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- We're finding out whether they're up to the job.
- Build your reputation— or reinforce a good one
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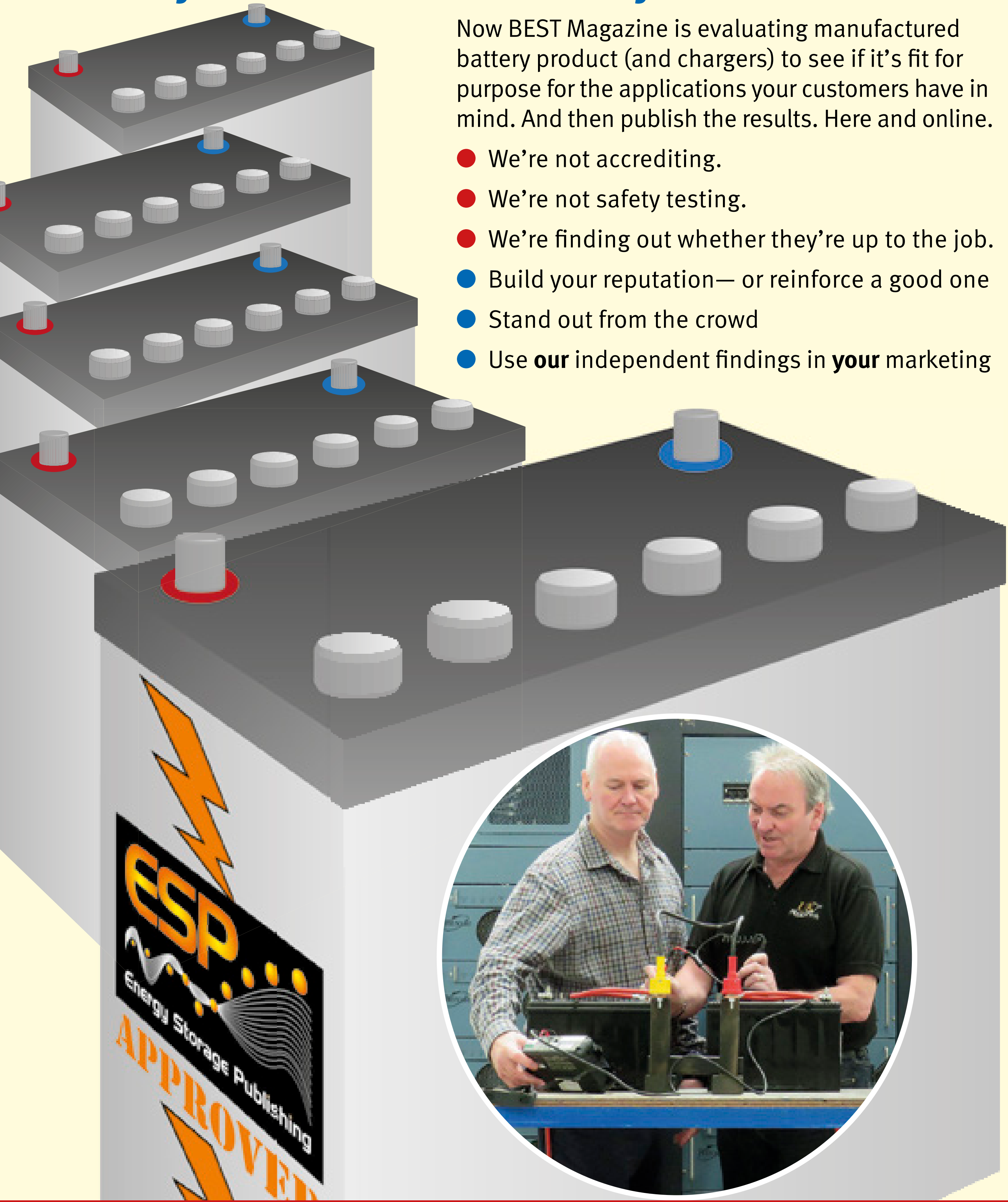


To your customers, many batteries look the same but we know they're not. To find out how you can benefit from this independent service, contact our Technical Editor, Dr Mike McDonagh at mike@energystoragepublishing.com

BEST Battery Review service completes its first lap

BEST's new battery testing service was introduced earlier this year and we reported on the results of the initial stages of our first project in the summer 2018 edition. This article follows on from that report— and completes the Project 1 test schedule.

Project 1

Determination of 12V 100Ah flooded lead-acid monobloc leisure batteries for solar energy storage and comparison with lithium-ion 12V 100Ah batteries.

Since the summer edition was published, we have installed the new Digatron laboratory test equipment. This provides four circuits each with a 150 amp, 32V charge/ discharge capability enabling up to eight 12V batteries to be tested to four different programmes simultaneously. The software enables a full range of scenarios including constant current, constant voltage, constant power charge and discharge programmes, cycle tests, and the use of discharge power to be used for charging between circuits. The data recording includes almost every conceivable variation of electrical energy, including V, A, W, Wh, Ah cumulative and instant data. As demonstrated at the ELBC conference in Vienna in September, we can remotely access and control testing in real time from any part of the globe.

Dr Mike McDonagh demonstrates the remote access and control testing at ELBC for Kurt Gifford, VP of Sales of lead battery terminals firm the Water Gremlin Company

From discussions with readers of *BEST* at ELBC, it became clear that there were some misconceptions about the purpose and nature of our testing service.

To clear up any misunderstanding, the point of this activity is to allow potential battery users to form an opinion on the suitability of products for their intended application. In this case, it was to see how well a battery designed for one application would fare in another. The tests then are simply a way of determining, from a consumer's point of view, how suitable these batteries would be for a particular job. However, to be absolutely clear, **it is not:**

- Accreditation testing.
- Testing to national standards.
- A comparison between different manufacturers' designs or quality.
- Claiming to measure absolute battery performance.

