Getting The Most Out of Your LiPo Batteries

Believe it or not, LiPo RC battery care & understanding involves more than just *charge, use, recharge.*

The body of this article was authored by John Salt at https://www.rchelicopterfun.com/, an RC Helicopter enthusiast for many years. It is geared towards flying helicopters but his research in LiPO batteries over the last ten years is very deep. I modified this article where necessary to properly reflect use in race cars. At the end, there are great links to other articles authored by John.

Top 10 RC LiPo Battery Topics We'll Cover

Why Are LiPo Batteries So Popular In The World of RC?

LiPo batteries, short for **Lithium Polymer** battery, are a type of rechargeable battery that has taken the electric RC world by storm, especially for planes, helicopters, and multi-rotor/drone.

They are the main reason electric flight is now a very viable option over fuel powered models.

LiPo batteries have five main things going for them that make them the optimum battery choice for RC planes and even more so for RC helicopters over conventional rechargeable battery types such as NiCad, or NiMH.

RC Li-Po Battery Pros

- LiPo batteries are light weight and can be made in almost any shape and size.
- LiPo batteries have large capacities, meaning they hold lots of energy in a small package (high energy density).
- LiPo's are very good at maintaining a consistent voltage/power output as they discharge. The voltage/power drop however when they are reaching a fully discharged state is very fast (and damaging) when compared to NiCad, NiMh, or PB.
- LiPo batteries have high discharge rates to power the most demanding electric RC aircraft and vehicles. LiPo's also allow for fairly high charge rates so recharging in an hour or less is possible.
- Unlike NiCad or NiMh; LiPo's have no "memory-effect".

In short, Li-Po cells provide high energy storage density to weight ratios. They also give us a consistent voltage output, are capable of safe fast discharges, have quick recharge times, and can be configured in an endless variety of voltages, capacities, shapes, and sizes.

These benefits are important in any RC model, but for airplanes, helicopters, and quad/multi-rotor they are the reason electric flight has become so popular.

Face it, electric RC cars and RC Boats have been around for decades; but it wasn't until LiPo battery technology arrived on the scene that electric planes, helicopters, and quad/multi-rotor started showing up and are now surpassing gas, turbine, and even nitro in terms of power to weight ratios.

Why is power to weight more critical with RC aircraft? Because it simply takes ***way more power to get something airborne.*** Overcoming gravity uses substantial energy over something that drives on wheels or floats on water.

There are a few down sides with LiPo batteries however; once again proving there is no perfect RC power solution (yet).

RC Li-Po Battery Cons

- LiPo batteries are expensive compared to NiCad and NiMH. They have come down in price over the past several years, but are still quite costly.
- Although getting better, LiPo's don't have very long lifespans when used in high demand applications like RC flight; perhaps only 100-300 charge cycles (much less if not cared for properly). The harder they are pushed, the shorter their life expectancy. If

used gently however in low load applications (TX & RX battery packs for example), they can easily last well over 500 cycles.

- Safety issues - because of the high energy density storage coupled with the volatile electrolyte used in LiPo's, they can burst and/or catch fire when mistreated.
- Because of this fire danger, RC LiPo's are classified as dangerous goods now by most shipping facilities world wide making shipping difficult, expensive, or even impossible for all but the smallest capacity LiPos.
- LiPo batteries require unique and proper care if they are going to last for any length of time more so than any other battery technology used in RC. Charging, discharging, storage, and temperature all affect the lifespan – get it wrong and a LiPo is garbage in as little as one mistake!

Before I start talking about the actual care & ratings of LiPo RC batteries, I thought I should go over the basics first.

Feel free to skip down the page if you don't care about the actual make up of a lithium polymer battery and just want to know what to look for when buying them, how to properly care for them, and get the most possible life expectancy out of them.

RC LiPo Battery Construction

LiPo Battery Plastic Pouch Cell

Almost every RC LiPo battery cell is packaged in a flexible plastic pouch, coincidentally called a ***"pouch cell"***.

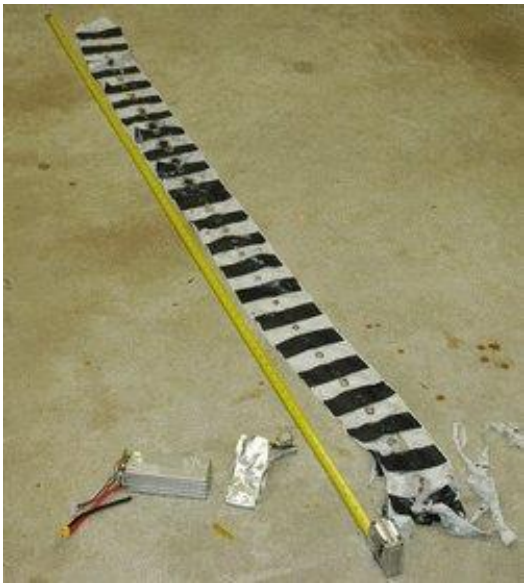
The picture to the right shows both a single pouch cell, along with three of the cells combined to create a typical 3 cell (3S) LiPo RC battery pack.

Pouch cells are the perfect solution for building multi-celled battery packs because the flat pouch cell can be stacked with no wasted air spaces like found within round celled battery packs.

Since LiPo's use this light weight plastic pouch instead of a metal can, less weight is the result making pouch celled LiPo's the preferred choice in weight conscious RC aircraft applications.

By contrast, heavier canned lithium cells such as the very popular Li-Ion 18650 cells that are used in everything from cordless power tools, to Tesla Motor's current battery packs, weigh in at 20% or more than similar capacity LiPo pouch cells.

These LiPo pouch cells also allow for more thermal expansion and even gassing (electrolyte decomposition) due to the flexible pouch over a metal can that most Li-Ion cells are encapsulated. So, they can also been considered as a safety feature to some extent.



The "Guts" Inside a LiPo Cell

If you ever open up a LiPo pouch cell, this is what you'll find.

A long piece of very thin white plastic micro porous film (the polymer), with the thin lithium carbon coated aluminum & copper anode & cathode electrodes laminated in an alternating pattern on the front and back side of the polymer separator film.

This long film (over 7 feet long in the case of this 5000 mAh cell), is folded accordion style back and forth upon itself resulting in an alternating anode/cathode stacking with the continuous thin layer of polymer separator sandwiched between them.

This entire folded cell matrix is placed & sealed into the soft plastic pouch, and will be saturated with a greasy/gel like solvent based lithium ion infused organic electrolyte; which incidentally has a very sweet solvent smell much like nail polish remover/acetone.

If you ever smell that unmistakable sweet solvent like odor from a lipo battery pack, it has a **leaking cell and should not be used under any circumstance!**

Before the final heat sealing of the pouch, it is pressed under a fair amount of pressure to ensure maximum contact is obtained between the polymer separator film and the anodes and cathodes. The tighter this lamination between layers is, the better the ion transfer efficiency and lower the internal resistance of the battery.

This pressing of the cell just before final sealing also removes any remaining air within in the cell. Low humidity & clean room manufacturing environments are also very important which adds to the manufacturing costs of lithium batteries.

If you're wondering what the burnt hole is in the center of all the plates, I purposely drove a nail through this cell to discharge it rapidly & watch the fireworks. The cell rapidly ballooned out, burst, and vented oxygen & flammable electrolyte but never caught on fire.

On the positive side, if it would have burst into flame, I wouldn't have this picture to show the "guts". I only did this because I dropped this heavy 6S 5000mAh LiPo pack on the hard concrete floor (yes - very dumb & costly butter finger moment) and one cell was damaged in the process. Lesson learned, don't carry more LiPo's than you can safely hold!

