BATTERY ADVANCEMENT
BETTER BATTERIES

Lithium Fundamentals For Golf Carts

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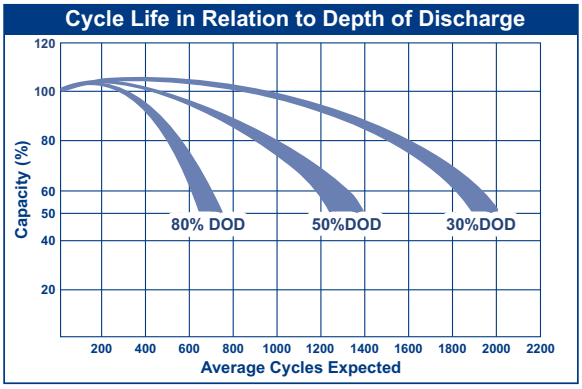
Introduction

There are lots of claims, stories, information, misinformation, and hype out there about electric vehicles. How does this apply to golf carts? What is important? And what do I need to know when they arrive? The purpose of this article to provide a practical understanding of Lithium batteries, and an overview of available options. This is what you need to know If its your job to take care of or be part of a decision to buy them.

Lithium batteries are a topic you are probably already be interested in, but perhaps not your bread-and-butter. Read on, you may have to stare at the graphs for awhile and read some paragraphs a few times, but it will be worth it.

The Status Quo

Electric carts have already replaced gas in many places. Roughly-speaking, they cost about 1/10th per km to operate, require much less work (especially if you exclude the Lead-Acid batteries), and if you trade them in after five years anyway, most Courses are happy with them. Let's begin our journey by looking at Lead-Acid battery characteristics, then compare to Lithium. Here is a graph from the US Battery User Manual. Have a look.



Briefly stated, what this shows is the less you drain a Deep-Cycle battery, the longer it lasts. With minor differences, manufacturers claim that discharging to no more than 50% Depth of Discharge (DOD), you should be able to run a cart around 1,200 days/cycles. You probably already knew this.

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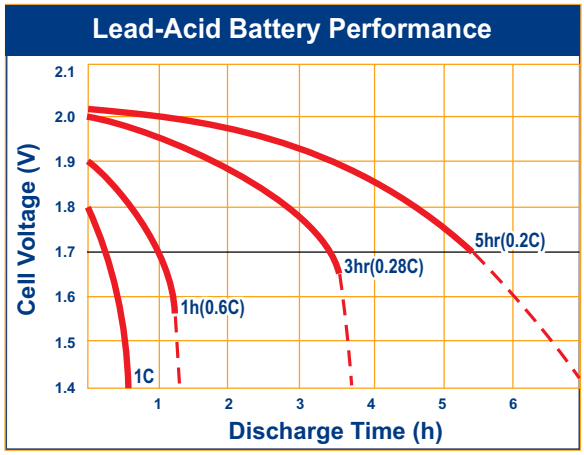

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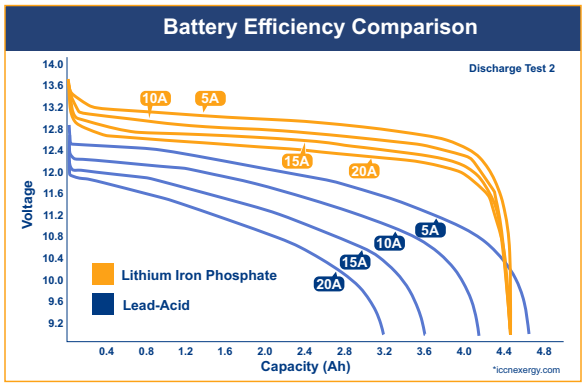
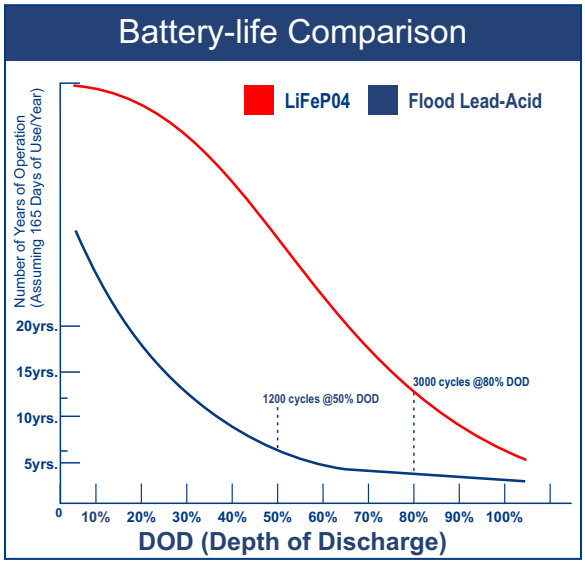


Now let's add Lithium to the picture (orange) in a slightly different graph. Note how: 1) Lithium batteries maintain their voltage as they drain much better than Lead-Acid (the curves remain flat), meaning better performance, 2) At higher currents their output voltage changes less and 3) their capacity (total Ah they can provide) hardly changes at all, as shown by where the orange lines meet the bottom axis.

Finally, let's look at another comparison which draws all of this together: can you grasp this one???



