

A new Arcona 435 with Lithium batteries installed. We tested 12 batteries from nine suppliers in the 60-120Ah range

# The lithium difference

Prices are falling for 60-120Ah lithium batteries with integral charge monitoring. Emrhys Barrell puts 12 units to the test

**B**oat owners have long relied upon the lead-acid battery to start their engines, run electric lights and, these days, to power inverters to run household items such as kettles, microwaves and more. Yet lithium batteries offer much better performance and lifespan, but at a much higher up-front price. So is it time for you to switch from the 19th century technology to the 21st?

The generally accepted rule of thumb with lead-acid is that your battery pack capacity should be double what you are likely to use in one day, or between recharges. This is because most lead-acid batteries should not be regularly discharged to below 50% of their capacity, or their cycle life will rapidly diminish. Some lead-acid technologies will improve on this, but at greater cost. At the same time the faster you take

power out of a lead-acid battery, the less overall capacity you will get. Typically a battery that will give you 100Ah if it is discharged at 5A, ie over a 20-hour period, will only give you 80Ah if you discharge at 20A, ie over 5 hours, and 50Ah if you discharge at 100A, ie over a

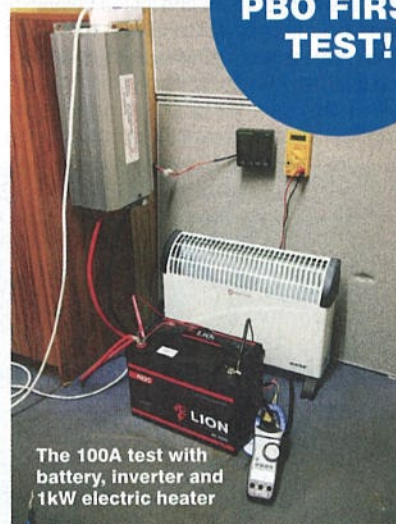
## ABOUT THE AUTHOR



**Emrhys Barrell owns The Thames Electric Launch Company, but has managed boatyards in the UK and USA, as well as a spell in the Merchant Navy. A qualified**

**Naval Architect, he has written many books and edited several boating magazines, and now provides regular equipment test reports.**

**EXCLUSIVE PBO FIRST TEST!**



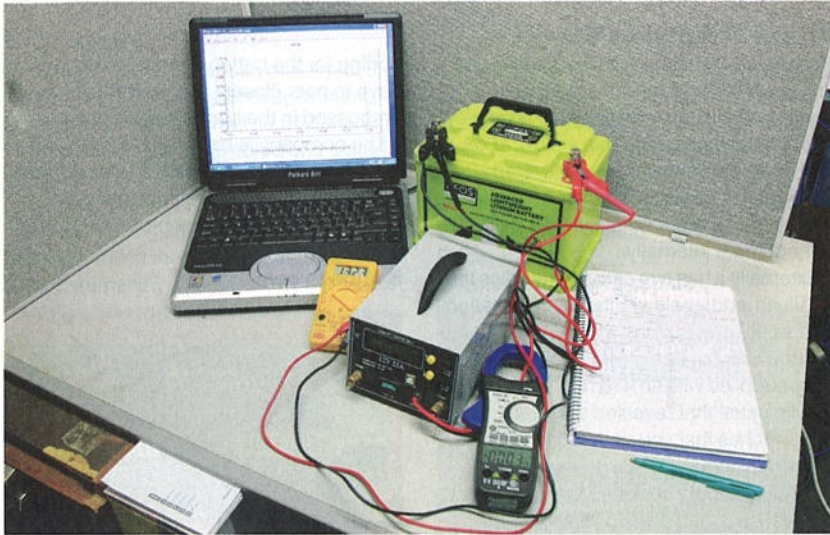
The 100A test with battery, inverter and 1kW electric heater

nominal 1 hour. This becomes especially significant if you are powering an inverter, or driving an electric boat.

Thus your nominal battery capacity will have to be even greater if you are regularly taking out high currents.

In addition, the number of useful cycles any battery will give you over its lifespan is governed by how low you take its charge each time, known as Depth of Discharge (DoD), and how fast you take the power out. The cheapest lead-acid leisure battery on sale in your chandlery will probably give you at best 100-125 cycles at 50% DoD. Regularly take this down to 80% DoD and the figure will drop to 25-30 cycles, at which point you will probably only have 50-60% of the original maximum capacity remaining. If you take the capacity down to 90% DoD – when the lights start to dim – you will probably get 10-20 cycles at most.





