THE LiPo Battery Primer

Text and Photography By Ralph Grant

Introduction:

I believe it was Spider-man's Uncle Ben Parker who exclaimed, "With Great Power, Comes Great Responsibility"! Recently at the field, there have been several people who have approached me with questions regarding LiPo batteries. Several are complete Newbies (We were all one once!) and some are seasoned veterans that I have watched charge batteries so swollen with no discernable corners or edges that they looked more like sausages than a LiPo battery!

The purpose of this article is to start at the beginning when it comes to LiPo batteries. There is a wealth of information online but I find that the searches on Google and others can lead you astray and don't seem to cover enough of everything.

I don't claim to be "Yoda" when it comes to LiPo's but I do know a thing or two about them after converting completely over from Glow Fuel when I re-entered the hobby in 2009.

Lets not get crazy technical here but I will say that the "Puffiness" of a degraded LiPo is caused by the release of gaseous oxygen when the cathode of the battery breaks down, chemically. If you read on, I will attempt to share my LiPo work-flow and if you dare to follow it, you will eliminate "Puffed" batteries from your fleet forever.

Battery Basics (Cell Count):

Lithium Polymer or as we call them LiPo (pronounced LYE-POE) batteries have revolutionized electric flying. The amount of energy you can get out of this battery in a compact and lightweight form factor is perfect for our models. LiPo batteries come in various cell counts depending on the number of volts that you want to generate. The number of cells required is typically governed by the design of the aircraft and the electric motor requirements specific to that airframe. Each motor has a kV rating which dictates its RPM (revolutions per minute) for each volt delivered. A single LiPo cell will deliver on average 3.7volts DC and approximately 4.2volts DC at full charge. The number of cells in a LiPo is usually communicated by this (#) S nomenclature. A single cell LiPo Battery is known as a 1S battery and a 4 cell LiPo is known as a 4S. Table 1.0 shows the nominal Voltage (average voltage depicted on the battery which is about 50%), the Minimum Safe Voltage (lowest charge to safely deplete a LiPo to is 3.0 volts/cell or 0%), and the Maximum Full Charge Voltage (greatest safe voltage to charge

LiPo Battery Voltage (Table 1.0)

Cell Count	Volts (Nominal)*	Volts (Min)	Volts (Max)	Usage
1S	3.7	3.0	4.2	Micro Plane / Heli / Quad
2S	7.4	6.0	8.4	
3S	11.1	9.0	12.6	Common Airplane / Heli / Quad
4S	14.8	12.0	16.8	
5S	18.5	16.0	21.0	
6S	22.2	19.2	25.2	Jet-EDF / Large Scale
8S	29.6	25.6	33.6	
10S	37.0	32.0	42	Giant Scale Plane / 700 Class Heli
12S	44.4	38.4	50.4	

*-Nominal Voltage is the "average" voltage of the pack and how the industry has chosen to describe and compare them.

The LiPo Battery Primer (Continued)

a LiPo to is 4.2 volts/cell or 100%).

So lets quickly jump back to that motor kV business. If a motor has a kV of 450 then the propeller will do 450 RPM per volt. If that airplane has a 6S battery (25.2volts at full

charge) then the 15x8 Falcon propeller on the 70" Phoenix Ryan STA in the picture above will turn about 11,340 rpm which is pretty typical for a large sport plane.

Battery Basics (Capacity):

Every battery made is typically rated in mAh or "milliamp hours". This is essentially the amount of current the battery can deliver for one continuous hour. Therefore, the 5000mAh battery in the Ryan can put up 5000mA for one hour before its voltage drops to 19.2volts or 3 volts per cell. This 5 amp / hour capacity when we convert from milliamps to amps can quickly be used to calculate the time of flight for the Ryan. If the plane averages about 50 amps at mixed throttle then it will fly for about 6 minutes (5Amp/50Amps=0.1 Hours). Obviously this is an overly simplified calculation because we rarely fly our birds at a constant speed, however it is a pretty decent rule of thumb and six minutes is where my timer starts to remind me on the Futaba 18SZ.