It is:

- A new concept to check battery performance in real applications.
- An opportunity to establish appropriate test methods for particular products in their

working environment with industry professionals.

- A chance to appraise all the battery features including the ergonomics and ease of maintenance.
- The opportunity to get a message to existing and potential customers about the benefits of a particular supplier's design.
- A method of checking the benefits or otherwise of design or material changes to a battery's construction.
- In short it is simply a good marketing tool, which benchmarks a product for its intended application.

A new possibility for the *BEST* battery testing applications was highlighted at ELBC. It was during demonstrations of the test facility in the UK, using a remote link from the supplier stands of UK Powertech that a high degree of interest was shown by battery component suppliers.

Tests are now under discussion with these suppliers to determine the benefits of their products to the performance of various types of battery. This was an unforeseen application of the *BEST* test protocol, but nonetheless an ideal use of the resource. In this case, the *BEST* test team will help to establish suitable test procedures and arrange both laboratory and field trials, to determine the benefits of new battery materials, components or ancillary equipment.

This first project arose from an enquiry from a PV specialist wanting to check the performance and suitability of readily-available and reasonably-priced, lead-acid leisure batteries in a domestic PV arrangement. In addition to testing these batteries, the specialist also wanted to compare performance with that of a cheap lithium iron phosphate battery available on the Internet from China ***(Fig. 1)***.

Fig 1: As received Numax lead-acid and Chinese lithium-ion batteries

After assessing the application and re-reviewing the existing application data, the tests decided on were as follows:

Characterisation of the batteries' performance, namely capacity, ability to absorb charging current and ohmic internal resistance.

Application simulation tests. These were based on an actual PV installation using historical power generation data recorded over the last two years. The two months of December 2017 and March 2018 were chosen as the most suitable periods for the battery comparison tests.

This final report incorporates the previous data from *BEST's* summer edition.

Test batteries:

Four lead-acid: Numax flooded monobloc leisure battery 12V 95 ah (C_{20}) sealed design, lead calcium grid alloy, 500 cycle life. Price: £92 (approx. US$120) per 12 volt monobloc

Four lithium-ion: Unbranded Chinese lithium iron phosphate chemistry, 12V 100 ah leisure battery. Price: £500 per 12V monobloc.

Battery application:
Energy storage from a domestic solar array currently feeding directly into the house and grid supply. The purpose of the installation is to reduce power consumption from the grid at peak periods (5pm to 7pm) and reduce energy bills. Excess energy from the solar panels is diverted from battery charging to the electric immersion heater.

The critical features for this solar application are:

- Availability of power from the solar arrays to recharge the battery.
- Efficiency of energy conversion for energy storage.
- Efficiency of battery charging.
- Battery capacity and discharge characteristics related to the application.
- Speed of battery recharge.
- Current and power draw on recharge.
- Payback and amortisation of batteries based on round trip efficiencies.
- Battery attributes that facilitate their installation and operation from a customer and maintenance perspective.

Test schedules

These fall into four categories for both battery chemistries:

1. **Delivery**: Packaging, external condition, cleanliness

(any acid, dirt, grease etc.), any damage, state of charge, instructions, safety, maintenance and disposal/ recycling instructions.

2. **Design:** Terminal size shape and position, SoC indicators, vents and caps, ease of maintenance, manual handling, weight and dimensions.
3. **Laboratory**: Establish basic performance criteria of capacity, voltage, impedance, DC-IR, charge acceptance, volts drop on load, charge-discharge energy efficiency. BMS characteristics and limitations. Reproduce operating parameters of field tests to predict battery response in the intended application.
4. **Field trials**: Ease of installation and monitoring when installed in their applications. Typical aspects monitored will be state of charge, amount of maintenance, completion of duty cycle, energy balance and efficiency, operating temperature, the duty cycle, customer feedback.

Results

Schedules 1 and 2

Lead-acid

The as-received condition and packaging plus the design features noted on the batteries are summarised in ***Fig 2*** and ***Table 1.***

Packaging-as-received condition:

- The lead-acid batteries were collected at the distributor's premises. There was no packaging.
- Casing was clean with no dust or terminal grease on the lid. The labelling was clear and on straight. Looked solid and well made, overall first impressions were very good.
- The terminals were dual design providing both a lead SMMT automotive terminal and a male 6mm screw thread to provide flexibility for connecting to the appliance.

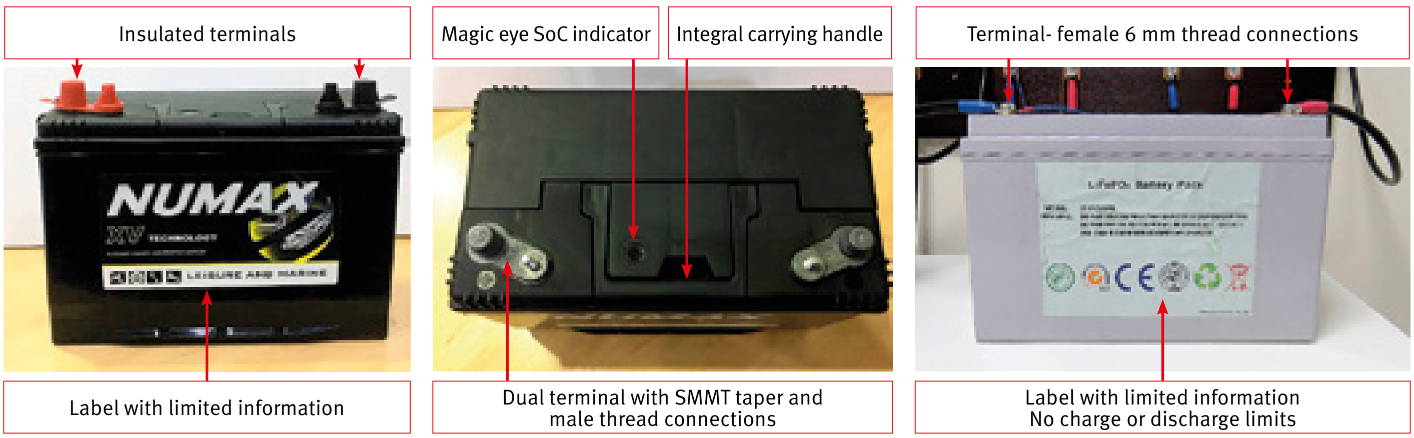
Design features/customer aids:

