The Truth about Lipo's by Peter Barrow

Updated Sept 2013

Introduction.

Lithium technology, used as I have since they came out, can be very rewarding. I have tried to make this user sheet to point out both the good and bad points. They can be used as successfully as Nimhs and NiCads.In the late 1970s I can remember people getting their hands damaged by exploding NiCads. But we learned to use them reasonably safely. Lipos are becoming safer, because we are becoming to understand what we can and cannot do with them. Some of the makers of lipos are on there 6th or 7th generation cells now. These latest cells are subjected to some very stringent tests to make them even safer.The following is my own personal research from the web and experiences over the last 6 years of using lipos.

History

Lithium ion cells were first thought of in the early 1960s and the first commercial cell came from Sony in 1991. This revolutionised the portable electronics industry. Their have been numerous improvements over the years and lot of legislation to make them safer before they were allowed to be sold to the public. The latest requirements are the following: verification of compliance now required by UL1642, UL2054 and SBA G1101. These requirements included crush and penetration tests.

Also now Robbe have this statement on their cells (this is a simplified version of the kokam pages): Extra safety: Specially treated Lithium material: batteries do not burn and do not explode, even if mishandled in any of the following ways:

- Drilling a 5 mm Ø hole through the pack
- Bending the pack along its length with a force of 13 kN
- Slitting the centre of the cell, approx. 15 mm
- Heating to 150°C for ten minutes
- Overcharging at 5 Volts and 0.4 C for about 2.5 hours
- Reversed-polarity charging at 5 Volts and 0.4 C for about 2.5 hours
- Short-circuiting with 100 mOhm for 2.5 hours

http://at.robbe-online.net/rims_at.storefront/en

So even the main retailers are showing how safe there cells are. These cells are the lastest generation. I would advise everyone who buys Lipos to only buy cells that are rated 20c or greater. These cells have past the compliance regulations.

Basics

Lithium polymer and Lithium Ion cells are similar technology. The main differences are: Lithium Ion cells tend to be in cans like Nimhs and now in similar packs to lithium polymer blocks. Lithium polymer cells comes in plastics sacks with a special polymer insulation material between the plates in the sack. These packs are made up in blocks.. They are also lighter than lithium ion. The nominal voltage for a lipo

cell is 3.7 volts which is part charged. The nominal voltage on lithium Ion is 3.3v. Again, this is the part-charged status. These are the cell equivalents we tend to use to work out what number of cells to use. NB: this tends to be a industry standard.

- 2 cells = 6 cells 7.4v
- 3 cells = 10 cells 11.1v
- 4 cells = 12 cells 14.8v
- 5 cells = 15 cells 18.5v
- 6 cells = 18 cells 22.2v
- 8 cells = 24 cells 29.6v

Disadvantages

A drawback of the lipo battery is that its life span is dependent upon aging from time of manufacture (shelf life) regardless of whether it was charged, and not just on the number of charge/discharge cycles. However, this is far better for the modeller than the latest Nimh cells that degenerate almost in front of our eyes. At a 100% charge level, a typical lipo battery that is full most of the time, kept at 25 degrees C or 77 degrees F will lose roughly 20% capacity per year. The capacity loss begins from the time the battery was manufactured, and occurs even when the battery is unused. Different storage temperatures produce different loss results with a fully charged cell:

- 6% loss at 0 °C (32 °F)
- 20% at 25 °C (77 °F)
- 35% at 40 °C (104 °F)

When stored at 40% - 60% charge level, these figures are reduced to 2%, 4%, and 15% at 0, 25 and 40 degrees Celsius respectively. This can be reduced by storing your cells in a cold room or fridge. Cells must be stored around 40% charged in a cold area 0c to 10c. This reduces loss in capacity to around only 2% a year. So a 5000mah pack will only lose 100mah in capacity. As batteries age, their internal resistance rises. This causes the voltage at the terminals to drop under load, reducing the maximum current that can be drawn from them. Eventually they reach a point at which the battery can no longer operate the equipment it is installed in for an adequate period. This varies from maker to maker. Some will only give 50 or 60 charges. Where as some will give over 700 charges.
Also there are problems charging unbalanced cells. This can be very dangerous. Also high and low temperatures are not the friend of lipo cells. A cell going above 60c will lose performance and will balloon. A cell going above 70c will break the bag. Newer types of cells will not explode or burst in to flames, but give out a gas and smoke (see the link in the history section). Older cells will ignite and you will not be able to put the fire out. If you have several cells together, the 1st cell will burn and when you think it has gone out, the next cell will ignite. Also sub zero temperatures can cause damage to your cells. Any prolonged sub zero temps can cause cell to go out of balance or to balloon within a couple of charges. Any cell going in to deep discharge (below 2.8v) can be irreversibly lost. Some times by using a good charging system they can be brought back to life. But the charge time can increase to over 40 hours. So be patient. Also going above 4.23v reduces the

life of the cell and if the voltage continues to climb can cause the cell to balloon and degrade.
There are folded and flat plate cells. The folded cells have a greater internal resistance and are heavier. These cells get hot very quick in our applications. The Graupner cells I tried recently went over 60c in a mono 1 and only lasted about 8 runs before my Schulze charger would not charge them. They were shown on the Graupner site as 100 amp discharge and having a 4800mah capacity. The flat plate types are very thin in comparison and lighter. They have a lower internal resistance. These are the best types to use. They have C ratings up to 70C now, but they are larger. Some of the newer cells are over 8000mah but are either very long or quite bulky.

