battery systems; lithium-ion batteries; country reports on collection and recycling; and the best available technologies for battery recycling. The congress is an ideal platform to exchange information, meet business partners and to access new potential clients.

Info: www.icm.ch/icbr-2014

28 September - 2 October

INTELEC 2014

Vancouver, Canada

The theme of this year's conference is "Resilient Communications Energy for our Connected World". Topics include powering through disasters, high voltage DC power systems, advanced energy storage systems and many others that are critical to operational success.
The conference will also include tutorial sessions and an industry exhibition. At INTELEC 2014 you will be able to engage with global leaders and experts in topics such as powering through disasters, high voltage DC power systems, advanced energy storage systems and many others that are critical to operational success.

Info: www.intelec2014.org

6 – 8 October

Battery + Storage 2014

Stuttgart, Germany

Battery + Storage is a conference and trade fair aimed at speeding up the change to alternative energy sources. It addresses all players involved in the manufacturing of battery and energy storage systems for mobile and stationary implementation— from raw materials to turnkey battery systems.The target groups include trade visitors from the storage system manufacturing industry, service providers, researchers and representatives of end user industries, including the electric mobility, energy supply and electrical engineering industries.

Info: www.messe-stuttgart.de/en/wes/visitors

8 – 10 October

Africa Electricity

Johannesburg, South Africa

The Africa Electricity Exhibition and Conference showcases a wide range of products and services from the power, lighting, new & renewable, nuclear and water sectors in southern Africa. Africa Electricity, now in its fourth year, has become the place for energy professionals to network, learn, source solutions and do business in southern Africa. The exhibition will take place in the heart of the vibrant South African capital, Johannesburg, making the exhibition easily accessible for domestic and international visitors.

Info: www. africaelectricity.com

16 – 17 October

5th Annual Green Mobility Convention 2014

Beijing, China

GreenMobility 2014 will feature speakers from Asia-Pacific and around the world discussing green mobility issues with 300 international delegates from all areas of the green mobility industry.
Discussions and presentations will include national policy guidance on vehicle development; battery development; EV commercialisation and industrialisation roadmap; advances in EV technology; OEM's strategies; infrastructure for EVs; and rapid charging.

Info: www.cdmc.org.cn/2014/gm

28 – 30 October

Power Nigeria

Lagos, Nigeria

Power Nigeria is a showcase for the power and energy industry including power generation, transmission & distribution, lighting; new and renewable energy; nuclear energy; and water. It is a prime place to source new suppliers; network with industry professionals; and learn about new products from experts in the free technical seminars.
This is the place to witness the latest technological advancements in power, electricity, energy, lighting, water, nuclear and renewable energy sectors to find out how they can help your business.

Info: www.power-nigeria.com

11 – 14 November

Electronics Recycling Asia

Singapore

As a major producer and exporter of electronic goods, recycling in Asia is a hot topic. WRF 2014 Asia will examine global strategy for the recycling of electronics. Discussions will include the latest in recycling plants; the best available recycling technologies; metal and scrap trading; information on how to recycle hazardous scraps and recycling batteries out of electronic scrap.
There will be optional tours to local recycling facilities and workshops on latest standards for recycling.

Info: www.icm.ch/wrf-2014

14 – 17 October

InterBattery 2014

Seoul, South Korea

InterBattery is Korea's only trade show for the secondary-cell and rechargeable battery industry, organized by the Korea Battery Industry Association and Coex. This exhibition has been designed with the industry needs in mind to see first-hand the latest global trends and buyers in the field. The show incorporates the entire industry from batteries for portable products up to large energy storage systems and automobile batteries, with an expo dedicated to smart grids.

Info: http://interbattery.or.kr

Nice, French Riviera

14·ELBC
Edinburgh • 9-12 September 2014

14th European Lead Battery Conference and Exhibition

Edinburgh | Scotland | September 2014

REGISTRATION IS NOW OPEN

The International Lead Association is pleased to announce that the 14th European Lead Battery Conference (14ELBC) and Exhibition will be held at the Edinburgh International Conference Centre, Scotland on 9-12 September 2014.

14ELBC will provide an ideal opportunity for anybody involved with the global lead battery industry to review and discuss the most recent technical advances associated with lead-acid batteries, especially in the areas of emerging new automotive and renewable energy systems.