- Integrated flat carrying handle
- Magic eye electrolyte level indicator
- Dual terminal take off, SMMT taper and threaded male screw.
- Dimensions: 302L x 175W x 220H
- Weight: 21.3 Kg
- Rated energy density (C_{20}): 53.5 watt hours per kilo and 95 watt hours per litre.

Table 1: Battery characteristics

Property	Lithium Iron Phosphate	Lead-Acid
Resistance (milli-ohms)	20	11.2
5 A Discharge time/Wh	20:27/1328	20:47/1258
21 A Discharge time/Wh	04:59/1281	03:52/974
Dimensions (mm)	L340 x W170 x H210	L302 x W175 x H220
Weight (kg)	14.2 Kg	21.3
Wh/Kg	94	59
Wh/l	109	108
Carrying handle	No	Yes
Other user features	No	Magic eye electrolyte level
Performance label data	Operating temperature	None

Fig 2: Lead-acid battery (two pics on left) and lithium-ion battery (right)



Lithium-ion

Packaging-as-received condition:

- Batteries were not packaged and very dusty
- Label not on straight and very crumpled
- Appearance did not inspire confidence in the product.

Design features/customer aids:

- M6 female bolted terminals
- sealed lid
- Complete absence of carrying handles or any SoC device,
- Dimensions: 340L x 170W x 210H
- Weight: 14.2 Kg
- Rated energy density: 84.5 watt-hours per kilo and 99 watt-hours per litre

Schedule 3 laboratory tests

Battery characterisation

These consist of tests devised to firstly ascertain the battery performance characteristics appropriate to the application, and secondly to devise a series of test algorithms which simulate the service conditions for the battery. In these particular battery trials, before the Digatron testing equipment was commissioned, the first of the laboratory tests was conducted using a constant power load from an inverter and results taken using handheld monitoring equipment.

Initial discharge and recharge tests using an inverter and constant power load for lead-acid batteries *(Figs 3* and *4, Table 2)*

These were obtained using a 1.04kW load under similar conditions expected in the field trials. The maximum measured load was 1.04kW and the charging is via a three-stage taper charger rated at 40 amps maximum output. Two batteries were connected in series to provide a 24V, 2.4kWh supply based on a C_{20} discharge rating.

Initial discharge tests

Average current on discharge was 44.05 amps, Average voltage was 23.74V (1.04kW). This represents an average discharge rate of $9C_{20}$. From this we could expect a run time of 0.95 hours compared with an actual run time of 1.5 hours, far higher than expected from the catalogue rating.

Fig 3: Numax lead-acid battery constant watt discharge data from initial report

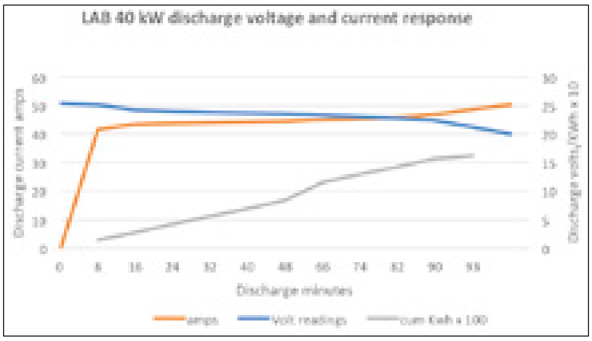
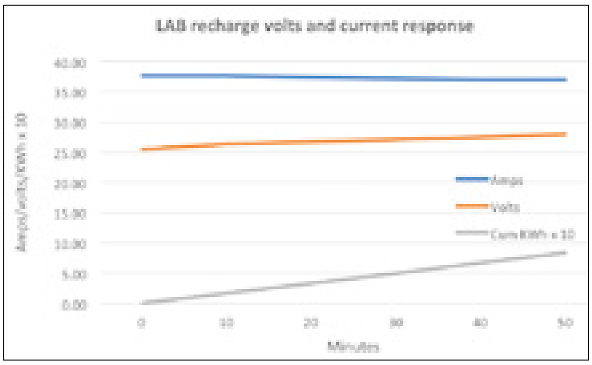


Fig 4: Numax lead-acid recharge data from initial report



Initial recharge tests

The batteries draw the full current output from the inverter/charger for at least 50 minutes, ie, a little under 38 amps. This gives a charge/discharge ratio of around 0.86 with the equipment supplied. This is a high ratio for lead-acid beneficial in this application where recharge time is critical.

The kWh returned are 0.841 in 50 mins compared to 1.63 removed in 93 mins. This represents a 52% return of the energy removed in under an hour. Again, this is a high figure for lead-acid batteries.

Digatron battery characterisation tests

Once the Digatron test unit had been installed, it was possible to conduct very accurate controlled tests to ascertain functioning capacities, level of charge return with time and the batteries internal resistance.

