Lithium-ion Batteries in RVs

(Last updated 30 July 2015)

Lithium-ion batteries in caravans and camper trailers, fifth wheel caravans and motor homes pack a lot of energy for their size and weight: ideal for those who free camp and lightening overweight RVs. All can be used as 'deep cycle'. Their chemistry and working is so different from other batteries they are almost a different species. This article on lithium-ion batteries in caravans, by Caravan and Motorhome Books' Collyn Rivers, explains why, and how to buy, install and use them.

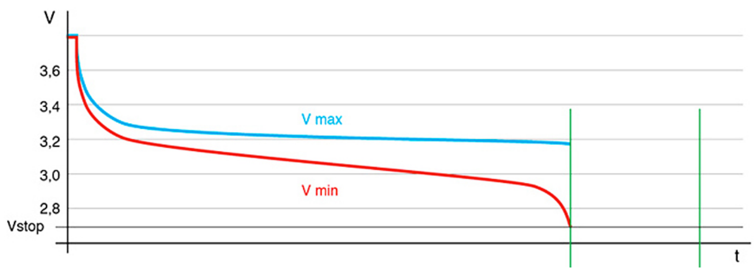
Lithium-ion battery types

Lithium cobalt oxide (LiCoO2) batteries store the most energy – a bonus for aircraft makers. In January 2013 however, one of them started a fire in a Boeing 787. United Airlines reported two more such fires a day or two later. All Boeing 787s were grounded for a time. These fires made headline news, but the lithium-ion batteries (LiFePO4) in caravans have very different chemistry.

This LiFePO4 battery is claimed to be able to be charged by most good quality two-stage battery chargers – the battery management system is inbuilt.

Lithium-ion LiFePO4 batteries are less energy efficient but still only a third to a quarter the size and weight of lead acid batteries of similar *rated* capacity (i.e. about 105 watt hours/kg). They are non-toxic. They *can* ignite but as the graphite (used for one electrode) must well exceed 1000 degrees C to ignite in effect they are close to non-flammable.

This graph shows the typical (per cell) voltage during discharge. That most probable for an RV is slightly above the blue line. (That shown by the red line is virtually of non-stop starter motor current levels of discharge).



Unlike a lead acid battery's 12.8-11.4 volts, lithium-ion LiFePO4 output remains almost constant. The output voltage depends on the load, but that of lithium-ion batteries in caravans and motor home use is likely to remains at 13.1-12.9 volts. Voltage drops steeply at 10% or so remaining, but as lithium-ion batteries are damaged (some are ruined) if fully discharged, deeper discharge is automatically limited.

This close to constant voltage output of lithium-ion batteries in caravans virtually eliminates low voltage fridge issues, and halogen lights dimming. It is also of benefit to RV owners who free camp but have battery issues associated with so-called converters. See Electrical Converter Problems in RVs-update.

Easy current flow

Like syrup flowing through a pipe, lead-acid batteries resist charging and current. Typical deep cycle examples can only deliver current of up 5% of their rated capacity to achieve their typically claimed rating – e.g. 5 amps for 20 hours (for a 100 amp hour battery).

If the current draw exceeds that (typical 5%) that battery loses energy in the form of heat. A microwave oven that draws about 1300 watts (110 amps at 12 volts) will virtually flatten a 100 Ah lead acid battery if used for 20 minutes. It depletes a 200 Ah battery by about 55 Ah, and a 400 Ah battery by about 45 amp hours. This resistance to working likewise limits charging. Few such batteries can be charged at more than 15% or so of their amp hour capacity. AGMs will accept 25%-30%.

Lithium-ion batteries have *far* less internal resistance. That microwave draw quoted above will barely affect even a 100 Ah LiFePO4. Likewise they charge at hugely higher current. About 50% of their amp hour capacity is typical (if such charge is available), but even 200% – 300% will not harm them.

Most 12 volt lithium-ion batteries of 18 Ah and above can readily and safely supply starter battery level current. All can serve as deep cycle batteries. Their *charging* efficiency too is high. Vendors claim 92.5-95%: that of lead acid batteries is about 80%.