I also highly recommend investing in a good model airplane Watt Meter like the Astro-Flight version in the picture below so that you can test your power system on the ground. Every electric aviator needs one of these critters and

it can be had from Tower Hobbies for about $60 bucks. Money well spent in my book.

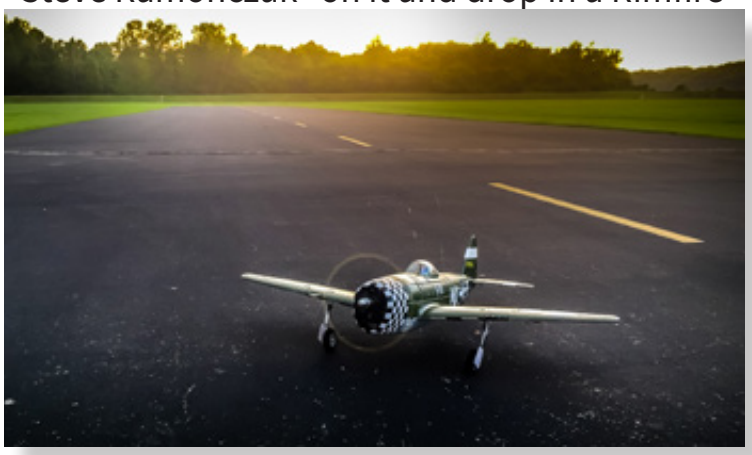
Battery Basics (C-Rating):

Every LiPo battery comes complete with a C rating. Actually 2 C ratings (A Discharge and Charge). The purpose of the C rating is to demonstrate the amount of power the battery can put out or the amount of power it can receive during charging. The way you need to think of a C rating is as a multiplier on the capacity. So in the case of the Ryan, I fly a Revolectrix Diamond Label 6S 5000mAh battery that is rated at 60C on its label. This means that since the battery is a 5A battery, it will put out a whopping 300A! Of course as we calculated before, it would only do it for 1 minute or so before it was depleted and it would be completely destroyed!

So, who really cares about a crazy C rating? To be honest, on a big 6S 5000mah battery a 60C battery was really a waste of good money. The C rating on a large capacity battery is more of a bragging status symbol amongst model aviation nerds. Where the C rating really matters is on smaller craft and lower C rated batteries. Lets assume you have a little E-Flite

The LiPo Battery Primer (Continued) - By Ralph Grant

P-47 Thunderbolt and you decide to go all "Steve Ramonczuk" on it and drop in a Rimfire



1250kV EF1 Outrunner motor and a Castle Edge Lite 75A ESC in an attempt to break the foamie warbird sound barrier. Will your existing 3S, 2200mAh battery with a 30C rating work with this new power-plant? Lets do the math, (2.2A x 30C=66A peak). Should you use it? I personally would not. You want your ESC to be rated higher than your motor/prop combo and the (C rating * Capacity) of your battery to be greater than your ESC. Think of the LiPo as a fueltank. In this case 66A is smaller than 75A so I would use a slightly better C rated battery in case the ESC needs more power Scotty!

What about the Charge C rating we mentioned? The charge C rating is typically 1-5 on most batteries. Big ones like the 5000mAh Revolectrix say you can hammer them with 5C or 25amps during charging. That means that you can fully charge a 50% storage charged one (more on this later) in only 6 minutes (2.5/25x60) since you only need to put 2500mAh in it to top it off. If you have a charger that can handle 625 watts (The Revolectrix Cellpro Powerlab 8 is rated at 1344 watts so you could do two!) you could charge that battery in 6 minutes if you were in that big a hurry. However, I would never really charge greater than 2C on big batteries and 1C on small ones because it is kind of hard on the batteries.

Battery Basics (More on C Rating):

The reality is that you should always error on the side of caution when making decisions on C ratings. Why? Because most of the C ratings on batteries are actually marketing BS used to increase sales. The only way to really check the C-Rating on a battery is to build a test rig and measure it. Make no mistake, there is NO battery out there that can withstand a sustained 40C load for a minute or more without sustaining permanent damage. But, regardless of labels, if money is no object you can be assured that the best LiPo packs out there are by Revolectrix and Dinogy. You can bank on it that either of those will deliver the C rating they say on the label but they are $$$!

