Are Lithium Batteries for Voyaging?

A look at the practical aspects of these energy storage devices

by Dave McCampbell


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Dave McCampbell built a plywood battery box to provide a container for his boat's new lithium batteries.

If you are full-time cruisers like us, your electrical system, including batteries, is critical to your safety and comfort, so it has to be right. These days, you have multiple options when it comes to constructing your house bank. Some are better than others for a given cruising situation. All should be deep cycle capable, have a lengthy service life, and be part of a well-thought-out electrical system. It's even better if they require little or no maintenance. And all must be understood and treated well or they will give you continual grief and drain your financial resources unnecessarily. Possibly worse, your cruising partner will be very upset if the lights go out!

Some years ago, when purchasing my first real serious cruising boat, a CSY 44, I believed that boat batteries, like those for a car, were basically "plug and play." When the lights go dim or the car won't start, remove the dying battery, attach the positive and negative cables to the new battery, and it's done. I soon learned that there was much more to taking care of boat batteries if I was to have a reliable system and achieve long service life. Now we have much better battery charging, maintenance equipment and protection systems. We also have better deep cycle technology, and at least four common battery type options.

Flooded lead-acid (FLA) batteries are the most common and initially the least expensive. But they also require the most maintenance. They represent original battery technology and have been around since the 1860s. Like almost all lead-acid batteries, they must be fully recharged almost daily. This helps avoid premature failure from sulfation resulting from being left in a partial state of charge (PSOC). They must be watered at least monthly with pure distilled water. Charging current limit is only about 25% of rated capacity, and large loads significantly deplete voltage. They require about 15% more amp hours to be replaced than what is removed under load. However, they are cost-effective for many cruisers, readily available, and their state of health can quickly be checked with a simple hydrometer.

More modern technology includes gelled electrolyte (Gel) and absorbed glass mat (AGM) batteries. Sealed versions of Gel batteries became popular in the 1970s with AGM batteries arriving in the 1980s. Both are good, safer options with relatively longer cycle life, produce no noxious gasses, and require little maintenance. Our boat's current Sonnenschein Gels are now 13 years old and doing fine. But because of their age, I suspect they are near the end of their service life. There are also significant charge and discharge advantages. Both Gel and AGM batteries are in the valve regulated lead-acid family (VRLA), which includes batteries that are leak- and maintenance-free. Although they are significantly more expensive than FLAs initially, having used both, I

Battery suppliers

Rolls Battery Engineering
rollsbattery.com

Mastervolt
mastervolt.com

Victron Energy
victronenergy.com

Lithonics Battery
lithonicsbattery.com

ReLion
relionbattery.com

Lynx Battery
lynxbattery.com

Sterling Power
sterling-power.com

Roadpro
roadpro.co.uk

believe they are a much better choice for a marine house bank. See sidebar 1 for a more detailed comparison of the three technologies.

A good safety record

Lithium is the newest battery technology, with lithium ferrous phosphate (LiFePO4) being the best choice for cruisers. There are several other lithium technologies currently used in everything from cellphones to electric vehicles and satellites. Some are safer than others and have advantages for different applications. They have been in common use since the late 1990s. LiFePO4 did not become popular with boaters until the early 2000s. Early lithium types had a bad reputation for catching fire. But modern LiFePO4 cells and batteries are now widely available, have earned a good safety record during the past 20 years, and if properly installed, are almost indestructible.

Replacing a common lead-acid battery system with a lithium setup is complicated and requires considerable careful study. Not all experts agree, the technology is still evolving, and there are several different types of lithium technology. On a cruising boat, it is not as simple a "drop in" replacement project as some might suggest. See sidebar 2 for a comparison of common marine lead-acid and LiFePO4 technology.

So, if you are a part-time cruiser with no long-term cruising aspirations and you don't have time for extra study, a complicated installation, and extra expense, you might want to consider one of the other technologies. If you cruise on a lightweight catamaran, want a very long-term battery solution, and have plenty of time to research the technology and do the installation, a LiFePO4 house bank may be for you. It helps if you are not on a tight budget and are cruising in SE Asia near China, the largest lithium manufacturer in the world. If you are so inclined, consider familiarizing yourself with the following basic LiFePO4 concepts.