Lithium-ion batteries do not vent gas unless charged/discharged at more than triple their amp hour capacity. Venting is likely to occur above that. Their makers claim the emissions are neither toxic nor explosive but ventilation is advised to limit heat build up.

Lithium-ion battery management

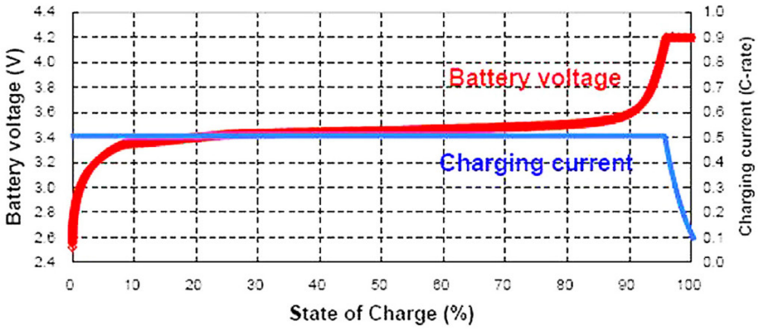
Unlike lead acid batteries, the actual voltage of each (nominally 3.2 volt) cell of a lithium-ion LiFePO4 battery *must* be individually monitored and automatically corrected (balanced) because charging current ceases when any such cell is fully charged. Twelve volt lithium-ion batteries in caravans typically have four end to end connected cells. If unbalanced the first that's fully charged restricts further charging of those remaining – limiting achieving full battery capacity. Such balancing has to be at cell level so the management system is located within the battery pack, or in some batteries, externally.

Control of charging and discharging voltage and current levels is also essential. This may be included within that battery management system, or by the battery charger.

Lithium-ion charging

There are two main approaches: that recommended by LiFePO4 battery and battery charger makers, and that of 'do it yourself' (DIY) users. Both approaches regard individual cell management as vital and (most) that discharge *must* be limited to about 10% remaining charge. Most DIY users are more conservative about that final state of charge.

This graph shows the relationship between charging voltage, current and a typical LiFePO4's state of charge at high rates of charge. A similar effect occurs at lower levels.



A 12 volt lithium-ion LiFePO4 battery is commonly claimed to charge safely to 80-85% at an applied 13.6 or so volts and many DIY users (including the author) do just that. As discharge *must* be curtailed at 10-20%, usable capacity is 65-75%. This is better than the 50% or so from lead acid batteries but, the industry (in effect) argues that, as charging deeper enables you to utilise more of the capacity paid for, why not do so.

A common industry approach/recommendation is to charge a lithium-ion LiFePO4 battery at substantially constant current to about 90% of full charge. If fuller charge is required that *final* part is at a tightly controlled fixed voltage of a typical 14.6 – 14.65 volts. Achieving this requires very accurate control (95% charge is about 14.4 volts, 98% charge is about 14.8 volts).

Some DIY users claim that fully charging will quickly wreck such batteries, yet industry testing at voltages far beyond that employed shows that still provides a handy 2000 or so such cycles of use. (See under 'Battery life' re industry definition of 'cycles of use'). Some makers explain that battery life is extended by limiting charge and discharge levels: that, as with all rechargeable batteries, what is being sold is usable amp hours. You use a lot of amps over shorter time, or less amps over longer time.

It is surprisingly hard to measure voltage (and current is harder) accurately and consistently – let alone control it. It thus makes sense for most DIY users to limit charge voltage such that the battery charge is limited to 80-85%. A lithium-ion LiFePO4 battery is truly safe at that. There is general agreement re automatically terminating discharge at 20% remaining charge.

Lithium-ion battery chargers

Some lithium-ion battery makers advise that, for charging from 230 volts, a good quality basic two-stage charger is all that is required but warn against any chargers that include *automatic* desulphation. This is because the associated 16 plus volts is too high (but most chargers with that function have it optionally selectable). Also unsuitable (say LiFePO4 makers) are chargers with a final *lower* voltage stage as that may preclude the battery reaching full charge.

Alternator and/or solar charging

It is commonly claimed (for LiFePO4 charging), that 'normal alternator charging' is fine. That cannot be – there has been no such thing as a 'normal' alternator since 2000. About then, alternator outputs began to vary, from 12.7 volts to plus 14.7 volts. Some have voltage that varies with load.