Discharge tests

Results for both chemistries from the Digatron equipment using a constant current discharge mode are given in ***Figs 5*** and ***6***. These are at 20-hour and 5-hour rates respectively, ie, assuming the label rating is for C20 and

Table 2: Test results for Numax lead-acid voltage limited battery recharge data

	Mins					
	0	10	20	30	40	50
Volts	25.40	26.35	26.65	27.02	27.44	27.97
Amps	37.60	37.70	37.40	37.20	37.00	37.00
Cum KWh x 10	0.00	1.66	3.32	4.99	6.68	8.41
Kwh cum	0.00	0.17	0.33	0.50	0.67	0.84

for C5 ampere hour ratings. The reason for this test is to measure the performance of the Numax lead-acid against the lithium-ion battery. In this case the C20 rate is 5 amps to give 100Ah and the C5 rate chosen is 20 amps. Obviously, the lead-acid battery will not give five hours, but this is a comparison test and not a standard capacity test. It is designed to show the different characteristics of lithium-ion and lead-acid chemistries. From the results, it is clear that lead-acid is more efficient over long discharge times, giving a total of 104Ah and 1258Wh compared to the lithium-ion performance of 102 and 1328 for the same tests. For high rate discharges it is clear that lithium-ion has a considerable advantage giving 104Ah compared to 81.2Ah for the lead-acid battery.

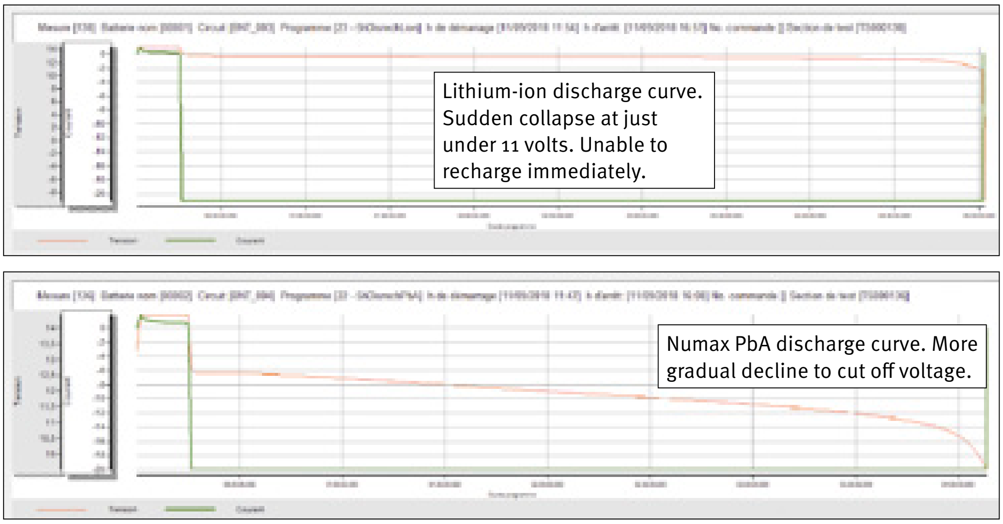
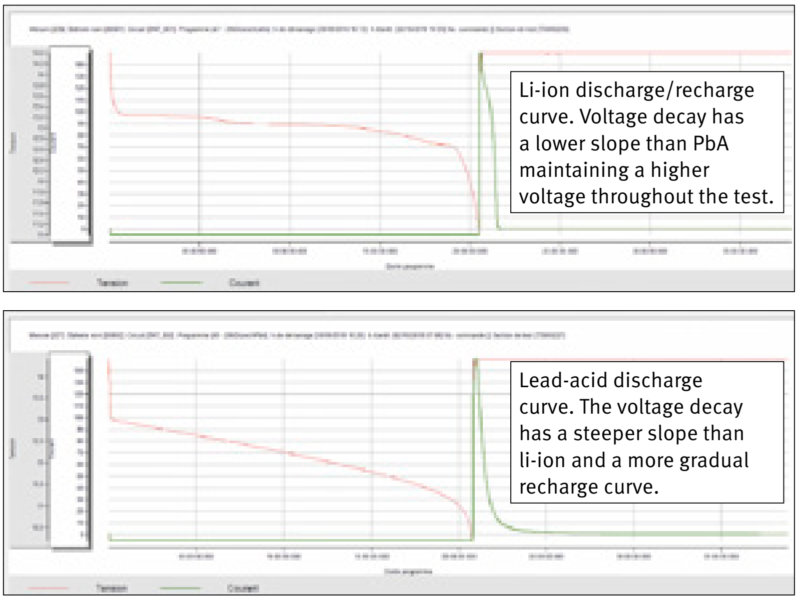


Fig 5: Lithium-ion and lead-acid 21A discharge data

Fig 6: Lithium-ion and lead-acid 5A discharge and recharge curves



“The lithium-ion battery failed suddenly just below 11V and dropped to 3.5V where it stayed. It could not be recharged. Its rest voltage stayed low, fluctuating rapidly between three and five volts”

The lack of discharge information on the lithium-ion label gave an unexpected consequence. Using 2.5V per cell as the cut-off voltage, the end of the lithium-ion discharge test was set at 10V, which is a normal end value for a lithium iron phosphate chemistry.

The lithium-ion battery failed suddenly just below 11V and dropped to 3.5V where it stayed. It could not be recharged. Its rest voltage stayed low, fluctuating rapidly between three and five volts. The solution, as it turned out, was to disconnect the battery and leave it for several days, by which time the voltage had been restored and was stable. The battery could then accept charge and the testing continued.

Recharge tests

These tests are designed to ascertain how quickly a battery will be recharged under the conditions of the intended application. It is not a formal charge acceptance test, but it does give an indication of how quickly a battery can be recharged after a discharge. In this case, the field trials are for a PV solar application where battery charger outputs have a maximum current output, usually between 20 and 80 amps with 50 amps being the most popular. For these tests the Digatron test equipment output was 150 amps. It is not representative of the type of equipment most commonly found in this application, but it does help to give insight into the battery chemistries' relative performance. How much current is drawn and for how long at a fixed voltage is a critical factor in assessing autonomy periods for solar-based applications.