LiPo Essential #1: Quality LiPo's.

The best thing you can do to insure that you don't damage your LiPo's is to start your journey with the best batteries you can afford.

I hate to break it to you but if you are buying a 4S 5000mAh LiPo and its $29.99, save your money. I've had excellent results with Admiral, Pulse, Venom, and Revolectrix. Personally, I think Admiral batteries from www.motionrc.com are some of the best value in LiPO's. I've got dozens of them and not one bad cell in the lot and I've never seen one Puff following these

The LiPo Battery Primer (Continued) - By Ralph Grant

principals!

LiPo Essential #2: Great Charger!

Once you've spent your hard earned coin on batteries, you need a great balance charger that you can count on. It must be big enough to charge batteries at 1C or more quickly and it absolutely MUST have storage charge capability. My own opinion is that the absolute best chargers out there are the

Cellpro Powerlab Series by Revolectrix. These chargers allow you to charge, discharge, monitor, and cycle any current or future battery chemistry.

Their software is fully upgradeable and at 1344 watts when teamed up with a solid 24 volt 55 Amp Power Supply you can charge all your LiPo's for a day at the field in minutes.

LiPo Essential #3: Multiple LiPo's.

To enjoy flying electric planes you need multiple LiPo batteries. There is nothing fun about sitting around as a spectator waiting for

things to charge. The reality is that it's also not great for your batteries to be charged while still warm from discharging in your plane. Get multiple batteries so that you can fly and charge low temp LiPo's. Make sure to get batteries that match your paint scheme as well so they look cool laying in front of your bird!

LiPo Essential #4: Cycle New Ones.

A prime athlete would never roll off the couch and run a 100 meter sprint. You shouldn't expect your LiPo's to do it either. When I purchase a new LiPo I always cycle it at least 3 times at 1C on the charger before pulling high amps out of it in flight.

LiPo Essential #5: Balance.

You MUST ALWAYS balance charge a LiPo. What is balance charging you ask? Depending on the internal resistance of each cell in a battery, each one discharges at a different rate. Its not uncommon for a cheap LiPo to have cells that vary by as much as 1/10th of a volt after it discharges. Balance charging allows your charger to measure the voltage of each individual cell and only charge low cells. When you only charge a LiPo based on the total voltage, the charger doesn't know the voltage it is applying to each individual cell, it only knows the total voltage. As you can see in Table 2.0, each of the LiPo's have the same full

The LiPo Battery Primer (Continued) - By Ralph Grant

pack voltage of 25.2 Volts which Table 1 says is the fully charged safe state for a 6 cell LiPo. Both seem safe. The problem here is that on LiPo #1 the bad cell #1 has caused cells 3-6 to be dangerously overcharged at 4.6V which certainly caused damage to the LiPo or worse, caused it to catch on fire! If you don't balance charge you are certainly damaging your LiPo's and putting your property and life at risk while charging to greater than 4.2V!

6S LiPo Battery Balance Charging (Table 2.0)

Cell #	LiPo #1 Unbalanced	LiPo #2 Balanced
1	2.6	4.2
2	4.2	4.2
3	4.6	4.2
4	4.6	4.2
5	4.6	4.2
6	4.6	4.2
Total	25.2	25.2

LiPo Essential #5: Installation.

Always install your LiPo so that it is solidly mounted with both Velcro and straps. Many of