Technical presentations at the Conference will bring delegates right up-to-date with the latest research and development information from around the globe, and will be of keen interest to both manufacturers and users of lead-acid batteries, as well as to the scientific community. An extensive Exhibition – expected to involve over 100 exhibitors – by suppliers to the industry of equipment, materials and technology, will also take place.

Since the first meeting in Paris in 1988, the European Lead Battery Conferences have developed a reputation for high quality presentations on the design, manufacture, performance and use of lead-acid batteries. Over 600 delegates and 100 exhibitors attended 13ELBC in Paris in 2012, and similar numbers are confidently expected in Edinburgh.

Please visit: www.ila-lead.org/conference/14elbc

14ELBC Conference Secretariat:

Maura McDermott
International Lead Association,
Bravington House, 2 Bravingtons Walk, London N1 9AF United Kingdom
Tel: +44 (0) 20 7833 8090 | Fax : +44 (0) 20 7833 1611 | E-mail: 14elbc@ila-lead.org

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14eEBC
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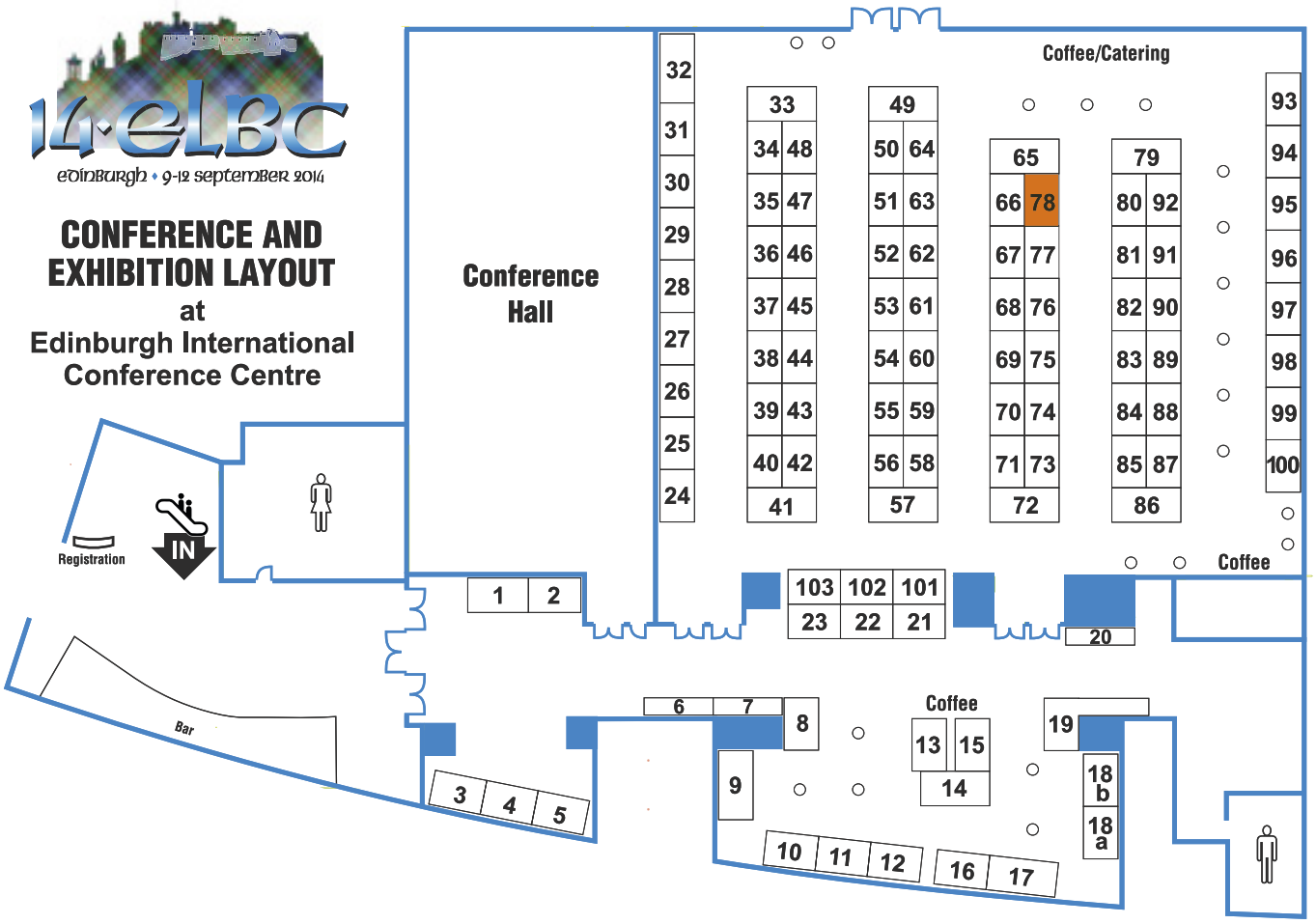
CONFERENCE AND EXHIBITION LAYOUT
at
Edinburgh International Conference Centre