Figs 6 is the 100% discharge and recharge curves for both chemistries. Each figure shows the charge voltage and current response for the two discharge conditions for both lithium-ion and lead-acid batteries. For the 100% discharge both batteries have a high current draw, which initially exceeds the test unit's capability, giving 150 amps as the maximum output. Once the current drops below 150A it is evident that the lithium-ion battery continues to draw a higher current for longer before dropping to 0A when it is fully charged. The lead-acid battery never reaches a full SoC and continues to draw a gradually diminishing current until it reaches a stable state with no current change for an hour.

Internal resistance tests.
The method used is a DC ohmic resistance method.

The Digatron programme contains two discharges at different rates: 50 and 25A. The difference between the rest volts V_r and the discharge volts V_i divided by the current gives the ohmic resistance. Using ohms law $(V_i - V_r) = I \times R$

For lithium-ion: R = 20 milliohms

For lead-acid: R = 11.2 milliohms

Laboratory Application tests
Test algorithm
Fig 7 shows the monthly energy available from the PV panels for 2017. ***Figs 8*** *and* ***9*** give the hourly energy levels for one day in December 2017 and one day in March 2018. These are the patterns chosen to run the cycle tests in the laboratory to compare the performance of the lead-acid and the lithium-ion batteries. The requirement for this peak shaving application is 3.84kWh. In our field trial application there are four lead-acid solar batteries in a 24V, 200Ah series-parallel connection. It is known that the energy input requirement will only be achieved in six months of the year. The battery has six hours or less to take advantage of the available light in the low-light months. The output depends on the usage but will have a peak draw of 2.3kW.

Predictably, December is the worst month for solar energy input, giving less than the output required for the application. March is better but still limited. In this case, the charge efficiency is a key factor in determining the

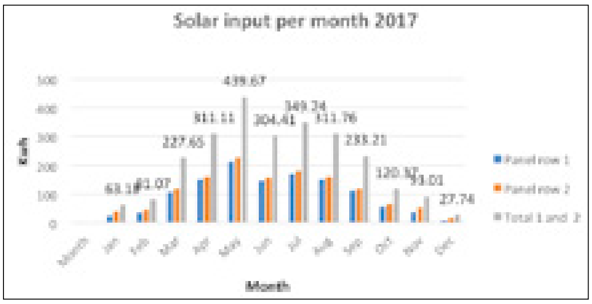


Fig 7: Monthly solar input for 2017 Manchester UK

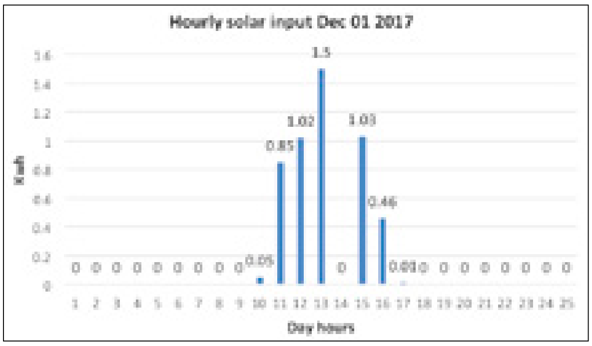


Fig 8: Solar input for Manchester December 2017

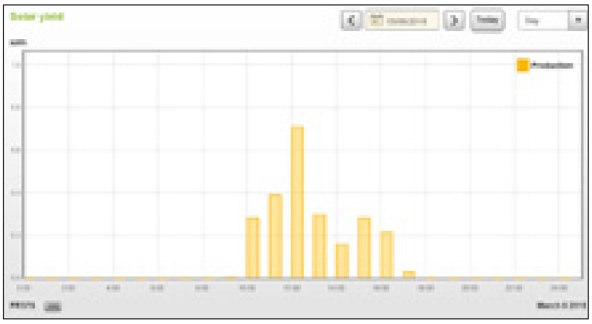


Fig 9: Solar yield March 2018 Manchester

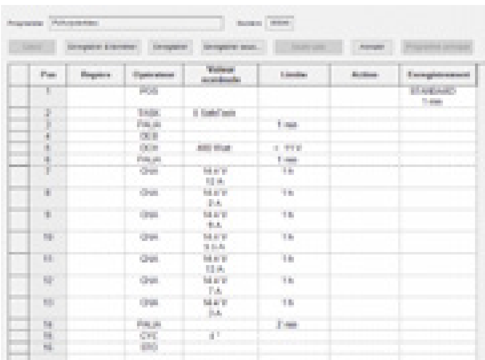


Table 5: Domestic PV simulation for December Manchester UK

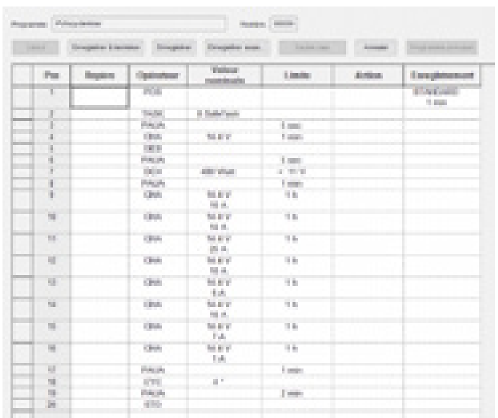


Table 6: Domestic PV simulation for March Manchester UK

run time for the battery. Based on these two actual results, two Digatron programmes were devised for December and March, ***Tables 5** and **6*** respectively. These were used to test the performance of both battery chemistries.

In the simulation tests there is a constant load of 480W for two hours per 12V battery giving a total output requirement of 0.96kWh. This is a high demand but it conveniently gives a faster cycle time and is representative of a domestic peak shaving requirement. The recharge currents are based on a watt input converted to a DC input from the charger to the battery and are variable depending on the SoC of the battery and an upper voltage limit of 14.4V.