The 25A test set-up, with battery, discharge meter, data logger, ammeter and voltmeter

Better leisure batteries on sale will improve on these figures, but usually not by much, and you'll generally have to look to traction batteries, designed to power electric vehicles, to get over 500 cycles at 80% DoD. Deep Cycle batteries from Vetus, and Lead Carbon batteries from DBS Leoch both claim even greater cycle lives.

And the final bugbear with a lead-acid battery on your boat is sulphation. Leave it over winter at 80% charge, and that will become its maximum capacity, no matter how much you charge it up afterwards. Do that two years running and you are down to 60%.



The MK discharge tester takes a constant 25A, and shows the capacity on a screen

Lithium batteries claim to turn all these performance expectations on their head. They claim discharge capacities of nearly 100% even at 100A discharge, and cycle lives of 2000+ at similar discharge currents and 80% DoD.

The aim of our exercise was to put these claims to the test.

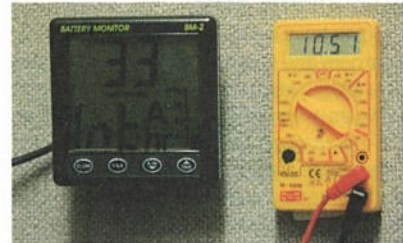
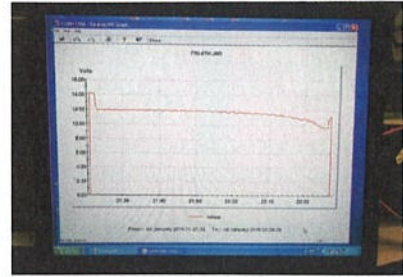
To ensure fairness across the range we charged each battery on test with an approved lithium charger – either the one supplied with it, or with a Victron Smart Charger, or Mastervolt ChargeMaster Plus. We then carried out three measured discharges (with recharging in between each) and measured the Ah they delivered:

1. At 25A – using an MK constant current discharge tester
2. At 100A – by connecting each to an inverter, with a 1kW electric heater plugged in
3. At 150A – as above but with a 1.5kW heater
4. Finally we measured the maximum current they would deliver for 5 minutes, on the



Current was measured with two different clamp ammeters

**BELOW** Almost flat discharge curve for a lithium battery. Capacity (Ah) was measured with a NASA Battery Monitor (bottom left)



grounds that this is what you would use to boil a kettle or power a microwave.

■ Some batteries being tested only had a 90Ah or 60Ah rated capacity, so we only took 90A and 60A from these to test actual performance compared to claimed performance.

■ Some batteries could deliver the 150A, some could not. In all cases it was the

internal battery management system (BMS) that determined when they shut down, with different manufacturers choosing different cut-off points that they thought would enable their unit to deliver the best long-term results and cycle life.

■ The temperature of our test facility varied between 10-15°C. Most makers' stated capacities were achieved at 25°C, so our results were bound to be slightly lower than the claimed figures, by approximately 2-4Ah.

## Lithium: what you need to know

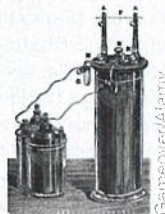
For over 100 years most rechargeable batteries used lead and sulphuric acid, first invented in 1859 by Gaston Plante. Then in 1970 along came lithium batteries which are 50% lighter, with no memory effect, up to ten times the cycle life, and able to give nearly all their rated capacity at even the highest discharge rates.

But lithium does have downsides. The first is cost, at up to four times the price of an equivalent output lead acid battery, and the second is safety. Lithium is a highly reactive metal that reacts violently with water, or even moisture in the atmosphere if the cell

Pictorial Press Ltd/Alamy



Gaston Plante invented the lead-acid battery in 1859



Gameover/Alamy

is damaged, and if it catches fire, using water to extinguish it only makes the situation worse. Using compounds of lithium

significantly reduces, but does not eliminate the fire hazard. Lithium cobalt oxide (LiCoO<sub>2</sub>) has high energy density but greater safety risks especially when damaged. Lower energy but safer compounds include lithium manganese oxide (LiMn<sub>2</sub>O<sub>4</sub>) and lithium iron phosphate (LiFePO<sub>4</sub>). The latter has become the material of choice for moderate performance batteries, and accounts for all the units we tested.