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Where lethal voltages and rhetoric pass harmlessly to earth

Bored in the USA

It's easy to be bombarded by news 24/7, 365 days a year. The *Scribe* gets his fix from UK national broadsheet newspapers– one from the left and one from the right– usually on an hourly basis in working hours.

Then there are Reuters and all the other newswires Energy Storage Publishing has at its fingertips. For personal edification, there's an endless number of TV and radio channels in the UK.

Brits like your *Scribe* are notorious snobs about US TV news, in fact US TV 'period'. Indeed, when locked away in American hotels, your *Scribe* rarely turns on the TV. Hotel room screens are now just portals to any number of paid services (cough!), while finding real broadcast TV is a battle in itself.

The only news I could find on TV concerned the rightful removal of a racist owner from control of his basketball team and perennial US tornadoes. All coverage of the coming conflagration in the Ukraine was non-existent. All this is by way of a pre-amble to losing trust in the news services one once trusted— like the BBC.

Your *Scribe* stumbled across a BBC radio documentary through the Internet concerning the future of the battery industry in a series with an excellent reputation— BBC Radio 4's In Business.

You could almost predict the synopsis: the concerns that battery technology is not keeping up with advances in computer power and smart phones, the demands of the EV industry and inevitably, large-scale energy storage.

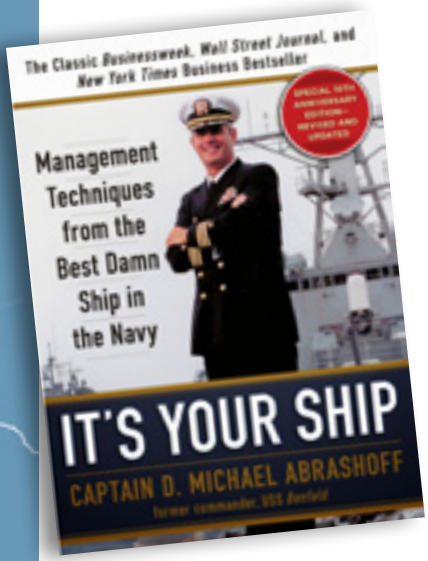
The themes were correct but the 'experts' interviewed were poorly chosen. A manager from Tesla's sales operation in London— yes, London of all places; a gadgets reviewer; a materials expert in from the University of Cambridge; and the inevitable 'out on the technical edge' Israeli concern, which hasn't made a single working battery.

Not a single opinion from one real battery maker, be it lithium-ion or lead-acid or anything else— in the USA, Korea or Japan. No battery maker was willing to speak, presenter Peter Day said. Appalling! Yes, it smacks of low budget programme making with researchers in short trousers, but these days, you can do all the interviews on Skype.

The result was shameful but who is being shamed, the programme makers or the industry?

The *Scribe* thinks a bit of both. And a lot of the blame goes on the p*ss poor PR the battery industry has always had since this writer has been around it, where obtaining comment or even corroboration of facts in a battery story is as hard as finding truffles with a tame pig. No wonder the electronics and automotive industries and the public has a poor view of the world of batteries.

The *Scribe's* own view of the world of batteries wasn't lifted any higher at this year's Battery Council International (BCI) meeting. Now totally stripped bare of any technical content, it is what it is and the time is ticking away towards the enrolment to the quarter-century club (2021). That's if the Grim Reaper doesn't recycle him first.



This year we learned that 'good food' is the magic ingredient for improving performance— well, certainly the case if you happen to be in the US Navy, according to *Captain Michael Abrashoff*, former commander of the *USS Benfold*, author of million-selling management guide *'It's Your Ship'* and, last but not least, this year's BCI guest speaker.

Alliterations aside, you'd have thought that obtaining better performance from one's workforce, was lot more challenging than

that. Remuneration certainly helps but there's nothing more demotivating than inferior technology and plain boredom that being ready for action (which hopefully never comes) is likely to entail. Food and conditions in the trenches of World War I didn't improve much over five years— the game changer was **THE TANK**.