Figs 10** and **11 compare the voltage and current responses of both the Numax and Chinese batteries during their charge and discharge cycles for the months of December and March respectively. ***Fig 12*** shows the watt hours given out and taken in by the batteries during the December cycles. This gives a measure of the efficiency of the batteries' charge discharge performance. The efficiency, E, can be calculated from the data as:

E = (watt hours delivered/watt hours absorbed) x 100%

There is a critical aspect to this and that is the fact that the lead-acid battery is not fully charged in either of the two cyclic tests due to the restricted charging voltage of 14.4V. This means that the output gradually declines to a point where the

Fig 10: December cycle tests for lithium-ion and lead-acid batteries

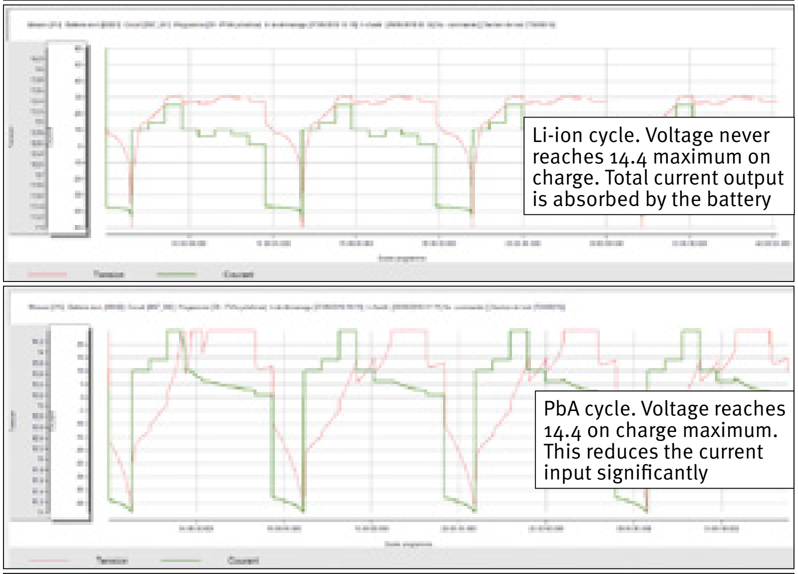


Fig 11: Lithium-ion and lead-acid cycle results March

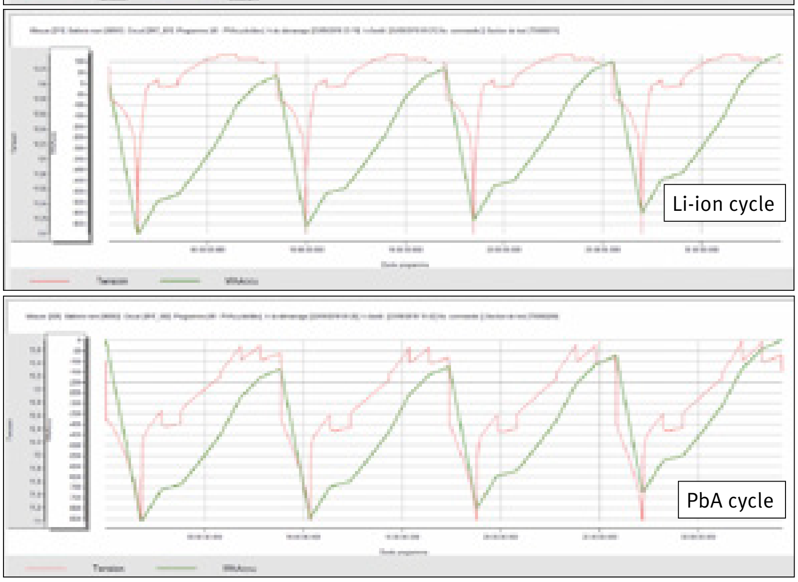


Fig 12: Watt hour balance for December lithium-ion and lead-acid

Cycle	Lithium iron phosphate			Lead-acid		
	Run time	Discharge W	Charge W	Run time	Discharge watts	Charge watts
December						
1	1:27	700	731	1:24	676	724
2	1:27	698	731	1:22	660	724
3	1:27	698	728	1:22	659	723
Efficiency			**95%**			**92%**
March						
1	2:11	1051	1105	1:47	853	984
2	2:11	1050	1104	1:47	859	980
3	2:11	1051	1103	1:47	858	981
Efficiency			**95%**			**87%**

Table 3: Energy balance for Pv cycles December and March

input is more than the output by a factor equal to the battery efficiency as given below:

watts out = E x watts in

From ***Table 3*** it is evident that the lithium-ion battery gives better watt hour returns than the lead-acid battery for both months but has a real advantage in March, where the lead-acid battery's input is restricted by the 14.4V charging voltage, in contrast to the lithium-ion battery which does not reach the limiting 14.4 volts of the charger.

In the case of the December cycle, the output reaches steady state at 669Wh for lead-acid and 698 watt hours for lithium-ion. This translates to run times of 1hr 21 mins for lead-acid and 1hr 27 mins for lithium-ion. This is a difference of six minutes, which is a result of the efficiency difference between lead-acid and lithium-ion in this particular cyclic algorithm. In the case of the March cycles, we see that the better charge efficiency of the lithium-ion again is able to give longer run times than the lead-acid battery, which increases to 24 minutes.

Section 4 Field trial results

Fig 13 is a photograph of the PV solar array that is north facing and ***Fig 14*** shows the power conversion and battery charging equipment. The PV array is 4kW output and the charger inverter supplies a maximum of 4.8kW under voltage-controlled conditions to the battery. The charger was set at 14.4V maximum with a taper profile for both battery chemistries. The controller was set to charge the batteries as priority then divert to heating water when the batteries were full. This is the profile used for peak shaving using battery power for 15% of the house load, in this case, DC lighting, refrigerator and TV— giving a maximum total of 1.38kW for two hours. The battery bank is a 2P 2S arrangement of lead-acid GEL VRLA batteries rated at 12V and 100Ah to give a 24V 200Ah

Fig 13: Domestic PV array

Fig 14: Domestic PV Power conversion and battery back up

or 4.8kWh maximum output when fully charged. The trial batteries were fitted in July with very bright sunshine and almost cloudless days.