Hard Case vs Soft Case RC LiPo Batteries

Hard case LiPo's use a hard plastic shell to house the soft plastic LiPo pouch cells of the battery pack.

Hard Cased RC LiPo Battery Pack

This gives them added protection from moderate impacts and rough use that often occurs with ground RC vehicles such as cars and trucks; where saving weight is a secondary concern over that of protection.

Naturally this is vehicle dependent as some RC cars and trucks offer good physical battery protection. This is also application dependent; racing with other vehicles is likely to see more "impact" events for example. ROAR requires all competition vehicles to use LiPo packs in hard cases.

Many hard cased packs as also shown in that photo have built in bullet connectors within the case to accept the main power and balance wiring.

RC air vehicles however (helicopters, planes, and quad/multi) rotors), generally use soft case RC LiPo batteries.

Soft Case RC LiPo Battery

As shown with the above soft cased LiPo, the cells are simply encased in a light weight shrink wrap to create the battery pack. There may or may not be a thin, light weight layer of foam protection also wrapped around the pack before the shrink wrap is applied.

Both power and balance wiring is soldered direct to the cells within the pack further reducing weight and avoid more failure prone connection points.

The main advantage to a soft case is obvious - less weight and a smaller form factor as there is no bulky case around the cells. For RC Car racing ALWAYS use a hard case pack!

The other advantages with soft cased RC LiPo batteries is you can see when they are puffed (which will be covered later on in the article). Hard cased packs on the other hand can have puffed cells totally hidden within the case, but the hard case will usually

burst when the puffing gets bad enough. LiPo cells enclosed in thin heat shrink also have moderately better heat dissipation over ones that are enclosed in a hard case.

So, for electric powered RC aircraft, the vast majority of us will use soft cased LiPo packs for those primary advantageous reasons.

The one "RC aerial discipline" exception I can think of that "bends" this general rule of using only soft LiPo packs is FPV quad-rotor racing.

Those little buggers will often be banging into each other and anything else they fly into that conventional RC pilots want to avoid at all cost.

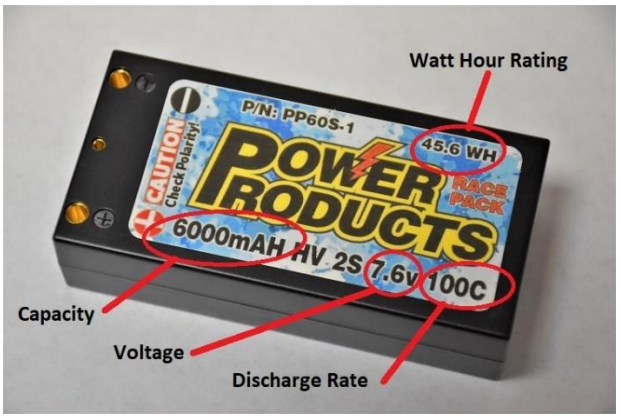
Just like racing ground vehicles, "some" (certainly not all) FPV racing pilots use hard cased packs on their racing quads if the quad copter itself doesn't protect the LiPo battery pack well.

RC LiPo Battery Ratings

Now that I have bored you to death with LiPo RC battery basics, time to get into the main topics at hand.

First are the 4 main rating numbers you will see on the Li-Po battery:

- **Voltage**
- **Capacity**
- **Watt Hour Rating**
- **Discharge Rate**



Typical RC LiPo Battery Rating Numbers

1. Cell Count / Nominal Voltage

Unlike conventional NiCad or NiMH battery cells that have a nominal voltage of 1.2 volts per cell, LiPo battery cells have a ***nominal voltage of 3.7 volts per cell***.

The benefit here is fewer cells can be used to make up a battery pack and in some cases on smaller micro sized RC aircraft like most toy helicoptersor hobby grade micros like the Blade mCX2, or Nano QX; a single 3.7 volt LiPo cell is all that is needed to power the motor and electronics.

Quickly - What the heli is "*nominal voltage*"?

Nominal voltage is usually referred to as the ***"resting voltage"*** of the battery cell or battery pack. There are exceptions of course in this determination.

Nominal resting voltage is an industry standard (agreed convention) that varies for all battery chemistry types; but for our RC LiPo chemistry, the usual nominal voltage standard given is 3.7 volts per cell. Note: In the picture above you see the letters 'HV'. This is the newer 'High Voltage' pack which means the nominal voltage is 3.8 volts per cell. For this 2S (explained below) pack, the total nominal voltage is 7.6 volts.

That voltage however is not the fully charged voltage of the cell (which is as high as 4.2V), nor is it the 50% storage voltage (3.85V), or even the 80% discharged state resting voltage (apx. 3.75V).

This will all be covered in detail throughout my LiPo article, but nominal voltage numbers often confuse folks and I get a fair number of related questions. To keep things simple, just think of 3.7 volts as the guide number used to determine the voltage value you see printed on the LiPo battery pack sticker for standard cells.

Enough nominality :-) Back to the article...

Other than the smallest of electric RC models, RC LiPo battery packs will have at least two or more cells hooked up in series to provide higher voltages. For larger RC models that number can be as high as 6 cells and even more for larger birds or HV (high voltage) applications.

Here is a list of LiPo RC battery pack ***"nominal"*** voltages with cell counts. If you are wondering what the 1-14S in parenthesis means; it's the way battery manufacturers indicate how my cells hooked in series(S) the battery pack contains. **Fully charged voltage** of the packs is the number in green.

- **3.7 volt battery = 1 cell x 3.7 volts (1S) 4.2V (HV: 3.8 volt, 4.35 volt charged)**
- **7.4 volt battery = 2 cells x 3.7 volts (2S) 8.4V (HV: 7.6. volt, 8.7 volt charged)**
- **11.1 volt battery = 3 cells x 3.7 volts (3S) 12.6V (HV: 11.4 volt, 13.5v charged)**
- **14.8 volt battery = 4 cells x 3.7 volts (4S) 16.8V (HV: 15.2 volt, 17.4 volt charged)**
- **18.5 volt battery = 5 cells x 3.7 volts (5S) 21.0V**
- **22.2 volt battery = 6 cells x 3.7 volts (6S) 25.2V**

- **29.6 volt battery = 8 cells x 3.7 volts (8S) 33.6V**
- **37.0 volt battery = 10 cells x 3.7 volts (10S) 42.0V**
- **44.4 volt battery = 12 cells x 3.7 volts (12S) 50.4V**
- **51.8 volt battery = 14 cells x 3.7 volts (14S) 58.8V**

I should point out you may run across packs or cells hooked up in parallel to increase the capacity. This is indicated by a number followed by a "P". Example: 2S2P would indicate two, two celled series packs hooked up in parallel to double the capacity (2S2P is actually a popular configuration in high capacity LiPo receiver packs). Another pertinent example is the 6000 Shorty pack in the picture. It has four cells, in the 2S2P configuration.

So, those are the voltages you need to know and each RC model or more specifically, the motor/speed controller combination will indicate what voltage is required for correct operation/RPM.

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2. Capacity

Capacity indicates how much power/energy the battery pack can hold and is indicated in milliamp hours (mAh), at least on our smaller RC packs. This is just the standard way of saying how much load or drain (measured in milliamps) you can put on your battery for 1 hour at which time the battery will be fully discharged.

For example an RC LiPo battery that is rated at 1000 mAh would be completely discharged in one hour with a 1000 milliamp load placed on it.