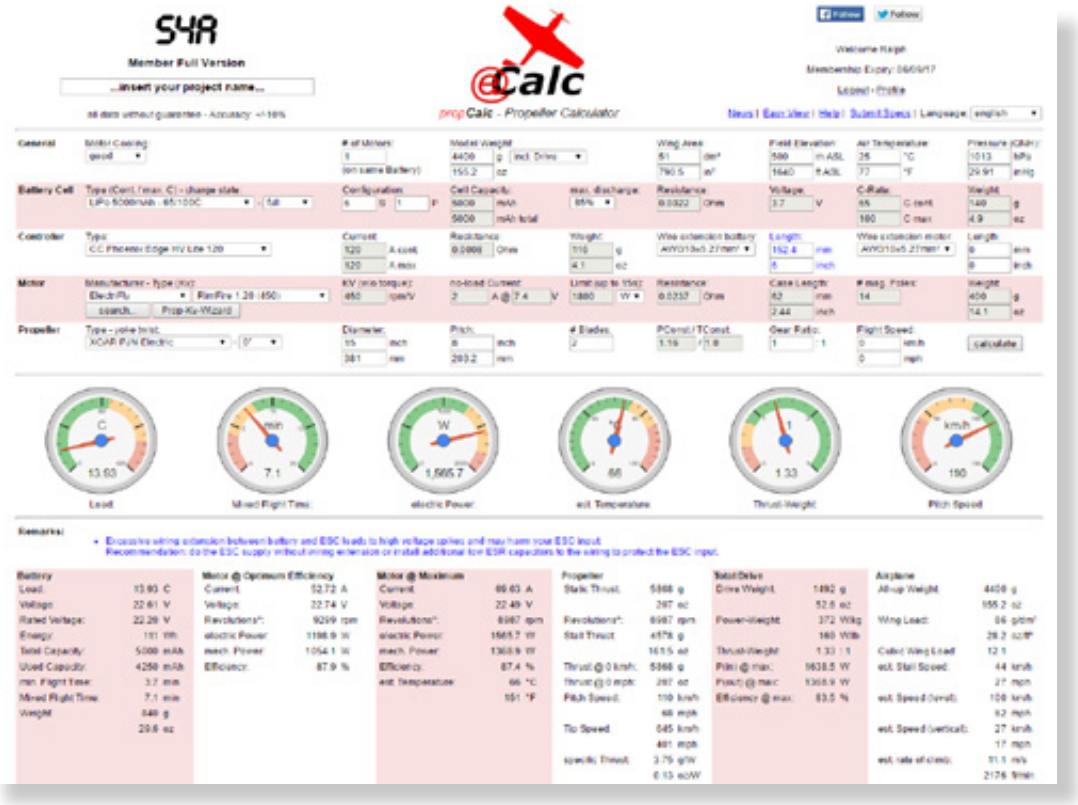
the fully aerobatic 3D planes like the Extreme Flight MXS above easily experience as much as 14g's. That means your 600g Pulse battery is going to weigh 8.4kg's or 18.4Lbs during high G maneuvers. Nothing will damage a LiPo and completely destroy your plane more than being jettisoned from your aircraft 200' above the runway! In another scenario, if you plow your plane into the ground nose first and the battery isn't adequately strapped in, it could slide violently forward and rupture itself on the shaft of the motor resulting in a LiPo Fire and complete loss of your plane (Ask me how I know this) in dramatic smoking fashion. While your worried about the connection to the plane, you should also worry about the cooling of the entire system. An overheated ESC, Motor, and Battery will result in excess losses of power and damage to system components. Always make sure that there is an exit for warm air. The discharge area from the plane should have at least 2 times the entrance area to allow for the expansion of increased temperatures air as it warms during cooling.

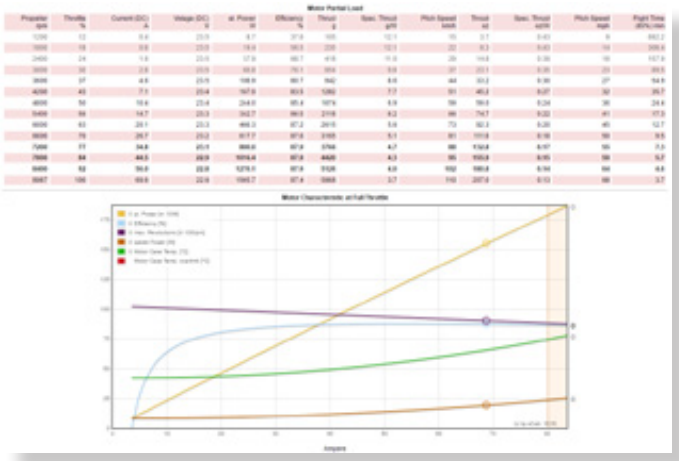
LiPo Essential #6: Power System.