You should be able to see that the Lithium batteries last many more cycles at 80% DOD. Keep looking until you get it. Lithium chemistry is much more resilient than Lead-Acid, and can easily be discharged to 80%, not just 50%. Also, as seen above, Lithium is much more efficient, so using them does not produce much heat, making them last longer. The sum of all of this is that you can use a smaller battery; 60Ah is sufficient in most cases, and because of their increased efficiency (especially as Lead-Acid gets older), you will save about $300 per cart on electricity over five years. Also, because they are smaller and more efficient, they charge in less than half the time! Add to that the savings due to zero-maintenance, less wear-and-tear on your cart and turf due to reduced weight (one-third to one-quarter), and you can see why you should get the Lead out.

The point is not to put-down Lead-Acid; Lithium batteries are also not perfect. Most types cannot be charged at all below -4C (although you can still use them), and Lead-Acid batteries are much, much better at providing short, intense bursts of current. Flooded Lead-Acids make great starter-batteries for automotive use, but neither of these are a requirement for golf carts, while efficiency and longevity are! Lithium batteries are the right choice for a golf cart.

Caring For Your Lithium

Practically-speaking, there is one major difference when it comes to Lithium. For Lead-Acid, always plug them in when not in use, right? Always. Leaving them sit when not fully charged increases sulfation, and your job is to prevent this as much as possible with proper use, maintenance, charging and storage. For Lithium this is much easier, but there is one thing which is important: storage. This may make your hair stand on end if you are used to Lead-Acid batteries, but do not store them fully charged over the winter. And you don't need to be fanatical about topping-up during the day either. Really, and don't worry because unlike Lead-Acid, the capacity-meter is dead-on.

Why?? The equivalent of sulfation for Lithium batteries is dendrite-formation: little needles of Lithium. When fully charged, dendrites grow, reducing efficiency and capacity of the cells. Dendrites are similar to Lead Sulfate crystals for Lead-Acid, but they form much more slowly. And they form when the battery is left fully-charged (or close to it) instead of when they are not. Of-course, you will still charge your batteries every day and that is fine – just don't make it a religion and your batteries will thank you for it.

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BATTERY TYPE	DEGRADATION	PRIMARY CAUSE	RESULTS
Lead-Acid	Lead Sulfate Crystals	Form when not fully charged	Dramatic effect on battery life
Lithium	Lithium Dendrites	Grow when fully charged	Much less effect

Self-Discharge

For Lead-Acid, leaving them at less than 100% for the winter is not a good thing. Although a Lithium battery is not really "full" at the maximum charge, storing them that way over winter could reduce battery life by 10-20%. This is going to sound crazy, but any Lithium expert will tell you to **put them away for the winter at 50%.** See the Table below, and you will see why. They will last the winter without being charged.

Battery System	Estimated Self-discharge
Primary lithium-metal	10% in 5 years
Alkaline	2-3% per year (7-10 years shelf life)
Lead-acid	10-15% in 24hr, then 10-15% per month
Nickel-based	**Li-ion, NiCd, NiMH**
Lithium-ion	**5% in 24hr, then 1-2% per month (plus 3% for safety circuit)**
BatteyUniversity.com/article/bu-802b-what-does-elevated-self-discharge-do	

This is difficult to believe, but the Writer personally left $10,000 worth of Lithium batteries sit in an unheated garage for what ended up being four years, checking them occasionally. They were still not fully discharged. Also, their self-discharge rate is less in the cold, so you can easily leave them for the Winter at 50%. I know you will worry for that first Winter, but if they start out at 100%, you are going to be growing dendrites, instead of just letting your batteries hibernate. Turn down the heat and check them after a few months. Enjoy your Christmas, and watch the icicles grow instead. So, in conclusion: 1) storage is something you need to do differently (by doing nothing at all, but do it correctly!) 2) charging is a little bit different too – just let them slide until you need to charge them, and this will prolong their life by 5-10%. 3) Like gel-cells, no maintenance, so you don't have to worry about watering, and that summer-student slacking-off. Lithium is nothing to be afraid of!

Your Options for Lithium

If you are considering Lithium-powered carts, you now have three options. I personally like EZGO, because they have been the innovators: they introduced Lithium batteries and AC motors 4 or 5 years-ago, which is a great combination. Club Car tried and failed and is now trying-again. Don't be too negative. Yamaha has a new Lithium cart now too, and they have made a great choice: they added an off-the-shelf shelf Lithium battery to their old carts, and it is a good one – it is 105Ah, so will easily last 10, probably 15 years. It is a Lithium Iron Phosphate (LiFePO4) battery too; LiFePO4 is more stable (think fire risk), lasts longer, and the battery comes with its own built-in Battery Management System. They didn't have to re-design the whole cart, so it was an inexpensive solution, and will work well.

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Speaking of off-the-shelf batteries, if you are looking to just replace your batteries, there are several options out there. They are all LiFePO4. One good thing about buying LiFePO4 replacements is after 10 years or so, you can just combine two batteries in parallel; they will fit! They degrade very slowly, so you will probably get another 10 years out of them! Also, there is one start-up company which will lease you Lithium batteries.

Finally, if you are running gas carts, you should consider Lithium, as the operating cost is so much less. Many Courses have not done this because of the cost of upgrading their electrical service, plus they think they now need a heated cart-barn. Because you can store Lithium without charging (outside), this is no longer necessary, and instead of a new barn and upgrading your service, install solar! You get free power when you need it (in the middle of the day – especially nice days), and during the Winter when the Course is shut-down, you can put power back into the grid and collect between $5,000 and $10,000. This really makes-sense.

I'm glad you made it to the end! If you have any comments or questions, call us at Battery Advancement (BA).

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