If this same battery had a 500 milliamp load placed on it, it would take 2 hours to drain down.

Note, as the discharge rate increases, the capacity of a battery actually becomes less than stated due to efficiency losses; but in our discussion here, we are keeping things simple and "linear" :-)

As you can imagine for an RC model helicopter with that kind of current draw, it would be very advantageous to use a larger capacity battery pack such as a 2000 mAh pack. This larger pack used with a 15 amp draw would double the flight time to about 8 minutes. It's not quite that simple, and there are other considerations to be aware of which will be covered, but you get the idea.

The main thing to get out of this is **if you want more track time, increase the capacity of your battery pack**.

Recommendation:

1. Offroad Buggy, 17.5 Brushless Motor: 3600mAH 2S Pack
2. Offroad Buggy, Modified Brushless Motor: 6000mAH 2S Pack

3. Offroad Buggy, 4WD 17.5 Brushless Motor: 6000mAH 2S Pack
4. Offroad Buggy, 4WD Modified Brushless Motor: 6000mAH 2S Pack
5. Oval, 2WD Stock Classes: 5000mAH or higher 2S Pack
6. Oval, 2WD Mod Classes: 6000mAH or higher 2S Pack
7. Oval, 2WD SC Mod: 8000mAH 2S pack

RC LiPo Battery Capacity Cell Size Comparison

Unlike voltage, capacity can be changed around to give you more or less flight time.

Naturally because of size & weight restrictions, you have to stay within a certain battery capacity range seeing that the more capacity a battery pack has, the larger and heavier it will be.

Think of increasing the RC Lipo battery capacity similar to putting a larger fuel tank in the RC vehicle.

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3. Watt Hour Rate

This is the total power this pack contains. It is required when shipping batteries and for ROAR approval. It simply gives you the potential energy this pack has and is useful for comparison between different packs to verify the power.

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4. Discharge Rate

This one is probably the single most over rated & misunderstood of all battery ratings.

Discharge rate is simply ***how fast a battery can be discharged safely while remaining healthy.***

Remember that ion exchange thing further up the page? Well the faster the ions can flow from anode to cathode in a battery will indicate the discharge rate.

A battery with a discharge rating of **10C** would mean you could & safely discharge it at a rate **10 times more than the capacity of the pack**, a 15C pack = 15 times more, a 20C pack = 20 times more, and so on.

Using our 1000 mAh battery as an example; if it has a 20C discharge rating, that would mean you could pull a maximum sustained load up to 20,000 milliamps or 20 amps off that battery (20 x 1000 milliamps = 20,000 milliamps or 20 amps).

From a purely theoretical time stand point, this equals 333 mAh of draw per minute so the 1000 mAh pack would be completely exhausted in about 3 minutes if it's exposed to the maximum rated 20C discharge rate the entire time.

Calculation as follows: 20,000 mA divided by 60 minutes = 333 mAh which is then divided into the 1000 mAh capacity of the pack giving us 3.00 minutes).

Most RC LiPo Battery packs will show the continuous C rating and usually a maximum **burst C rating** as well. A burst rating indicates the battery discharge rate for short bursts (**a few seconds maximum**) of extended power. An example might be something like "Discharge rate = 25C Continuous/50C Bursts".

The higher the C rating, usually the more expensive and even slightly heavier the battery gets. This is where you can save some money, and maybe even a little weight.

Getting an extremely high discharge rated pack when there is no way you could possibly pull the full amount of power is not required but it won't hurt either.

The most important thing is you can't go with too low a discharge C rating or you will damage your battery and possibly your ESC (electronic speed control).

Just like the maximum charge number, **the maximum discharge number is what the manufacturer deems is safely possible, but not at all what will give you the best life.**

So how do you know what C rating to get when purchasing your LiPo RC Battery Pack?

The easy answer most will give is to get the largest C rating you can... If money is not an object, I agree with that almost 100%.

However, for beginners & intermediate racers, stretching your RC battery budget by purchasing lower C rated packs when you're first learning so you can get a few extra packs makes more sense in my opinion.

As a ***very general guide line***, 50C discharge rated packs are the norm for most reasonably priced packs for the novice classes.

All this said, Li-Po packs are coming down in price all the time. If you find a 50C pack for the same price as a 100C when that is all you need, go for the 100C pack - it should run cooler and have a longer life span. Like most things, pushing a Lipo pack hard close to its limits will wear it out and reduce its overall lifespan (by a large degree in some cases).

If however you get a pack with a **C discharge rating** **at least double** of the maximum you intend to pull out of it; with proper care, there's no reason you shouldn't be able to get 300 charge and discharge cycles out of it with average degradation.

Using Pack Temperature To Gauge Discharge C Rating

Lastly, taking a temperature reading of your packs after running them is another good way to gauge if you're using a high enough C rating. I'm afraid to say it, but just because a pack says it is rated at 30C doesn't necessary mean it is in real world applications.

Realistically, C ratings are somewhat meaningless because they are not verifiable. On top of that, as packs age, their internal resistance increases which lowers the C rating and makes them run warmer.

The general rule is if you can't comfortably hold a LiPo pack tightly in your hand after using it, **it's way too hot!** This equates to anything higher than about 50C (122F).

That is even way too warm as far as I'm concerned. Nothing higher than 40C (about 104F) is what I consider safe and I rarely have my packs go much past 35C (95F) unless it's also very hot outside as well. So, if you find your packs are getting warmer than this, it's a good bet you should consider moving up to a higher discharge rating for your next LiPo pack/s.

Leaving your packs in the car on a hot sunny day can certainly heat them up well past 40C as well. Internal or external heat - both have the same negative effect, hot LiPo's are miserable and they won't last long.

Before we continue, one more important topic to cover. In most cases, the highest charge current rating the manufacturer states the battery can be charged at **safely is 2C.**

A 2C charge rate as shown on our example battery, would mean you can safely charge that battery at ***2 times its capacity.*** With that 6000 mAh pack example above, the calculation is 2 x 6000 mA = 12,000 mA or 12.0 Amps.

Please note however, charging at maximum rates will shorten battery life as is discussed further down this page in the LiPo charging calculation section. This is a ***safe*** maximum number, not a ***best for maximum life*** number in other words.

Lower charge rates are always better for increasing LiPo battery life!

Over Discharging LiPo's

The Most Common & Destructive Mistake Made!

Okay, if there is only one thing you get out of this entire page, that is to understand how damaging it is to over-discharge a LiPo battery.

LiPo battery cells/packs will heat up fast and be irreversibly damaged when over-discharged **under load**. The larger the load, the worse the damage.

The over-discharged threshold value to remember is **never lower than 3 volts per cell! I use 3.3v as the lowest to discharge for safety and life of pack reasons.**

Even if you have a 60C pack and can only draw one quarter that amount of power, if you push it hard right down to 3 volts per cell under load - it will become very warm/hot and will shorten its life substantially. You may even boil off some of the electrolyte causing the pack to "puff" (more on battery puffing further down the article).

Most ESC (electronic speed controls) have what is known as LVC (low voltage cutoff). This is a ***safety feature that is suppose to prevent*** LiPo's from being over discharged past 3.0V per cell during use. In my experiences, LVC is nothing more than a last ditch effort to avoid maximum battery harm and certainly not something to rely on.

If you fly/drive all the time to LVC, when the ESC either powers down the ground vehicle or reduces power to the air vehicle (giving you time to land), your RC LiPo batteries will live very short lives. Even when the LVC is set to 3.2V per cell under load, that is still likely over discharging the battery and causing harm.