The main points to note here are that the average SoC of the lithium-ion batteries was better than 99% while the lead-acid batteries were around 87%. This is despite the fact that the daily input for this period was consistently 18kWh or more. The problem for the lead-acid batteries was the time available to recharge, approximately 12 hours per day with a variable input of between 0.4 and 3.25kW. This had little impact on the run times, the batteries still delivered the two hours autonomy required. However, it has to be said that the full load was not drawn every day and there was no problem for both battery chemistries to meet the full demand.

The user comments can be summarised as follows:

- Both battery chemistries were simple to install due to the bolted connectors.
- The Numax leisure batteries had a handle, which made them easy to lift and move about.
- Handling of the lithium batteries was less convenient due to the absence of a handle, but they were still fairly easy to move due to being half the weight of the lead-acid.
- The Numax batteries did not give off any smell when heated up.
- The Numax lead-acid and the lithium-ion batteries would be suitable for this PV application and able to provide the required two hours autonomy throughout the test period
- More information on the labels of both batteries— in terms of the charge and discharge voltages— would have saved time spent on Internet searches and given peace of mind to the user.

Discussion of results

In line with the purposes of the testing, the discussion will not compare performances to national or international standards. The main focus will be the ability of the batteries to meet the application requirements, and to understand the round-trip efficiency and projected life cycle costs when using these batteries. A comparison is given of battery properties for the two types that are intrinsic to the chemistries, rather than particular manufacturers.

Test schedules 1 and 2 delivery and design

Lead-acid

The visual inspection of the lead-acid batteries showed a well-made product with three useful features: a dual connection terminal, a carrying handle and an optical state of charge indicator. The handle worked well and folded flush into the lid, which ensured maximum flexibility in fitting into tight spaces. The batteries had no leakages when tipped on their side and, visually at least, the lids appeared to be sealed. Fitting the batteries into the application was no problem as the access and space available did not present any challenges. The handles proved useful, as did the bolted part of the terminal connector. These received favourable comments from the user.

There is some concern with the possibility of gas evolution during charging due to it being a flooded design. The specific application chosen had an open well-ventilated area with well controlled voltage limited charging and there was no issue with gas evolution. The magic eye used as an electrolyte level indicator showed that the batteries over the trial period did not need topping up. The weight measured after the tests also showed a negligible loss. In fact, this gave at least a projected five-year topping up interval.

Lithium-ion

First impression of these batteries was not good. The labels were particularly poor with no discharge or charging limits. There were creases in the labels, which had clearly been affixed in a careless way— possibly by the selling agent with no clear idea of the limitations of the design or the internal BMS and control electronics. This would present a serious problem for users whose control electronics may be set to a common discharge value of 1.8V/cell. They could find themselves with an unusable battery after the first discharge. Not the best example of lithium-ion battery technology, but it was the cheapest model using this chemistry, that the testing client could obtain.

Laboratory test results
In the early stages of the test programme, before the Digatron equipment was available, the first simulation tests of the solar application were started using a typical constant power load and an inverter-charger common in domestic solar energy storage. In these tests, the lead-acid battery exceeded the label rating for capacity (modified according to the Peukert relationship) and had good charge acceptance, having drawn the maximum current from the charger for almost an hour. The return in one hour of 0.84kWh of the 1.61kWh removed in the discharge test is a significant result, particularly for those occasions when the battery is not fully recharged in the darker months.

This conclusion was tested when the Digatron equipment was installed. The tests carried out— namely capacity, recharge, internal resistance and application simulation cycles— were designed to measure the ability of the batteries to meet the application requirements. The efficiency of the batteries in providing and absorbing power was also measured by the Digatron equipment, which was programmed to provide the cumulative watt-hours for each programme. In the case of the cyclic PV simulation tests, this provided a measure of the round-trip efficiency for both types of battery.

The first tests, ie, capacity at different discharge rates, gave interesting results for both chemistries. The first notable result was the ability of the lithium-ion battery to give almost the same capacity at the 20-hour and the 5-hour rate. The 100Ah rating was not time specific, this was justified by the results where the lithium-ion chemistry achieved 99Ah at a 5 amp and 98.5Ah at a 20 amp discharge rate. In contrast, the lead-acid battery gave slightly more at 103Ah for the C20 rate and only 78Ah at a 20 amp discharge rate. Whilst it seems to be a poor result compared with lithium-ion, it is in fact a good result for a lead-acid battery whose capacity is highly dependent upon discharge rate.

The recharge results
The ability to meet the required autonomy relies as much on the charge acceptance as the battery capacity. The efficiency with which the battery absorbs energy is critical to obtaining the required energy from the limited solar input in the time available. This holds for the economics as well as successfully meeting the technical requirements. Using the Digatron software, we were able to devise a programme that simulated both the worst light condition and a moderate light condition measured in December and March respectively. There was no issue in the summer months, as both types of battery would be fully recharged. The question was whether or not the lead-acid would be able to absorb sufficient energy to meet the application requirements and how it would compare with the lithium-ion battery.

The December results show that the lithium-ion batteries would give approximately six minutes more run time than lead-acid, ie, 1 hr 27 mins and 1 hr 21 mins respectively. The efficiencies for both of these are calculated from the energy inputs and outputs, which were measured by the Digatron unit.