### Lithium construction

The actual battery consists of a multiple pack of basic cells, and







### Sterling AMPS 60 and AMPS 100

Sterling have been supplying battery chargers and inverters for many years and one of their largest markets is emergency vehicles, who use their inverters to power the increasing array of 240V equipment used today. Concerned about the poor performance of lead acid batteries when used at high currents and down to low DoD, they looked for alternatives. Along with the lithium AMPS range they also supply battery-to-battery chargers, enabling the vehicle's alternator to rapidly re-charge the batteries.

The two units performed remarkably well in the 100A/60A discharge test, delivering 119Ah and 77Ah respectively, both 20% above their rated capacities. The 60 maintained this performance at 95A, but the 100 fell away at 150A, only delivering 55Ah. Sterling put this down to the BMS in the 100 cutting off early. The maximum current figures reflected the same fact, with the 60 delivering 120A for five minutes, but the 100 only delivering 160A. Internally they have four prismatic cells each; outside there's a removable carry strap.

Prices: £599 (AMPS 60) and £1,250 (AMPS 100).

■ [sterling-power.com](http://sterling-power.com)

### Super B Epsilon 90

The Super B was the most expensive unit on test, but also one of the best performers. Its nominal capacity is only 90Ah, but it maintained this at 25A, 100A and 150A discharge. It also delivered 190A for five minutes. This will be down to the fact that it has a multi-cylinder cell arrangement internally.

Externally it has two carrying handles that fold flush, and labels with its full specification, and safety precautions. When it arrived the voltage was cut back for transport, but you were supplied with an Allen key to open up a plastic panel that revealed a row of dip-switches that you pressed to re-set it for normal use.

A USB memory stick had the full owners manual on it, and an app allows you to monitor the battery from your phone via Bluetooth.

Disconcertingly there is no colour-

coding for the battery terminals, and you have to peer closely at the symbols embossed in the black plastic case.

The company is based in Holland, and does its own in-house testing for capacity and discharge, with external testing for compliance. The cells come from China.

Price: £1,860.

■ [super-b.com](http://super-b.com)



### Mastervolt MLI-E

Mastervolt is one of the largest companies on the world marine electric power market, with a wide range of chargers, inverters, and batteries. They have had large 24V lithium battery packs for some years now, fitted to many of the biggest sailing yachts and superyachts, but this is their first



self-contained 12V unit. In fact, apart from different colours for the plastic handles, it looks very similar to the Super B Epsilon 90 (above).

Certainly the performance figures are almost identical, and all the same comments about the case and the BMS apply, including the lack of colour coding for the terminals.

Mastervolt say the battery has 240 cylindrical cells in it, and it is built, assembled and tested in the Netherlands.

Both this and the Super B have an identical LED display on the top showing state of charge, and warning you of low voltage, and they both offer you an App to monitor the battery via Bluetooth.

Price: £1,530.

■ [mastervolt.com](http://mastervolt.com)

## Lithium: what you need to know continued...

➔ these can vary considerably in size, and shape. They can be flat in format, known as prismatic, in which case the battery may only have four in total. Or they can be cylindrical, in a 'swiss-roll' format, with strips of anode and cathode rolled together with a separator in between. These cylindrical cells can be remarkably small, around the size of an AA battery for the 18650 size, with the result that an 85kW pack, as used in the Tesla car, has no less than 7,104 of these cells!

The nominal voltage of the lithium-ion cell is 3.2V, which means that multiples of four of these cells give you a battery with a nominal voltage of 12.8V, which

closely compares to the lead acid battery, which has six cells of 2.1V and a voltage of 12.6V. This allows you to make a straight swap of a lithium battery for lead-acid.

### Battery charge management

In order to preserve the expected life of a lithium battery, and to maintain safety, it is essential that it is not discharged below a certain voltage, at a maximum current, and the cells are kept at equal voltages. Also the charge current and voltages should not exceed certain values. For large battery packs in cars this has required a separate and sophisticated electronic

battery management system as well as a purpose-designed battery charger.