Any heli or plane I've flown with a 3.2V LVC right down to the point of LVC activation, the pack has always been over-discharged. I simply don't trust LVC for safe and long RC LiPo battery life as voltage under load is not a good indicator of state of charge in a LiPo battery. Loads can vary as well, and that too gives erroneous states of charge voltage readings.

So how do you know when to stop flying, driving, or boating?

THE 80% LIPO BATTERY RULE TO THE RESCUE!

A very good rule to follow here is the **"80% rule"**. This simply means that you should **never discharge a Li-Po pack down past 80% of its CAPACITY** to be safe (80% discharged in other words).

For example, if you have a 2000 mAh LiPo pack, you should never draw more than 1600 mAh out of the pack (80% x 2000). This is assuming a healthy pack as well that has the full 2000 mAh capacity (as packs age, their capacity drops).

This again is where computerized chargers pay for themselves many times over so you can see how much capacity the battery takes allowing you to adjust your flight times accordingly to stay within that 80% rule to get the most life out of your pack.

If you don't have a computerized charger to confirm the amount of capacity, another good indicator is to measure the open circuit voltage (no load voltage) of the pack or individual cells right after a flight/drive with a digital volt meter or other similar digital voltage measuring device. An 80% discharged LiPo cell, will give an approximate open circuit voltage of about 3.73 to 3.75 volts (about 3.74 to 3.76 volts for an HV pack).

A 3S LiPo pack therefore would show about 11.22 volts after a flight when it's about 80% discharged, a 6S pack would be in the 22.44 volt region. The longer you wait after the flight/drive, the less accurate this voltage method of determining an 80% percent discharge works because as the pack rests after the flight, the resting open circuit voltage recovers slightly, perhaps up to 3.78 - 3.80 volts or so.

I for instance use these little inexpensive LiPo battery monitors after most flights to gauge my flight times to ensure I'm not over discharging my packs much past 80%. These ones I use work with 2S to 6S LiPo packs.

They are also very useful to quickly identify fully charged and discharged packs when you get them mixed up by mistake so you don't accidentally put a discharged pack in your machine thinking it was fully charged.

Not sure about you, but when I go out for a full day of flying, I can easily have a couple dozen LiPo's on the go and it doesn't take much more than a simple interruption or memory lapse to get packs mixed up.

You just plug the little rascal into your balance plug on your LiPo battery after the flight (or drive) and it will show the voltage of each individual cell in sequence, followed by the full voltage of the LiPo battery pack.

Checking 80% LiPo Discharged Voltage

You can see in the photo above I have plugged the little monitor into this particular 5000 mAh 6S pack's JST-XH balance plug in a Bell 206L scale heli that I just finished building to get an idea of flight times to correctly set my flight timer. All cells in the pack were showing about 3.74V after this 8 minute flight which again is pretty close to an 80% discharged state.

So I set the timer to 8:00 minutes and it's working great (confirmed by charging the pack on a computerized charger to see how much capacity it takes). It should take about 4000 mAh of charge (80% x 5000 mAh).

I have at least half a dozen of these little monitors and take at least two or three out to the flying field to be sure I can always easily place my hands on one. Some are not that accurate however, so it's best to check them against a good calibrated digital volt meter or a good computerized charger that shows individual cell voltages to confirm they are giving accurate voltage readings. Generally, the cheaper they are, the less accurate they are.

Speaking of timing your flight, this is the standard way most of us use to know when to come back and land. All computerized RC radios these days have throttle stick activated timers for this very reason.

I *"usually"* find timing a flight just as accurate as having some sort of low voltage monitor or telemetry voltage warning for the exact same reason I mentioned above; voltage readings under load give unreliable state of charge accuracy because loads are always changing which cause the Li-Po battery voltage to dip and spike as well.

That said, if you have telemetry to monitor real time flight battery voltage - USE IT (if track rules allow)!

Telemetry is now offered on more and more computerized RC radios and is coming down in cost every year it seems. It's such a wonderful tool we now have that will warn

you if a cell in your pack is taking a dump during the flight or the pack is draining unusually fast for some weird reason; both of which timing won't catch.

Lastly, you may have simply put a discharged pack in your bird thinking it was fully charged (guilty as charged on more than one occasion), and telemetry will save the day.

All 3 methods in other words (timing, telemetry, and capacity during charging), will ensure your LiPo packs are rarely being over discharged. **:-)**

"I Just Over Discharged My LiPo - Is It Permanently Damaged Now? Can I Still Use It?"

Oh boy, I get this question a lot!

I'm afraid there are no hard rules here. I've certainly done it myself and more times than not, yes, the battery will be damaged. So much depends on the quality of the battery, size/capacity of the battery, how it was being used when it got over discharged, and how long it has sat in an over-discharged state.

For example, if you were flying/driving and sucking a fair amount of current when your Li-Po dropped to, or under 3 volts per cell, it's pretty much a given that the cell/battery has had a large amount of its usable life just sucked out of it.

It may not even be safe to use again. The larger capacity the battery and higher the current draw, the more likely damage will occur from the heat and gassing that's produced when over-discharging. Gassing will be covered shortly.

On the other end of the "abuse spectrum", if you over-discharge a smaller capacity LiPo battery down with very little current, it may be okay. Again, it all comes down to how much heat is generated when it's being over-discharged. The more heat, the worse the damage.

I have for example, over the years *accidentally* left a few LiPo RX (receiver) batteries powered up for several days (sipping milliamps), and by the time I realized my total brain-fart, they were dead. I mean stone cold dead - zero volts! Paper weights with no voltage potential whatsoever.

The only way I could even get them to charge was to force voltage into them until they built up enough voltage potential that my LiPo charger would allow me to start a normal LiPo charge cycle.

A few, not all were fine. Again, it all depends on the load that is being drawn and very likely the quality of the battery pack. I've done the same thing with some TX (radio) LiPo packs, and every single one was toasted! Of course ***catching them as soon as you can*** to hopefully bring them back to life will help your odds substantially.

Some of those RX LiPo packs are still going strong after 5 years, but again, these are in low current applications. A main flight pack on the other hand, I would be very suspect of moving forward, even if you were able to get it to charge up and it seems to work.

You would certainly want to check how healthy such packs are, and often to make sure they are not about to take a mid flight dump on you or light the race track up in a flaming ball of carbon fiber glory.

Which is a nice segue into our next topic - internal resistance!

Li-Po Battery Internal Resistance

Another rating???

Sort of... More of a measurement to be exact; but one that could be considered a rating in terms of cell performance, efficiency, and what's important to many of us - **health!**

Internal resistance of both the battery and the individual cells within the battery is one of the **very best ways to monitor your RC LiPo battery's condition both when new and as it ages.**

As far as I'm concerned, internal resistance of your LiPo's is one of the most important data sets you can monitor in this hobby, yet it's rarely discussed.

A very simplified way to think of internal resistance is how efficient the battery pack (and cells within the pack) are at flowing power from the battery to your model. The higher the internal resistance, the less efficient the pack is.

Just think of it in the same context as putting a big stinking resistor between your battery and your ESC/motor. The higher the resistance is, the larger the voltage drop will be, and the more the resistor (the battery in other words) will heat up, and the slower your motor will run.

Most decent higher capacity and higher discharge rated LiPo cells will have very low amounts of internal resistance, numbers of **2 to 6 milliOhm's** (0.002 to 0.006 Ohm's) of internal resistance when brand new are typical. Smaller micro sized LiPo cells will have higher resistances. It's not unusual for example to measure internal resistance numbers in the region of 200 milliohms on smaller 100 to 200 mAh micro park flyer LiPo cells when they are brand new.