Important decisions

Early on, the cruiser installing LiFePO4 batteries on a boat needs to make several important basic decisions. These include use of preassembled batteries or

Lead acid battery technology comparisons

- Gels are priced slightly higher than AGMs, but both are roughly double the cost of flooded lead acid (FLA) units.
- Gels can have as much as double the cycle life of AGMs and usually more than FLAs.
- Gels have a flat high performance curve until depleted; AGMs and FLAs lose capacity gradually.
- AGMs & Gels are less prone to sulfation than FLAs and are not usually equalized.
- Gels do better at higher temperatures, AGMs and FLAs are better at low temperatures.
- AGMs have up to five times faster charge rate than FLAs and are also better at this than Gels.
- Gels and AGMs are more sensitive to overcharging than FLAs.
- Gels and AGMs typically have a higher rest voltage than FLAs.
- FLAs require more maintenance attention than Gels or AGMs.

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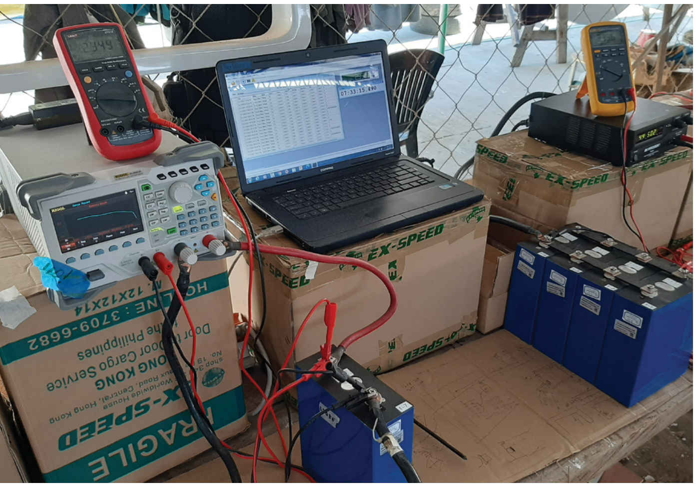

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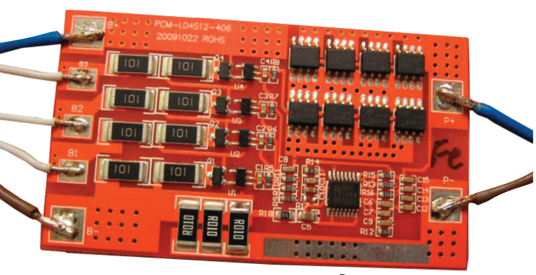
Above, McCampbell put together a testing setup for his recently purchased batteries before installing them in his boat. Right, balancing the cells in parallel.

individual cells, cell construction, cell configuration (prismatic or cylindrical), parallel (P) or series (S) wiring, and what battery management system (BMS) to use.

Batteries or cells - Marine preassembled battery packs usually consist of four prismatic cells in a rectangular case but can be configured many ways to produce various shapes, voltages and amp hour capacities. Preassembled battery packs are convenient and often include a BMS and balancer mounted internally. However, some but not all are sealed such that if something fails internally, the battery top must be cut off to access internal components. This keeps corrosion down but limits flexibility and repair/replacement options. Also, the BMS and wiring may not be optimum for mobile marine use.

Construction - As you might expect, not all LiFePO4 cells are created equal. Some have stronger cases (heavy plastic vs thin aluminum), larger terminals and bolts, better energy density, and better quality control of materials and cell internals. Energy density refers to the amount of energy (watt hours) that a cell can store. Greater energy density is better, as less can add significant size and weight to the cell. Careful matching of cells for capacity and internal resistance at the factory is important for the cells to be able to stay in balance, ensuring full usable capacity.

Cell configuration - Prismatic rectangular cells, with familiar positive and negative terminals, are preferred for boat house bank applications over the smaller cylindrical 18650 cells, with many spot-welded connections. Because of the multiple somewhat fragile spot welds, cylindrical cells are often used in static applications. Prismatic do it yourself (DIY) LiFePO4 cells typically are nominally 3.2 volts each and are available in a wide range of amp hour capacities. Four of these connected in series produce a battery of nominally 12.8 volts at the amp hour rating of the cells.