If your flying a pre-designed foamie from a reputable company, design of the power system is not really of concern unless you change the battery from 3S to 4S or make other modifications. However, if you have built your own custom power system for your dream 30's era racer, you need to insure that the entire system is adequately designed. An excellent tool that I use for this is eCalc, an on-line calculation tool located at www.ecalc.ch that allows you to subscribe to their service and run a series of electric airplane calculations. Basically you input parameters such as model weight, wing area, cooling quality, battery brand/model, ESC brand/model, motor brand/

The LiPo Battery Primer (Continued) - By Ralph Grant

model, propeller brand/model/size, and several other parameters. It then calculates things like total power draw, approximate flight time, estimated temperature of the Battery, ESC, Motor, estimated speed of the plane, propeller tip speed (break the sound barrier and it sounds bad ass!). It even gives you critical warnings if the ESC you selected is too small, the temperature is too high on your motor, the





battery is damaged, etc. It provides all of this data across the entire throttle range as well and graphs it for you. Bottom line is that if you use eCalc, the possibility of damaging any component in your power system is slim to none. I have never had a motor burn up, an ESC fail, or a LiPo Puff when eCalc has been used. This is a great tool and well worth the subscription of $11.00 per year which include Heli, Quad, and other calculators.

LiPo Essential #7: Measure. Twice.

The minute you land, check your cell voltages and see if there are problems.

On my more expensive or favorite airplanes I have pretty much gone to telemetry to tell me my total voltage in the air. I'm a big fan of talking telemetry. On the Futaba R7008SB series receiver you can add external voltage for computer radios like the 14SG, 18MZ, or new

The LiPo Battery Primer (Continued) - By Ralph Grant

18SZ so that it will tell you when low. On my 18SZ, it talks (similar to other Spektrum

models) and I have it tell me voltage when I throw a momentary switch. I especially like to check voltage under full power to see if I'm over-taxing the battery. Based on Table 1.0, we know that the 6S safe minimum voltage is 19.2 volts which would be 0%. I generally like to be on the ground with no less than 30% battery life which is about 3.6 volts/cell or 21.6 pack volts according to telemetry. That being said, if the voice over the radio ever says less than 18.0 volts, I know I have depleted at least one cell below my minimum safe voltage of 3.0 Volts and I land immediately. Its not uncommon to hear 20.2 volts under heavy load like climbing vertically and then when I spin out and cruise at half throttle flat and level I hear the voltage go back to 21ish volts. If you don't have telemetry, you really need to get yourself a cell tester and check on the ground. Either of the ones in the image above can be had for less than $15 bucks. They tell so much more than a simple multi-meter. Some of them will even help you setup servo's, check servo current, etc.

LiPo Essential #8: Storage Charge.

The minute you get home from the field, the work is not over. You must storage charge all batteries that were depleted and discharge all batteries that were not used. One of the most damaging things you can do is leave a battery

fully charged for long periods of time. This almost certainly is the biggest cause of puffed LiPo's. As mentioned in Essential #2, NEVER buy a charger that doesn't storage charge. Storage charging will balance all cells at a given voltage and render the LiPo in a neutral state. The target voltage I shoot for is 3.85 volts because that is the default storage charge voltage on the Cellpro Powerlab 8. It ends up being about 50% charge, close to the nominal voltage. Storage charging is probably the second most important thing to getting on the ground with a minimum of 30% charge.

LiPo Essential #9: Safe Charging.

There is a basic level of LiPo discipline or respect that must be maintained.
There is always a risk associated to the convenience of so much power available to you. These little bricks of plastic and Lithium compounds can get angry fast if you mistreat them. Under no circumstances should you deviate from the following charging basic rules of engagement. Don't get lazy here. If these rules won't work for you, stick to glow engines please.

The LiPo Battery Primer (Continued) - By Ralph Grant

1. Never charge unattended: This is why I like lots of power so that I can charge those LiPo's without getting bored and get out!
2. Never charge without a balance charger: We've talked about this, don't do it unless you have a package of hot dogs available when the impromptu cookout begins.
3. Never charge on or near flammable surfaces: The romans invented concrete specifically to be fantastic LiPo charging surfaces. Use them!
4. Place your batteries in a suitable container while charging: If your LiPo is under 3S and 3000mAh you can get by with one of the many charging bags out on the market.