In short, the smaller the capacity, the higher the internal resistance.

To calculate the total internal resistance of a series wired pack, you would then add these cell resistance numbers together. As an example, a 4S pack with each cell having 4 milliohms of resistance will show a total internal resistance of about 16 milliohms (0.016 ohms).

To calculate voltage drop of this pack, we then would use good old Ohm's law (V = I x R). A real world current draw number for a larger electric powered RC vehicle might be around 50 Amps, so plugging that into our formula would be V = 50A x 0.016Ω giving us a voltage drop of 0.8 V.

As the LiPo pack ages, the resistance always increases and that voltage drop will get higher and higher, causing the motor to run slower and slower. The pack will likewise run warmer and warmer, and will slowly lose capacity as well.

So, the best way to use internal resistance (if your charger supports this very useful function) is to take an IR reading of your LiPo/s when it/they are brand new.

I will then write that number (or the IR of all the cells in the pack) somewhere on the pack with a permanent marker so I will always have a brand new IR base reference for that particular battery. I then put some clear tape over the numbers so they don't slowly rub off over time.

As this pack ages, or if I ever over-discharge it, I can simply reference how the resistance is increasing, or if one or more cells is/are getting ready to take a dump!

Another IR tip is to **measure IR at the same temperature** when you are comparing IR readings. As LiPo cells warm up, ion exchange efficiency increases, and therefore, the internal resistance decreases. I normally take readings while packs are at room temperature as in that example above. If I took an IR reading right after a hard flight when that pack is "toasty", most of those cells would be reading 1 milliohm or less.

How do you measure internal resistance?

This again is where good computerized chargers come into play. The good ones that support this feature will check the "IR" of each cell. Note: Most chargers are not very accurate when compared to other chargers. Use this method for comparing YOUR packs.

Charging LiPo Batteries

Charging RC LiPo Batteries is a topic in itself. To start, here's a short video I made going over the simple basics of the process on a typical "4 button" type charger (the most common type of computerized RC charger).

LiPo, LiIon, and LiFe batteries obviously have some very different characteristics from conventional RC rechargeable battery types. Therefore, charging them correctly with a charger specifically designed for lithium chemistry batteries is critical to both the lifespan of the battery pack, and your safety.

Maximum Charge Voltage and Current

A 3.7 volt RC LiPo battery cell is 100% charged when it reaches 4.2 volts (Note: HV cell (3.8v) is fully charged at 4.35v). Charging it past that will shorten life substantially. In fact, the cell phone industry did a study looking at the effect of LiPo fully charged voltages in relation to cycle life. These tests were done under ideal laboratory conditions and of course the 80% depth of discharge rule was obeyed! Here are the results:

- **Charge to 4.1V gave over 2000 cycles.**
- **Charge to 4.2V gave about 500 cycles.**
- **Charge to 4.3V gave under 100 cycles.**
- **Charge to 4.4V gave less than 5 cycles.**

Folks in the RC world have reported similar results and one ongoing test seems to indicate if you set your maximum charge voltage to 4.15 volts per cell (if your computerized charge gives you that option), you should be able to get about 800 cycles (again if all the other LiPo usage rules are religiously obeyed).

More and more people are considering this 4.15 termination voltage the "***sweet spot***" for both performance and cycle life for RC usage. Most RC chargers don't give you that ability, but if yours does, you may want to consider it.

*One caveat to this I should mention are the new generation of "**high voltage**" LiPo cells. There are a few manufacturers that are producing LiPo cells that can handle as high as 4.35 volts and maintain a 500 cycle life.*

No matter what your maximum charge termination voltage is, keeping each cell in the RC LiPo battery pack at that same voltage is another important rule to understand once I start talking about **Balancing** RC LiPo batteries, so keep that in the back of your head for right now.

It is critical that you use a charger specified for LiPo batteries and select the correct voltage or cell count when charging your RC LiPo batteries if you are using a computerized charger. If you have a 2 cell (2S) pack you must select 7.4 volts or 2 cells on your charger. If you selected 11.1V (a 3S pack) by mistake and tried to charge your 2S pack, the pack will be destroyed and most likely catch fire. Luckily, all the better computerized chargers out there these days will warn you if you selected the wrong cell count.

All LiPo battery chargers will use the constant current / constant voltage charging method (cc/cv). All this means is that a constant current is applied to the battery during the first part of the charge cycle.

As the battery voltage closes in on the 100% charge voltage, the charger will automatically start reducing the charge current and then apply a constant voltage for the remaining phase of the charge cycle.

The charger will stop charging when the 100% charge voltage of the battery pack equalizes with chargers constant voltage setting (4.2 volts per cell) at this time, the charge cycle is completed. Going past that to 4.3 volts (except for HV cells) will shorten battery life substantially as we have already seen.

LiPo Battery Charging Current

Selecting the correct charge current is also critical when charging RC LiPo battery packs. The golden rule here remains to be "***never charge a LiPo, LiIon, or LiFe pack greater than 2 times its capacity (2C)."***

For example a 2000 mAh pack, would be charged at a maximum charge current of 4000 mA or 4.0 Amps. Going higher will shorten the life of the pack. Moreover, if you choose a charge rate significantly higher than the 2C value, the battery will heat up and could puff up.

Higher than 2C charge rates...

Most LiPo experts say you can safely charge at a 3C or even 5C rate on quality packs that have a discharge rating of at least 20C or more and have low internal resistances safely, but it will reduce LiPo life.

Even though there are more and more LiPo packs showing up stating 3C, 4C and even 5C charge rates; this is just indicating it's still safe to charge at those rates and not risk thermal runaway within the battery; but it really has nothing to do with actual battery life. The simple fact is constantly charging any LiPo over 2C will have an impact on its life expectancy.

I will charge at higher than 2C rates on occasion when I'm in a rush to get out to the field or want to get into the air again quickly; but I always try to charge at 2C or lower rates most of the time. It all boils down to **speed vs. life** and your budget. If you don't mind taking some life out of your packs in favor of getting back in the air or out on the track ASAP, then charging at higher C rates might be a viable compromise for your particular needs.

I would also strongly recommend never charging over 2C if the ambient air temperature (and the pack) is over 30C (about 90F).

The seven main things that shorten LiPo battery life are:

1. **HEAT**
2. **LEAVING A LIPO FULLY CHARGED FOR SEVERAL DAYS**
3. **OVER DISCHARGING (voltage & current)**
4. **OVER CHARGING (voltage & current)**
5. **INADEQUATE BALANCING**
6. **IMPROPER STORAGE VOLTAGE (more on that shortly)**
7. **PHYSICAL DAMAGE (dropping, over tightening straps, prying cells apart, using too much/too strong Velcro etc.)**

RC LiPo Battery Balancing

Finally onto RC LiPo battery balancing – what is balancing and why it's important?

Remember me telling you to keep the 100% charged voltage value of 4.2 volts per cell in the back of your head? Well, here is where that number comes into play. For a single cell (3.7 volt LiPo battery) you don't have to worry about balancing since the battery charger will automatically stop charging when the 100% charge voltage of 4.2 volts is reached.

Balancing is required however on any LiPo battery pack that has more than one cell since the charger can't identify from different cells and know if one might be overcharged even though the total voltage of the pack indicates otherwise.