The breakthrough with the current new crop of marine lithium batteries is that they all include integral battery management systems, either in the case or as a simple plug-in device, and as a result of this they can be charged with existing chargers.

The only stipulation is that the charger must deliver a maximum voltage of 14.4V, typically a gel lead-acid setting.

However some of the suppliers indicated that if you are going to get the maximum capacity into their batteries, you should use a charger with a specific lithium setting, and some supplied us with one.

Or if the battery is in a boat or motorhome, with an engine-driven alternator, they recommend you fit a

**'The 85kWh battery pack in a Tesla car is made up of 7,104 AA-sized cells'**



## Transporter

Transporter is the European division of the US company Dragonfly Energy, which is big in the recreational vehicle (RV) market. All its products are assembled and tested in the USA.

The one Transporter unit presently available has a multi-cylinder internal make up, using the ubiquitous 18650 cells. Externally it differs from all the others on test in having copper lugs with nuts and bolts for connecting the positive and negative cables, as opposed to recessed thread stainless steel terminals.

Transporter say this gives a better electrical connection and avoids straining the internal connection to the cells if you should overtighten the bolts, or if they should corrode after some years service in a salt-water environment.

It has a removable carrying strap.

It performed well up to 100A, but if the

current exceeded this, even by 1A, after 30 seconds the BMS shut-down, and would not reset until you applied a charge voltage. This is clearly a design decision intended to prevent damage to the battery in the event of repeated long-term overload, but it seems unnecessarily fierce to us.

**Price: £1,195.**

■ [transporterenergy.co.uk](http://transporterenergy.co.uk)



## Victron Smart 100

Victron are another major player in the world portable power market, including marine, off-grid, and back-up power supplies, with chargers, inverters, solar panel controllers and a wide range of batteries. Up until now their lithium batteries have required a separate external



BMS, and the Smart 100 is the same, but we are told new self-contained units are coming out shortly. Internally the cells are of the four large prismatic type, with active continuous balancing. The batteries are assembled in China or Eastern Europe, but the company carries out its own in-house testing.

Externally the unit suffered from no colour coding of the terminals, with just embossed symbols, and had no way of lifting it except a tiny ridge round the top of the box.

Performance was excellent, exceeding its rating at 25A, 100A, and 150A, and delivering 205A for five minutes, and it has a phone App for battery monitoring.

**Price: £1,465.**

■ [victronenergy.com](http://victronenergy.com)

## Relion RB100 and RB100HP

Relion are another US company, with an extensive range of Lithium batteries, 12V, 24V and 48V, all made in China, and new models coming out all the time. They work in all the off-grid markets, and have their own development division.

The two units we had for test vary only in their maximum current capabilities, and as we understand it are similar internally, with multi-cylinder construction, but different BMS settings. This was borne out in our tests, with both delivering close to their rated capacities at 25A and 100A, but the RB100 giving just 82Ah at 150A, compared to the RB100HP's 102Ah.

Maximum currents showed the same difference, with 178A for the RB100 and 198A for the high power version.

The RB100 has a pair of folding plastic lifting handles, as opposed to the RB100HP which has a lifting strap.

**Prices: £1,000 (RB 100) and £1,100 (RB100HP).**

■ [dbsleoch.co.uk](http://dbsleoch.co.uk)



battery-to-battery charger between the engine start battery and the lithium service battery, to give maximum charge rate, while protecting both the alternator and battery from excessive currents.

### The BMS

The Battery Management System (BMS) is the key component of all lithium batteries and battery packs. If the voltage drops below a certain preset level, usually somewhere between 9.0V and 10.0V, or the current goes too high, the BMS switches off an internal relay and the current stops.

If this happens, some manufacturers leave the battery permanently switched off until a charge voltage is applied to it, whereas others allow the battery to reset after a few seconds once the load has been disconnected.

Lithium batteries will require a suitable smart charger



The BMS will also balance the individual cells in the battery – that is bring all the voltages to the same level. This is important for long life.

It will also shut the voltage across the terminals down for transportation.

### Engine starting

None of the lithium batteries we tested

claim to be suitable for engine starting. For this you need a very high current for short bursts – in the order of 200-400A, and they are just not designed to produce this regularly.