Put one battery per bag. Studies have shown that anything bigger than 3S - 3000mAh and all this little bag does is provide more combustible material to the

reaction! If your charging larger batteries such as 6S 5000mAh's, you really should invest in something more robust like the Bat-Safe charging box. This device not only contains the heat and fire within its double walled insulated interior, it also vents the gases that are escaping through a flame arrestor which filters the soot from the gases to reduce smoke damage (quite possibly worse than the fire). This box is a pretty cheap investment at $50 bucks and is available at www.bat-safe.com. If $50 bucks is overkill, get yourself a cinder block from the hardware store and place a plastic sandbag over the cell. When your LiPo unzips, it melts the plastic and the sand extinguishes it.

5. Wear safety glasses: If one of these babies lets go, the arc flash will generate hot materials at an alarming rate. It's one thing to get burned but a whole other story to be blind as well. I can fly with a few burns but I'll save using the Force to Fly for the Star Wars movies.
6. Have Sand Handy: These babies burn at greater than 1300°C. Now is not the time to toss your coffee or waste an extra Hoppy IPA on it. Sand is the best material for extinguishing a Class D Metal Fire which is why I recommend doing all your LiPo charging at the beach! You won't find a D on that ABC kitchen extinguisher either so don't bother with it except to extinguish other stuff your LiPo caught on fire.
7. Store them safely too: Remember, storage charge them before putting them away and they won't have much energy. Check cell voltages on a regular basis and re-balance on your storage charge setting as needed!

I also prefer to store my LiPo's in a fire proof cabinet that will allow the pressure to be dissipated. I acquired an old flammable solvent cabinet

The LiPo Battery Primer (Continued) - By Ralph Grant

that is double walled, insulated, and crazy heavy. I keep all my LiPo's in there. Although upon looking at this photo, I probably should get the flammable materials off the top of the thing

LiPo Essential #10: Disposal.

Once the thing is puffed up like a road kill possum and won't balance you need to get rid of it. Now is not the time to hand your beer to your buddy, say watch this, and poke it with a #11 X-Acto to "let the smoke out"! This is what you do:

1. Balance discharge the battery to no less than 3.0 volts per cell on your charger.
2. Dissolve a cup of salt in a container of water just deep enough to cover the entire surface of the battery and set the battery on top of the Leads so that they are submerged as well. The electrolyte salt solution will slowly discharge the battery. Leave it there for at least 24 hours.
3. Check the LiPo Voltage and when it is 0.0V you have completely and safely discharged the battery. Continue to soak until it is completely discharged at 0.0V.
4. Dispose of the LiPo in the kitchen garbage can. Thats right tree huggers, LiPO batteries are completely safe for the environment unlike NiMH and NiCd batteries in your other devices!
5. Go Fly with another LiPo! This is pretty much self explanatory but if you need some help here, give me a call!

LiPo Conclusion:

There are a lot of nay-sayers out there that will use this article as an example as to why they don't fly electric. The beauty of this hobby is that we can all enjoy it in any fashion that we like and there is something for everyone at every skill level and price point. I for one, love the electric convenience of pulling into the flying field and being in the air with a 48" airplane in less than 1 minute. When I'm ready to leave, I toss everything in the truck and I am gone in 1 minute. The convenience is immeasurable and the opportunity it provides for multi-engine is awesome!

Flying a B-17 on glow power was just not something that was within my skill set or patience level. Electric flight and LiPo power has made that possible at an affordable price. Electric power has enabled a number of people to experience this hobby without spending a fortune. You can be in the air for less than $200 bucks with a high quality airplane with electric power.

The LiPo Battery Primer (Conclusion) - By Ralph Grant

As said in the opening, "With great power comes great responsibility". If you consult this document and follow its recommendations, LiPo power will be a safe, affordable, and fun power system for all ages for years to come.

Happy Flying on Electric Power!

Feel free to email me at ralph@thegrantz.com with questions, comments, etcetera or even better, come talk to me at the field!

At the Field:

Photography By Greg Bowles, Secretary