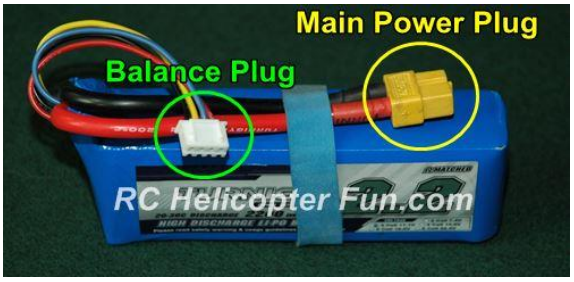
Balancing simply ensures multi celled LiPo batteries have the cells in the pack **within about 0.03 to 0.05 volts (30 millivolts) of each other**, so over charging or discharging of one or more cells won't ruin your battery pack, or become a safety concern with a large voltage difference between cells.

Some chargers will actually show you the balancing process in real time as shown in this photo while charging a 6-cell LiPo battery with my iCharger 4010 Duo.

There are individual loads being applied to cells 1 - 5 (shown with yellow arrows) that are discharging these individual cells slightly to keep them all at the same voltage (within that 0.03 volt range). The amount of load placed on each cell is shown by the bar graph beside the voltages; the more bars, the more load is being placed on the cell.

Circled in the bottom right corner, the maximum cell imbalance voltage of 6mV is displayed. This is the difference (delta voltage difference) between cell 6 @ 3.868V, and cell 3 @ 3.874V. These numbers constantly "dance" around during the charge cycle, always trying to maintain as little delta voltage difference between them all as possible.

RC LiPo Battery Balancing Plugs

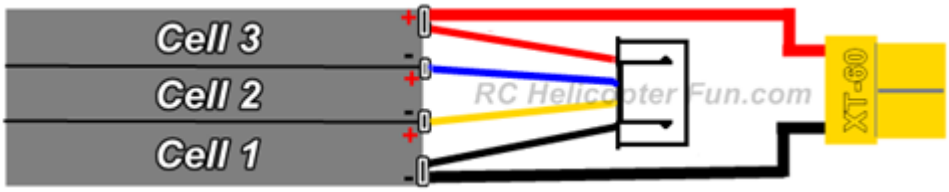


Okay, so now you know why a RC LiPo battery has to be balanced, the question now is how do you do it?

As shown in the photo above, every multi celled RC LiPo battery will have what is called a balance plug; also called a balance tap. This plug allows individual charging or discharging of each cell in the battery pack.

The balance plug will have one extra pin/wire than there are number of cells in the pack. The battery in that photo is a 3S (3 cells), and as you can see it uses a 4 pin/wire balance plug. A 4S pack would have a 5 pin plug, a 5S would have a 6 pin plug, and so on.

Shown below is how these balance wires are connected to the individual cells of a 3S LiPo pack, allowing both charging or discharging of each cell independent of the other/s.



RC LiPo Battery

Wiring Schematic

How To Balance A LiPo Pack

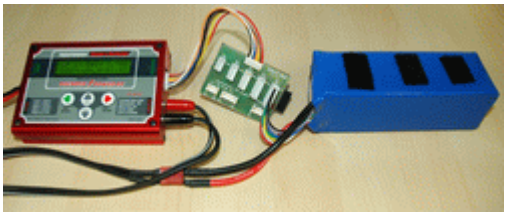
Charging Each Cell Individually Through The Balance Plug

Lipo's can be balanced while charging the pack through the balance plug with a balancing charger. This method uses the charger to individually charge each cell and ensure the voltages are the same in each cell as they charge.

Here a dedicated 3 cell charger is charging a 3 cell RC LiPo battery through the balancing plug/tap. The limitation using the balance tap for charging is the maximum charge rate.

Since the gauge of balance plug wiring and the plug itself are small, this method only works on smaller LiPo's or charge rates not much higher then 2.5 amps maximum.

A good clue if you are pushing too many amps through the balance leads would be a warm/hot balance plug/wiring. Depending on the balance plug and gauge of wiring being used, some people find even 1.0 Amps too much, so do monitor that plug and wiring if you do charge through the balance plug to ensure they are not getting hot.



Charging Through Main Plug While Charger Automatically Balances Through Balance Plug

The very best way to balance and charge a LiPo battery is by using a good computerized charger with built-in balance circuitry. With this set-up, the battery is charged through the main power plug and the balance plug/tap is plugged into what is called a balance board which is in-turn plugged into the computerized charger in most cases; however, some chargers will have the different balance ports built into the charger eliminating the need for a separate balance board.

The charger then puts a load on any cell/s the are drifting past the voltage of the others keeping them all in check. Chargers with built in balance circuitry also will either automatically select the correct cell count of battery (since they detect the number of cells through the balance plug); or warn you if you have the wrong cell count selected.

This feature offers one more very useful level of "goof-proofness" (not sure if that's a real word, but for me it should be).

Good computerized chargers with built-in balance circuitry, will confirm correct cell count, alter the charge & balance rates, and when balancing actually occurs in the charge cycle to ensure a "stress free" and safe charge/balance cycle that extends the useful life of the LiPo pack.

This is by far the safest way to charge higher capacity multi celled LiPo's and opens up a whole new world to more advanced charging methods such as multiple pack parallel charging.

RC LiPo Battery Balancing Plugs & Connectors

Balancing Plugs/Taps

Balancing plugs/taps currently come in several flavors and it is important to know which one your balancing charger, stand alone balancer, or balance board supports so you choose the correct plug type when purchasing your RC LiPo battery (or the other way around).

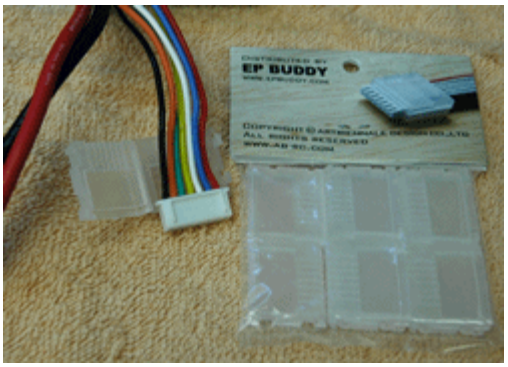
Balancing plugs/taps as I already mentioned, will have one more connector pin than the number of cells in the pack.

Here are the most common types of balance plugs...

JST-XH Plug

This is by far, the most common balancing plug type in use today. Used On: Align, E-Flite, Common Sense RC, Glacier, Gens-Ace, Great Planes, Esky, Electrifly, Losi, Rhino, Trinity, Turnigy, Nano-Tech, Pulse-Ultra, Venom, Zippy - just to name a few.

While on the topic of JST-XH balancing plugs, there are protection sleeves called AB clips that snap over the balance plug to give you something to grip while unplugging the balance plug instead of pulling on the balance wires (something I admit being very guilty of myself, especially after I started using para-boards while para-charging).



I started using these AB clips recently and they work so well to prevent the wires from being pulled out of the plugs because you can now actually grip the plug. They are super easy to install as you can see in the picture here. Just place the JST-XH plug in the unfolded AB clip and fold the clip closed - done!

Definitely a worthwhile purchase for the very little they cost! They are available in 5 sizes to fit 2S to 6S JST-XH balance plugs.

Thunder Power Plug

Used On: Thunder Power, FlightPower, Apex, EVO, MPX, Outrage, and a few other battery brands.

Polyquest Plug

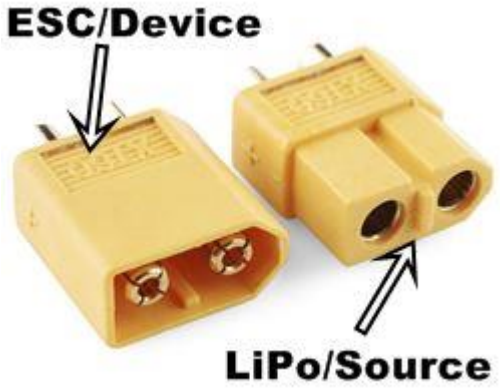
Used On: Polyquest, E-tec, True RC, Extreme Power, Impulse, Enermax, Hyperion, Poly RC, Xcite, Fliton, and a few others.