### Warranties

The warranty figures quoted for lithium batteries should be treated with caution. Most are based on figures provided by the makers of the cells, and these can often be hedged with caveats, such as tapering replacement values, rather than full replacement, and stipulations about how the battery has been charged and discharged, which could be difficult to prove if you have a claim.

For this reason you should read the small print carefully, and not assume that a unit with twice the warranty period is necessarily twice as good. ➔





**3 Lion 3L-100**

The 3 Lion is supplied by NDS from Italy, one of the largest European players in the off-grid market, with an extensive range of chargers, inverters, solar panels, controllers, and lithium batteries, catering for the RV and caravan market as well as for boats.

Because of this the battery comes complete with a multi-function control box, and display, which takes power from each source – engine alternator, solar panels and charger – balancing the need of the battery, and then distributes it to various outlets, with all functions being shown on an LCD display. This is all included in its price.

Externally the case was similar to several others in the test, suggesting many of them may well come from the same Chinese factory. Positive and negative terminals are colour coded. Internally it has 132 cylindrical cells.

Performance was above its rated figure at 25A, close at 100A, but only 82Ah at 150A. Maximum current was 190A for five minutes.

**Price: £1,299.**

■ [roadpro.co.uk](http://roadpro.co.uk)

**EZA 100 and EZA 130**

French company EZA is another major player in the off-grid, RV market. The 100 has prismatic Chinese cells, but they are assembled in Europe, and have a sturdy metal case compared to the plastic of all the others. The terminals are close together, and you would need to be careful with your spanner when connecting them. The unit has an internal BMS, and an array of LEDs on the top indicating state of charge.

Performance is close to its rated figure at 25A and 100A, but as it does not recommend being discharged at more than 100A we stopped here.

The EZA130 is a very substantial and sophisticated unit, again designed for the RV market, and assembled in France in a metal case. It has two inlet sockets and two outlets, and is designed to be connected to inputs from the engine alternator, plus an array of solar panels and a mains battery charger. The two outlets will



supply normal 12V demands, plus an inverter. Inside it has an integral battery-to-battery charger, designed to be used with the latest vehicle smart alternators, and a solar controller. It has an automatic shut-off that disconnects the battery when not in use for long periods.

Performance was up to its ratings at 25A and 130A, but again this was the maximum it was supposed to be discharged at.

**Prices: £1,299 (EZA 100) and £2,995 (EZA 130).**

■ [roadpro.co.uk](http://roadpro.co.uk) or [eza.fr](http://eza.fr)

**Lifos 68**

The Lifos is new onto the market, and while it was below our target 100Ah, we included it as it could be of interest to the smallest trailable boat, or as power for a small electric outboard. The company has larger models in the pipeline.

It has a neat folding plastic handle, and its terminals have clever brass tapered posts, which can be used for battery cables with clamp ends, or unscrewed for ring connectors.

Internally it has four prismatic cells, and is made in China under licence to Lifos.

Performance was at or close to its rated figures at 25A and 65A, but above 70A it

shut down, in line with its specification.

**Price: £699.**

■ [solartechnology.co.uk](http://solartechnology.co.uk)



**Lithium: what you need to know continued...**

**➔ Lifecycle claims**

We could not verify the cycle life claims of the batteries we tested, but they are all between 2,500-5,000 at 80% DoD, so are unlikely to all be wrong.

Having said that, when we asked the suppliers how they arrived at these cycle life claims, most admitted that the actual battery had not been cycled 5,000 times by them – it would take around 10 years to carry this out – but were based on figures quoted by the manufacturers of the individual cells inside the batteries.

And hereby comes one of the possible issues with lithium batteries. Nearly all lithium cell production is taking place in the Far East, and production standards and safety standards in their manufacture are difficult to verify. While there is an



Dinodia Photos/Alamy

**A report on battery labelling from the UK Government is due out soon**

international standard for Transportation, UN38.3, as far as we can find there are few – if any – internationally agreed standards for battery production.

This is an issue that is concerning the UK Government Office for Product

Safety and Standards. PBO spoke to them during our test, and they confirmed they are looking into the question of all batteries, including lead-acid, but in particular lithium, with regards to safety in use, and claimed performance, and safety when being transported.