One thing Abrashoff alluded to (but never actually stated) is that US military was a conscripted force— in all but name.

To get a well-paid job, you need a good education and the cost of a good education is well beyond the means of many ordinary US citizens. But Uncle Sam is happy to pay, if you don't mind putting your life on the line in return.

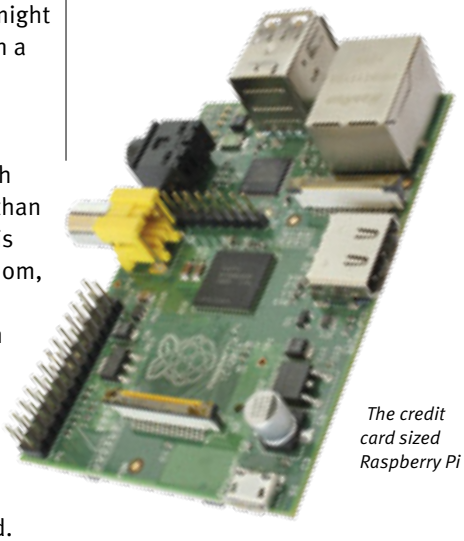
And many have no choice but to take the offer. So the Navy gets a smarter workforce that it might reasonably expect. And the lesson for the battery industry? If you hand out a few scholarships in your recruitment programmes, you might do even better than investing in a gourmet style works canteen!

Pi eyed?

The *Scribe*, entering his seventh decade on the planet, is more than aware that much of what fills his mind, in terms of received wisdom, is out of date. The physics and maths are still relevant (though less used on a daily basis) but the IT and electronics knowledge are fit for a museum— he learned Fortran in 1973 when "Dark side of the Moon" was released.

So in a fit of madness and a desire to think about how to fill long dark winter evenings which will come round again soon, the *Scribe* ordered a Rasberry Pi starter kit.

This little wheeze of a computer was designed to encourage kids to learn programming skills rather than just play games and acquire "office skills", like manipulating spreadsheets. Rasberry Pi is basically a tool to get you to learn Linux and to get this very simple computer to interact with other electronics to do useful things. For less than US$100.00 it's a steal though you do need a monitor and keyboard, a USB hub etc to get started.

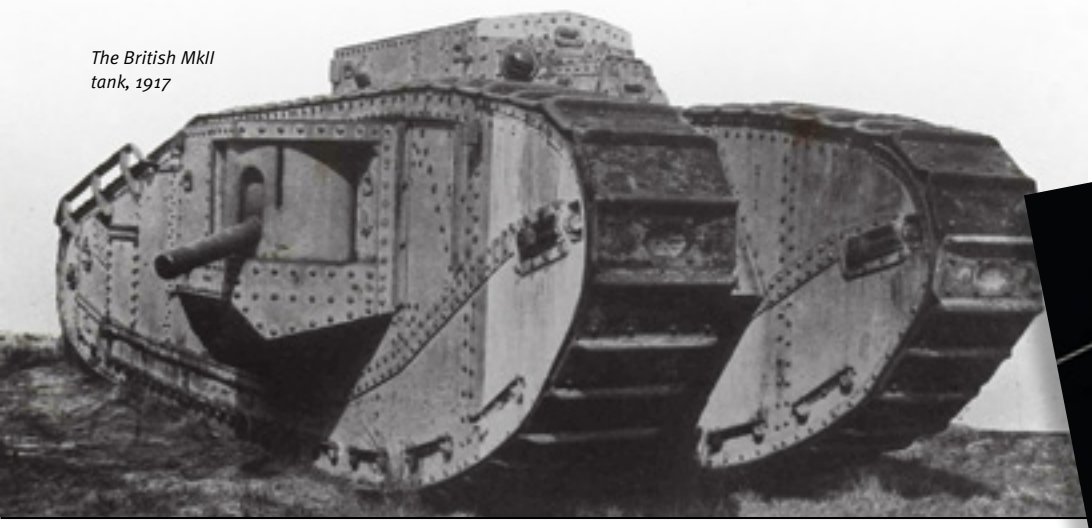


The credit card sized Raspberry Pi

Well you're bound to have those. And what will you do with your Rasberry Pi?

The project scope is endless: build your own drone, home automation. String a load of them together to make your own super computer or battery testing and formation controller? Or perhaps your own wireless triggered IED?