JST-EH Plugs

These are probably the least common type of balancing plug, but you will find them on a few big name battery brands such as: Kokam, Graupner, Core, and older Vampower battery packs.

You can get converters/adapters to use with different balancing plug configurations, but it is much easier and less costly if you just make sure you get the correct plug/tap that works with your charger/balance board when you purchase your LiPo battery.

RC LiPo Battery Main Power Connectors



Typical RC LiPo Battery Connector

I now cover RC Battery Connector types on my LiPo Battery Connector Page. This page includes RC connector types, power ratings, pros/cons of various connectors, and how-to videos if you are unsure of how to ***properly solder, splice, or crimp RC connectors.***

Many RC LiPo batteries and ESC's actually don't come with any connector/s (just the two wire ends insulated with heat shrink).

If you purchase a battery/ESC like that, make sure you purchase the correct connector/type and ensure your soldering skills are up to the task. Otherwise, better search for a battery/ESC that comes with the correct connector/plug type already in place.

Better Get Intimately Familiar With Soldering In This Hobby

Speaking of soldering; with all these LiPo battery plugs that will need replacing from time to time as they wear out (both on the battery and the RC model); you'll soon find out how necessary good soldering skills are once into electric powered RC.

If you're already a good solderer, great! If not, you better learn. **Soldering truly is one of the most important skills to acquire in this hobby!**

Again, I cover soldering with helpful videos on the RC connector page. I also cover soldering equipment in detail on my RC soldering for beginners page.

RC LiPo Battery Safety

I am not going to go into a lengthy safety speech here – there are enough warnings that come with Li-Po battery instructions that will give you all the information needed; specifically you should charge your LiPo's in a fire safe area and never unattended. That last point is easy to print in the instructions, but rarely practical in the real world.

Personally I don't have the time to sit down by my charging station in the workshop to keep an ever watchful eye on my LiPo packs charging - that is akin to watching the grass grow.

Here are my simple Li-Po charging safety tips that I follow :

- **I usually charge all my larger multi celled LiPo's directly on the concrete floor in the shop well away from any combustibles.**
- **I always wait at least 15 minutes after using a LiPo to let it cool down before charging it. This prolongs the life of the LiPo and prevents possible overheating and damage.**
- **I never ever leave the house (preferably the room) when charging LiPo's.**
- **I store all my LiPo's in a metal tool chest in various compartments so if one goes up in smoke it hopefully won't take them all. Ammo boxes are also an excellent choice (remove the lid seal however). I don't trust LiPo sacks or bags at all for storage!**

They are a complete waste of money for all but small packs IMO. You can pick up surplus ammo boxes for less money and they offer superior protection. Cheaper still are hollow concrete blocks or even ceramic/clay flower pots can work nicely to if you don't mind the weight & bulk. Cement board can also be used to make custom RC LiPo battery storage containers.

RC LiPo Batteries Safely Stored In Concrete Blocks

- **A visitor to my site told me about his very inexpensive safe charging area / storage solution - a used BBQ. You always see these things in the trash. Rarely is the housing of the grill damaged, they are tossed out due to internal burner corrosion or something similar. They offer great fire protection and are very much a "free" LiPo safety solution. Just might be the incentive to get a nice new shiny grill and use your old one for your LiPo's. A win - win ;-)**

- **Lastly – I purchased an inexpensive smoke detector that I have mounted above my charging area & storage chest so in the unlikely event a pack bursts during a charge cycle or while in storage, the smoke detector will sound and I will be alerted. I also have a small fire extinguisher mounted on the wall in my workshop for any fire that may occur, not just a LiPo fire. This all may seem excessive, chances are it is... but after watching the video below, I feel these are worthwhile precautions.**

I should also add, I've got well over 100 Li-Po packs now and never has one started on fire, even when I try to get them to start on fire. Still, it's cheap insurance and makes me sleep better knowing I have taken & continue to follow those safety steps.

Stay Safe, Use Ammo Boxes To Store Your LiPo's - Way Better Than Bags, Cheaper too!

A side Note: At Team Power Products, LiPo packs are stored in a heavy, double walled storage cabinet unless they are being tested or are being readied for sale. Large quantities are always stored inside the cabinet!

Most LiPo fires occur as a result of physical damage to the pack, (after a crash for example, or butter fingers dropping the pack on the hard concrete floor).

Over discharging the pack under high current loads can also let out the smoke and start a fire onboard your model as **thermal runaway takes over.**

Thermal runaway in a LiPo battery is a self sustaining reaction. Once started, this reaction keeps "fueling" more heat to be generated until the cell or entire battery puffs up, and might if you are very unlucky burst into flame. Remember, over discharging and heat are a Li Po battery's two worst enemies.

Fires can also occur during charging (charging at too high a C rating or at too high a voltage), and resulted from a human error.

Keep all that in mind if you feel these batteries are too dangerous.

RC LiPo batteries are fairly safe if the rules are obeyed. They are basically as safe or dangerous as you are; but that's not to say there can't be the odd weird pack/cell failure due to a shorted wire, cell, similar.

LiPo batteries are high energy storage devices, and just like any high energy storage medium such as gas, nitro fuel, or jet fuel; a LiPo also has the ability to give off the energy very rapidly.

"Puffed" LiPo Batteries

Puffed LiPo Battery Cell - OUCH!

I really got an appreciation of how strong a Li Po battery pouch cell is when something goes drastically wrong.

The above picture of a fairly new 6s 5000 mAh pack that had a faulty cell and shorted internally during a flight. This one cell (the front one) experienced thermal runaway, completely ballooned and got very hot! Too hot to touch in fact, and I was sure the entire LiPo pack was going to blow after I landed.

That was not the case however and the plastic pouch cell contained all the vaporized electrolyte (process called gassing). It was tight as a drum mind you, but no venting or fire occurred.

What Causes LiPo Puffing?

As was just mentioned, swelling up of a LiPo cell is caused by gassing of the electrolyte. If you really want to impress your buddies out at the flying field or race track, tell them this process is called ***"electrolyte decomposition."***

Electrolyte decomposition is the chemical breakdown of the electrolyte into its primary elements, mostly lithium and oxygen (lithium oxide - Li2O).

This compound will be deposited on the anodes or cathodes of the cell (depending if you are over charging or over discharging). The puffing happens when excess oxygen in this reaction is also released. Another reason why LiPo's are even more flammable during/after puffing - they can contain a fair amount of oxygen.

A good number of other elements & compounds are also released as the electrolyte decomposes such as CO2, but the main ones we should know about are Li2O with excess O2. If you want a deeper understanding of the chemistry involved in this complex process, here's a good article.

Is it normal to experience swollen or puffed RC LiPo packs? Can I still use a LiPo that is puffed?

As we just found out, LiPo cells can & will swell. It's actually somewhat normal as they age since electrolyte decomposition is occurring all the time. The speed at which it occurs, and if excess O2 or CO2 is released, is based on many factors including how hard you run the packs, how fast you charge them, their age, the quality of the packs, and of course how much they heat up.

As long as it is very-very minor swelling & goes away after the pack cools down, it has been my experience that you can usually still safely use the pack and keep the swelling in check; likely not to its full discharge potential however.