Companies such as Redarc and Sterling produce alternator chargers specifically for lithium-ion LiFePO4 (or with a LiFePO4 optional regime). They stress that their units must *only* be used with lithium-ion LiFePO4 batteries with management systems that include under/over voltage protection, cell balancing, and able to handle the charge current. Some also accept solar input. Redarc prefers to recommend that its LiFePO4 charger be used only with LiFePO4 batteries tested and approved by Redarc.

The (Australian designed and made) Redarc LFP 1240 alternator charges a LiFePO4 12 volt battery at 40 amps – it also accepts input from solar panels.

For charging caravan batteries, dc-dc alternator chargers etc should be located in the caravan, as close as feasible to the caravan battery bank. As these chargers are safely able to pump 40 amps or more into a LiFePO4 battery bank, it helps immensely to replace the existing cable from the alternator to the rear of the tow vehicle by one of approximately 13.5 square mm. Take it to the caravan via an Anderson plug and socket – and then 13.5 square mm to the charger and then to the battery. Unless that is done, the charging current will be unnecessarily restricted.

Lithium-ion battery temperature

Whilst this varies from maker to maker, LiFePO4 batteries have a preferred working range of -18 degrees C to about + 40 degrees C.

Lithium-ion battery life

Over time, the battery industry has developed a more or less de facto standard of defining the products' useful life. It is the number of cycle of charge/discharge that causes capacity to be reduced to 80% of that claimed when new.

With lead acid deep cycle batteries, longevity is very much a function of the depth of discharge (but is also shortened by chronic undercharging and discharging at loads higher than about 5% of the amp hour capacity (e.g. 5 amps for a 100 Ah hour battery). If discharged to 50% remaining at that 5% rate, the lifespan is a probable 1200 cycles, but only 200 or so if discharged to 30%.

A LiFePO4 is far less affected by the rate of discharge. Claims vary but that for most makers is about 2000 cycles if discharged to 20% remaining (virtually regardless of load). Some makers suggest that this can be extended by limiting the maximum charge to 90%.

Lithium-ion battery storage

This area is contentious. Possibly because lithium batteries are generally limited to 50% charge *whilst in transport*, many users claim that such a level of charge is also best for storage (but seemingly based on one report/recommendation). The University of Texas (that discovered phosphate as cathode material for rechargeable lithium batteries) however is widely quoted as stating that storing a fully charged battery has minimal impact on its life span. The issue is thus not clear, but will be updated if/when further reliable advise is released.

Lithium-ion battery pricing

Currently, no lithium-ion batteries are manufactured in Australia. All are imported and may have several levels of distribution – each adding overhead and profit. Some are claimed to be rebadged versions that can be bought otherwise cheaper. Lithium-ion batteries are expected to fall in price as they become increasingly accepted. The recent Tesla release will assure this.

This just (mid 2015) released lithium battery from Tesla may herald a major fall in storage battery prices. Pic: courtesy of Telsa Corporation (USA).

It is not however an area for eBay specials unless one is certain of what one is doing.

A sense of proportion

Whilst lithium-ion technology *is* a major advance in terms of weight and volume, the energy stored in a LiFePo4 battery – 120-165 Wh/kg (watt hours per kg) is trivial compared to that in fossil fuels. Most such are around 12,000 Wh/kg (or 2400-4800 Wh/kg allowing for the 20-40% efficiency of that which they fuel).

Battery reality is that the energy storable (for size and weight) barely increased between 1870 and and the advent of lithium-ion in the 1990s. The latter has resulted in a 3-5 times increase, but that *really* needed is at least 10-20 times *more*. Lithium technology is thus part of the answer, but *far* from the whole of it. The long term (RV) future is likely to include fuel cells plus a LiFePO4 (or its successor to cope with short term peak loads. See also Fuel Cells for Caravans.

Updates

As this area is changing rapidly this article will be updated every few months, or sooner if deemed warranted.

Collyn Rivers' main books in this area are Caravan & Motorhome Electrics, Solar That Really Works! and Solar

Success.