For our purposes:

Energy efficiency =
(watts out/watts in) x 100%

The lead-acid in this case ***(Table 2)*** was only 3% less efficient than the lithium-ion battery. This difference was less than anticipated, which was largely due to the low SoC of the lead-acid battery during this simulated cycle. The low SoC meant that the on-charge voltage never reached the 14.4V limit, so the level of the current was always at the maximum provided by the charger. The watts are the product of the volts and the amps and in this case the amps for both chemistries was the same and the charging volts for lead-acid were not much higher than those of the lithium battery. What is also interesting is that the lithium voltage was higher than the lead-acid for most of the discharge and fell off rapidly just before it hit 11 volts.

For the March cycle simulation it was a different picture. The higher energy input caused part of the lead-acid cycle to reach the 14.4V charge limitation. When this happened the current input dropped and continued to decline ***(Fig 11)***. This limits the energy absorbed by the battery. In contrast, the lithium-ion never does reach the charger voltage limit, so is able to absorb the full current output of the charger, enabling it to store more energy.

The practical outcome of this is that the lithium-ion battery gives a longer run time than the lead-acid battery. The difference here is increased to 24 minutes compared to the seven minutes from the winter condition. In fact the lithium-ion battery exceeded the autonomy requirement to give 2hrs and 11 mins compared to 1hr 47 mins for lead-acid. The efficiency is also interesting as it stays pretty consistent at 95% for lithium and drops to 87% for lead.

The interesting question at this point is whether or not the run time could be improved for the lead-acid case. If the battery were larger, the DoD would be less and the average SoC of the battery lower. If the DoD and SoC lead-acid could be reduced to the values in the December simulation simply by using a larger battery, then this would give similar efficiency and run time to the lithium-ion battery at a fraction of the cost. It would also increase the cycle life. Again, with the right DoD value, it may match that of the lithium iron design. This question provides a subject intended for a future article based on real experience in a telecoms application. However, it can be applied in this case to estimate the total cost of ownership (TCO) as given below.

Taking the spring test results as representative of the annual situation and making a calculation based on these efficiencies and outputs, we get a TCO as follows:

Cost of batteries + [(energy output/efficiency per cycle) x cycle life x cost of electricity]

“If the DoD and SoC lead-acid could be reduced to the values in the December simulation simply by using a larger battery, then this would give similar efficiency and run time to the lithium-ion battery at a fraction of the cost”

Assuming a cycle life of 750 for lead-acid, this works out at:

2 x (4 x £95) + [(0.98kWh/0.87) x 1500 x £0.16)] = £1,001.13

For lithium iron phosphate we have:

(4 x £500) + [(0.98kWh/0.95) x 1500 x £0.16)] = £2,247.58

The cost of ownership for the 100Ah case is clearly far less for the lead batteries even with a replacement set. The real issue here is that, to give parity with the lithium-ion run time and efficiency, we would only need one set of lead batteries of around 150Ah to give a similar cycle life. However, there is also the added benefit of the increased efficiency due to the lower on-charge voltages. Installing a larger battery bank reduces the TCO for lead-acid batteries from around £1,000 to less than £850. This is a crucial issue for determining the payback on PV installations. The lower TCO shown above makes the use of lead-acid batteries in solar installations far more economically attractive with lower payback periods compared with lithium-based technologies.

A more detailed analysis of this hypothesis, with test results, will be published in future— should funding be available to sponsor a comparison programme.

The purpose of this Project 1 test programme was to ascertain the suitability of the reasonably-priced Numax lead-acid battery for the intended application and to highlight any associated advantages or disadvantages. It was also to make a rudimentary comparison between this lead-acid technology and a low-priced lithium iron phosphate battery bought on the Internet.

In summary we can say:

1. The Numax battery exceeded the rated label capacity.
2. Its ability to absorb charge was high and comparable with more expensive lead-acid versions.
3. The cycle life was not tested, this is mainly due to lack of time and a suitable test regime for this application.
4. The TCO for PV peak storage is very low and will compare favourably with more expensive PV-specific lead-acid batteries.
5. Like any lead-acid chemistry, it could not compete with lithium-ion on charge acceptance or overall efficiency during the spring months.
6. The efficiency difference was small enough to make the Numax lead-acid battery a better financial investment.
7. With a larger Numax leisure battery the efficiency and cycle life would be improved

and still give a better TCO than the lithium-ion battery.

The Numax 100Ah leisure battery is suitable to be used in a solar application both as original equipment and as a replacement option. It performed well under load and gave high recharge efficiencies at lower states of charge in mid-winter. Although cycle life was not tested, its overall performance was comparable with more expensive designs of lead-acid batteries. With suitable sizing, the efficiency and cycle life could be improved to give autonomies and cycle efficiencies close to that of lithium-ion batteries at a fraction of the TCO and the initial cost.

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BEST Battery Review steals show at 16ELBC!

Dr Mike McDonagh 'roadtests' remote battery testing service in Vienna

World-beating battery-testing knowhow was on show in Vienna (September 2018) courtesy of the technical editor of Batteries & Energy Storage Technology (BEST) Magazine, Dr Mike McDonagh.

McDonagh put Energy Storage Publishing's (ESP) UK battery testing lab through its paces– remotely– for visitors to the European Lead Battery Conference, showing how the lab's services can be used to promote and boost battery sales, or supply invaluable feedback on the use of battery suppliers' components in their products.

Thanks to high-tech remote testing software, used in conjunction with Digatron-supplied battery cycling equipment, McDonagh demonstrated how he can programme and monitor batteries undergoing testing at the ESP lab from anywhere in the world– showing clients how their batteries are performing, real time.

"We can now offer a service backed up by extensive industry knowledge and experience, which will provide targeted, tailor-made testing for clients," McDonagh said. "This unique partnership with Digatron will provide the client with accurate results within a couple of weeks."

Among those at ELBC who expressed great interest in the service was Kurt Gifford, VP of sales of lead battery terminals firm the Water Gremlin Company *(left in picture, with McDonagh)*.