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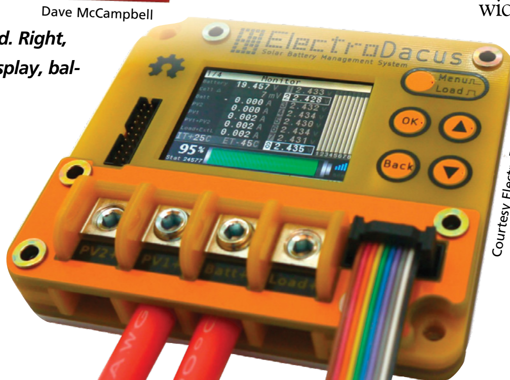

Courtesy ElectroDacus

Above, a BMS circuit board. Right, ElectroDacus BMS with display, balancer and heavy wiring.

Wiring - Terminology for wiring LiFePO4 cells can be confusing. In a typical LiFePO4 bank designation such as 4S2P, "S" indicates series wiring and "P" parallel. As an example, four 3.2-volt cells wired in series would be expressed as 4S. Two cells wired in parallel would be 2P. So two sets of four cells wired first in series and then the two sets wired in parallel would be 4S2P. Our eight cells will be wired this way so that the two four-cell 12.8-volt batteries can be wired through a battery selector switch where we can choose to use either battery or both. This way, if a cell in one battery has a problem we can't immediately fix, we can use the other battery until we can. Another example would be our current Gel batteries wired 2S3P, consisting of three parallel sets of two 6-volt batteries in series.

BMS - Choosing a capable and reliable BMS is a very important installation decision. It is the heart of a boat's lithium battery setup. Without its safety features, seriously bad things can happen, such

References and resources

WEBSITES:

- www.Marinehowto.com/lifepo4-batteries-on-boats/
- www.Nordkyndesign.com/category/marine-engineering/electrical/lithium-battery-systems/
- www.Batteryuniversity.com

WILL PROUSE's YOUTUBE SERIES:

- www.Mobile-solarpower.com/diy-lifepo4-video-series.html

FACEBOOK GROUPS:

- Lithium Batteries on a Boat- www.facebook.com/groups/427372107686109
- LiFePO4 Lithium Technical Discussions for Yachts-www.facebook.com/groups/598702467176941

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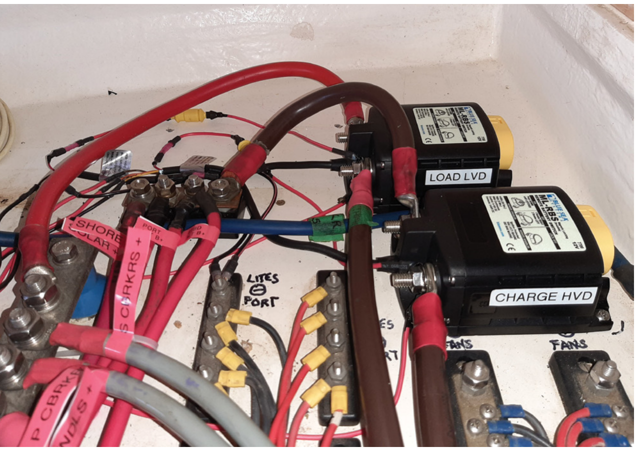

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McCampbell's latching relay setup on board his St. Francis 44 catamaran Soggy Paws.

as a major fire. Some are safer than others and have advantages for different applications. The BMS typically performs three functions: cell voltage monitoring, low and high voltage disconnect (LVD/HVD), and cell balancing. BMS units can be purchased for as little as $20, or as much as $500 US. As you might expect, you get what you pay for, so serious cruisers can't afford to use the cheaper gear.

Better units can control strong external disconnect breakers for handling higher amperage charging and loads, thereby keeping that high amperage away from fragile internal electronic components. They have more accurate balancing units capable of active multi-cell balancing, where excess voltage can be shunted to lower voltage cells in order to keep cell voltages near equal. They have the capability to more accurately monitor and clearly display many important individual cell characteristics. They use better quality components that are more reliable and less likely to fail. And finally, some have a conformal protective coating and an enclosure that help prevent board and component corrosion. These three functions can also be bought as separate units that have the advantage of selectable capabilities and single unit replacement if something goes wrong.