It may take the *Scribe* a while. He's still rustling up the courage to download Linux onto an SD card. Electronics isn't the fun it was 50 years ago. When things went wrong then, bad things happened— smoke, flame and electric shocks. Now when things go wrong, nothing happens: That's why batteries can still be fun!



The British MkII tank, 1917

Pink Floyd's Dark Side of the Moon (1973), Cover art by Storm Thorgerson and George Hardie.

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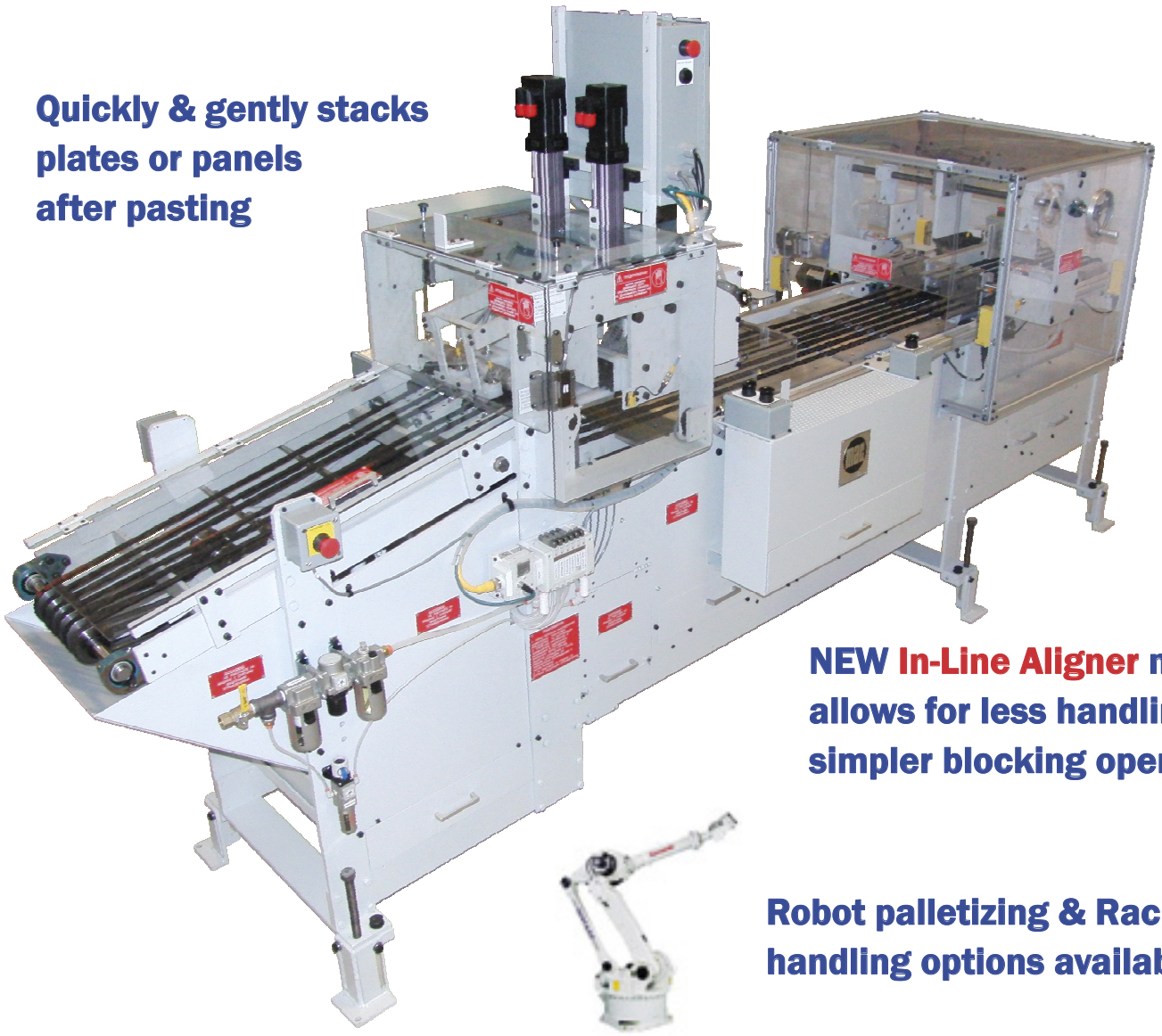

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