They are looking at composition, capacity, labelling and chemistry, and their first report is due out soon. We will keep you updated on their conclusions, but you can look yourself at [www.gov.uk/guidance/batteries](http://www.gov.uk/guidance/batteries).

This is not to say that the batteries we have tested are unsafe, but we would suggest that it is in order for you to ask the supplier of any battery you are thinking of buying to supply you with any relevant test reports supporting compliance and safety.



## PBO verdict

In simple terms, all the batteries on test delivered within 3-4Ah of their claimed maximum outputs at 25A and 100A, with some even achieving this at 150A.

Also as the lithium battery discharges, its voltage remains nearly constant, only falling away during the last 10% of the time. In contrast a lead-acid battery voltage falls in nearly a straight line, so the actual power available in a lithium battery is greater.

However, even though prices are falling, the headline figure for lithium batteries still looks daunting at more than five times the price of seemingly equivalent lead-acids.

But if you get ten times the number of cycles, then the whole-life cost becomes half. And of course there is the reduction in weight. Straight from the box, a lithium battery is around half the weight of lead, but factor in the increased capacity and the weight saving becomes even greater.

### Best buy

We normally try to give a suggested best buy in our tests, but in this case there is no one clear winner, and no single test measurement that we could fairly apply.

For instance the Sterlings give you more Ah for your money, but the Victron, Super B Epsilon, Mastervolt and Relion 100HP give you higher continuous currents.

All the units deliver almost exactly their rated Ah, within our experimental tolerances, but the claimed cycle lives vary. None of these cycle life figures could be verified in our test, and may have been

estimated using different depth of discharges. But in any case all reckon to give you at least 2,000 cycles, which for most leisure users is probably at least 20 years of normal use.

Similarly the prices could vary as soon as retailers start discounting them, and again prices are all moving rapidly – usually downwards – as the market expands.

It is generally agreed that those with multi-cell construction will have longer ultimate lives, but at a higher price, and again this is relative and unlikely to be significant for private use, but could become more important for something like a daily use ferry for instance.

### Worth the money?

So is lithium for you? Well, being realistic, if you only use your boat 10-20 times a year, and just run lights and navigation equipment, then lead-acid still probably wins by being more cost effective.

But buy the best you can find, with a gel-type top of the list. Keep it well charged up and with sensible use it will last ten years.

But once you start going out more often, or running an inverter, then lithium becomes worth looking at.

And bear in mind that new lithium models are arriving, and prices are falling almost by the day.



## RESULTS

Battery	Capacity (Ah)	Continuous current (A)	Max 30 sec current (A)	RESULTS				Cycles 80% DoD	Dimensions LxWxH (mm)	Weight (kg)	Price	Warranty (years)
				Ah @25A	Ah @100A	Ah @150A	Max Current for 5 mins					
3 Lion 3L-100	100	100	100	103	99	82	190	2500	337x175x190	13.3	£1299 <sup>§</sup>	3
EZA 100	100	100	130	96	95	-	100	2000+	320x130x250	15.1	£1,299	2
EZA 130	130	125	195	130	133*	-	155	2000+	380x265x200	25	£2995 <sup>§§</sup>	3
Lifos 68	68	60	80	68	65**	-	70	3700	258x175x200	7.8	£699	5
Mastervolt 90	90	200	350	90	90	88	190	5000	353x175x190	13.5	£1,530	2
Relion 100	100	100	200	99	98	82	178	5000	329x172x223	13.5	£1,000	5
Relion 100HP	100	100	800	103	102	102	198	5000	329x172x223	13.5	£1,100	5
Sterling 60	60	60	120	76	77***	78****	120	4000	260x160x210	10	£599	5
Sterling 100	100	100	200	120	119	55	160	4000	330x215x170	14.5	£1,250	5
Super B 90	90	200	350	90	91	88	190	5000	353x175x190	13.5	£1,860	3
Transporter 100	100	100	200	96	95	-	100	5000	324x173x229	13.1	£1,195	10
Victron 100	100	200	200	104	103	102	205	2500	321x152x197	15	£1,465	2

\*at 130A \*\*at 65A \*\*\*at 60A \*\*\*\*at 95A

§ 3 Lion inc BMS, Link Box and Display

§§ EZA130 inc internal battery-to-battery charger and solar regulator