Cycle life - LiFePO4 cell cycle life is affected by a number of different stress factors, including depth of discharge (DoD), charge and discharge rate, voltage limits, surrounding temperature, and quality of construction. Cycle life advertised by manufacturers differs and is usually under laboratory conditions. One example is based on the number of cycles possible at 80% DoD, 77° F, full-capacity charge and discharge rates until the cell reaches 70% of its original capacity. While it is possible to safely charge and discharge most LiFePO4 cells at amperages up to 100% of their capacity (1C), limiting the charge current to something closer to 0.2C will result in considerably longer cycle life.

Service life - The important service life comparison between lead-acid and lithium is overwhelmingly in favor of lithium because of its much greater cycle life. Generally, a typical lead-acid battery can be cycled hundreds of times, but LiFePO4 cells have a cycle life measured in the thousands. Therefore, a LiFePO4 battery will have a lower cost over time and per kWh.

Looking at lithium capacity graphs, we can see that maintaining 10 to 80% SOC will keep voltages out of the dangerous voltage knees where there are fewer useable amp hours and the voltage changes rapidly with time. Unlike lead-acid batteries, lithium cells do much better cycling in the middle of their SOC rather than at the top end.

Dangers - For a nominal 3.2-volt cell, exceeding the upper voltage limit of 3.65 or lower limit of 2.5 volts may permanently damage the cell, shortening service life. Storing a LiFePO4 battery at full charge in hot weather can result in rapid capacity degradation. Mistakes in charging regimen, such as using an extended acceptance or float phase in conjunction with short cycling can produce a "memory effect" that will negatively affect useable capacity. It's one thing to replace your lead-acid batteries every few years due to usage mistakes, but quite a bit more expensive to do so with lithium cells. So know what you are doing and be careful if you value full capacity and maximum service life.

Cell monitoring - Careful monitoring of individual cell characteristics mentioned above is important in determining if there is a problem with any of the individual cells. Monitors must be able to measure millivolts (0.001 volts) accurately. So it is good practice to keep a close eye on these at the cell level, especially during charging and balancing, and take corrective action as necessary.

System design - In order to provide holdover when daily charging is not possible, it is important to carefully size the bank and charging capability for the daily load. If solar is the preferred normal charging source, as it should be for full-time cruisers in the tropics, it should be able to fully replenish the daily load by midday in reasonably good sun conditions, and if not so good sun conditions, by the end of the day. Depending on the type of panels, how they are mounted, and the amount of shading, they should produce one third to one fourth of their rated wattage in amp hours on a sunny day in the tropics. As an example of a reasonably well-balanced system, 800 watts of quality modern monocrystalline panels should produce 200 to 265 amp hours a day. A LiFePO4 bank of 570 amp hours capacity should have a safe maximum of about 70%, or 400 amp hours useable capacity (between 10% and 80% SOC). If the boat used about 150 amp hours a day, and if there was no solar charging available, it could theoretically hold over a maximum of about 2.7 days. A smaller battery bank would allow less holdover time, and less solar would require more daily charging time. More load would require both more solar and more batteries. So it is worth spending time looking at this.

Any comparison between lead-acid and lithium batteries needs to consider multiple issues such as advantages, disadvantages, service life and cost (including associated equipment required).

Resources for further study

Careful study of reliable sources, including the several well-respected websites in th accompanying sidebar will provide a more detailed understanding of the basics, the protection needed, and the installation requirements. The first two sites provide a good balance of theory and practice on the use of LiFePO4 cells. This is specific to marine deep cycle house bank applications. The third, Battery University, has a wealth of technical info and facts regarding loss of cycle life.

As you delve into this complicated subject, remember that not everything you read on the Internet is true. There is no such thing as a *Lithium Batteries for Dummies* manual. So research carefully and pay close attention to trusted sources with well-documented advice. Take your time. It is not rocket science, but it is different from what we already know about lead-acid batteries. ■

Dave McCampbell voyages with his wife Sherry aboard their St. Francis 44 Mark II Cat Soggy Paws.