Remember earlier in this write-up where I mentioned the importance of having the internals of the LiPo cell (anode, cathode, & polymer separator), all pressed and held tightly together for maximum ion exchange, which in turn provides the lowest possible internal resistance. What do think happens when the cell puffs up slightly?

Yep, that strong "pressed" lamination bond between all those layers, can be compromised, not to mention the electrolyte has partially broken down. Which in turn

increases the internal resistance, which creates more heat while used, which creates even more puffing and can lead to good old thermal runaway!

Every "puffing" incident will be different depending on how much LiO2 & excess O2 has formed, and how much internal delamination between layers occurs.

If the internal resistance of a swollen cell is significantly higher than the other/s in the pack, that would be a damn good indicator too much Li2O has formed on the anode/cathode, and/or the bond between layers has weakened too much, and good reason to **stop using that pack right away.**

If however the internal resistance has not increased much with that slightly puffed cell, then it's still likely okay to use with relative safely, if you are careful.

As packs age, the swelling can and usually will get worse. It's basically a positive feedback loop. The initial puffing incident causes the resistance to increase, causing the packs to run hotter, increasing gassing, making the puffing & delamination worse, decreasing ion exchange efficiency, increasing resistance even more.

As a LiPo pack/cell is nearing the end of it's useful life it can show some very minor swelling that won't go away, even after the pack cools. This pack ***may*** still have some nice non aggressive flights or drives left in it, or it could be a ***ticking time bomb that is primed for a thermal runaway event!***

Some feel once a LiPo battery is showing any swelling whatsoever that won't go away, they are not safe to use and must be disposed of.

My own experience is as long as the internal resistances between slightly puffed & non puffed cells remain fairly equal, they all still balance up fine during the charge cycle, and they all still accept most of their charge capacity; as long as you treat them kindly with gentler flying/driving, you can generally get more safe cycles out of them.

Still, you are doing so at your own risk!

When in doubt, send permanently puffed LiPo packs/cells to the LiPo grave yard (AKA, the trash can **once fully discharged**).

Please Check your local bylaws for LiPo battery recycling. Not all areas allow disposal in the trash.

Puffed Lipo Fixes

Despite what you may have read or seen others do on the good old interweb, there is no safe or realistic way to vent or "de-puff" a swollen LiPo cell or battery and expect it to last afterward.

Regardless of excess build up of Li2O, possible delamination, and decreased ion exhange efficently which have all occurred; if you poke a tiny hole through the cell to

vent the O2, you have just introduced another problem - air contamination. Water vapor, even in tiny amounts will quickly cause more unwanted reactions within the cell and produce even more off gassing.

I've tried to vent puffed LiPo cells numerous times, even in a clear plastic bag filled with inert argon welding gas during the process. I pressed the cell tight after it vented, and then sealed the tiny pin prick hole.

Internal resistance on every swollen cell I've tried this on increased very quickly afterward during the first use, and soon the cells were more swollen than before with off the chart internal resistance values.

All were useless and dangerous afterward! DON'T vent puffed cells!

LiPo Battery Storage

We now know how a LiPo battery is made, how it works, the safety concerns, what to look for when purchasing one, how to charge and balance one, why over discharging is so harmful, internal resistance, and what puffing is all about; what more can there be to cover?

STORAGE!

How you store your LiPo's between uses will greatly affect their life span as well.

As I mentioned, a LiPo cell that drops below 3 volts under load (about 3.6V open circuit voltage) is almost always & irreversibly damaged. It will have reduced capacity or total inability to accept a charge due to cell oxidation. If your batteries are stored for any period of time after you use them at close to that magic 3.6 volt per cell number, you risk irreversible damage.

As batteries sit, they will naturally self discharge. LiPo's are actually very good in this respect and self discharge much slower than most other rechargeable battery types, but they still do lose capacity as they sit (about 1% per month). If you leave them for a number of weeks or months in a near fully discharged state, chances are they may be irreversibly damaged as the cells oxidize.

You must store them charged, **but not fully charged either** – that will also degrade/oxidize the cell matrix.

Fully charged LiPo batteries are not happy and must be used soon after they are fully charged.

Basically, the speed at which a LiPo pack ages (during storage) is based on both **storage temperature and state of charge.**

You are likely okay to store a fully charged RC LiPo battery at room temperature for up to 2-3 days without doing too much damage. Never ever store a LiPo in a hot car fully charged for an extended time, that will certainly cause damage (puffed and may even vent) as I explained earlier, but it's worth repeating.

For optimum battery life, store your RC LiPo batteries in a cool room if possible (slows down the chemical reaction) at about a 40-60% charged state. That equates to around 3.85 volts per cell (open terminal resting voltage).

The actual storage range is likely a little broader than this.

I've heard some say numbers as high as 30-80% are fine; but since computerized chargers set the storage charge at 50% (3.85 volts per cell) that's what I recommend and what I follow myself.

You can actually extend the fully charged storage time from a couple days to weeks by storing your batteries in the fridge (not freezer) close to 0 degrees Celsius (32F); again, that helps slow down the chemical reaction that oxidizes the cathode in the cells.

I often do this with my smaller packs seeing that I will often find myself wanting to go flying little micros with little lead time and it is very convenient having packs all ready fully charged.

If you do store your fully charged LiPo's in the fridge, pack them in a zip-lock freezer bag and squeeze out all the air before sealing the bag. This will prevent condensation forming on the battery packs when you take them out of the fridge as they warm up. You should allow the LiPo pack to warm up after removing from the fridge before using it of course. Small micro LiPo's warm quickly, big packs don't. This is why I only use the "fully charged cold storage" method with micro packs.

I only store in cold temps if I know I will be flying within a 2-3 week time frame. It wouldn't hurt to store at 50% charge capacity in the fridge all the time either; but it takes up precious beer chillin' real estate (priorities you know).

RC LiPo Battery Conclusion

Wow, this RC LiPo battery basics was a BIG topic and the single longest write-up page.

I hope you now have a better understanding of what makes an RC LiPo battery tick, what to expect, and how to properly care for them. Hopefully saving you from a few costly, and potentially dangerous mistakes.

On top of all that, what I really wanted to get across is that even though electric powered RC flight may not seem as complicated or fussy as fuel powered; **there is much more to it than most people first realize**.

My RC Helicopter eBooks are here to help you with those exact problems.

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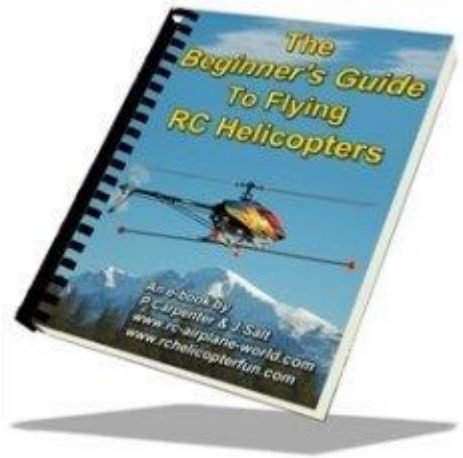

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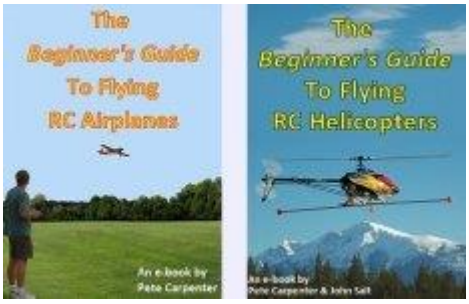

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