Advantages

Lipo batteries do not suffer from the memory effect. They also have a low self-discharge rate, compared with anything with a Nimh Cell. We know some Nimhs that will lose over 30% per day. Some are less, but the average is over 30% per month in Nimh batteries and 10% per month in NiCad batteries. The loss is voltage rather than capacity. I have recently done some tests to check this out. lipo's take around 5 or 6 charges before they are at there best.
Maverick 5000mah 20C cell.

- Charged at 5 amps from flat: 5647mah in
- Discharged at 2.5amps on auto on a schulze 5324mah out.
- Charged at 5 amps from flat again 5653mah in
- Left for 48 hours and discharged 5298 mah out

If we left Nimh cells for that time we could have lost anywhere from 10% to 50% or some I have had this year could be flat. The cells were left in a cold shed during the test. The main advantage is there weight. A 4s 6200mah pack will be around 560 grams (including cables), against 840 grams for the 12 Nimh cells (plus solder, connecting bars and wire). Some of the new types of lipo are getting lighter.Zippy compacts 4000 3s 11.1v weigh less than 260 grams now. Also the latest ETTI and Tenshock 3s 11.1v 4500mah pack are also below the 280grams. They are also similar in size to a 6 cell Nimh pack and thinner. Some of the latest car packs are over 7000mah 2s 7.4v and they also weigh less than 280g. Another advantage is voltage and capacity: The Voltage between charged and flat is 4.2v to 3v. This is only a 29% drop. But a Nimh drops from 1.5 volts to 1 volt; a 33% drop. The speed we would run at the end of the race would be faster than with the Nimh's. The capacity advantage come from the higher discharge rates allowed. For example: All the GP Nimh cells we have been using are only rated at 30amps. As the Nimh's have increased in capacity, the output rating has not changed. where as the lipo's are rated in C rates. IE if a 5amp capacity lipo is rated at 15c then the maximum discharge is 15x5 = 75amps. 5amps at 20 c = 100amps and 5 x 30c =150amps. Therefore we gainin the voltage not dropping and we can actually get the capacity out of the cells. Most good lipo's rated at 5000mah will give nearly out there amp hour capacity at there maximum constant discharge rates. Here are some test figures:

- All the cells were discharged at 48amps.
- Maverick 5000ma 4637 ma out
- Fullymax 5300ma 4492 ma out

- Kokam 4800 ma 4327 ma out
- Graupner 4800ma 3521 ma out
- The test on the Graupner cells was cut short due to temperature going above 60c. How ever the voltage was almost at the switch off point, so they would have only run for another couple of seconds.
- These test figures were done a while ago.

The latest lipo's have no problems delivering high currents. There are cells with 75c discharge rates.
Example of the differences in performance.
My hydro 2 does 4minutes 20sec with the GP4600 cells. With the 5000mah Lipo I get nearly 6minutes. Doing the calculations gives us: GP 4600 (4.4capacity @ 30amps) amps 4.4 x 60 = 264amp minutes ÷ 4.33 = 61amps average discharge rate. A maverick 5000 (4.8capacity @ 50amps) 4.8 x 60 = 288amp minutes ÷ 6 = 48amps average discharge rate. (Also over the years while using Lipo's lap times have increased dramatically. Or is it? Maybe it is because the NiMH gets very hot and loses so much energy in heat. The heat has to come from somewhere and the only available energy is the cells. However the lipo's come off a lot cooler. Therefore being more efficient. We all know that if we discharge at higher rates then the run time comes down, but if the cells were designed to be discharged at higher rates then the voltage drop would not be as bad. That's where the lipo's have a major advantage. With the high discharge rates we have even in mono 1 the capacity is dropping in the Nimh cells every run. Also because we discharge the Nimh's at high rates there life span is limited. We have had quite a few Nimhs cells blow up over the last season. Even the Germans were having problems with limited life span and exploding Nimh's. They have now been running Lipo's for a few years now.
There were some tests done, where some Lipo's were charged and discharged until they reached 80% capacity. They varied from 75 charges with a well advertised lithium retailer to 750 charges for kokams. They were charged at 1 C and discharged at 50amps. At the moment some of the cells I am using have been used since last season and are still going at the last meeting in September and no reduction in performance. That's over a season of meetings for less than £50. Some of my Kokams that I use for flying are over 9 years old and still working. On average if you buy good cells you should get a lot higher number of charges than Nimh cells. This is dependent on usage, storage voltage and the Storage temperature. The other main advantage is that it levels out the racing. In Belgium this year 2013 at the World championships. Lipo's were very evenly matched. Your boat and your driving made more difference than the batteries.

Selecting Equipment

- An area not covered yet is chargers and controllers. Most of us that have bought controllers and chargers in the last couple of years, will have noticed they are all lipo compatible. All the latest controllers for brushless motors are lipo friendly. Some controllers can be programmed to set the cut off voltage for the Lipo pack manually as well, but most are automatically set. If you set lipo mode, they detect the connection voltage and this in turn sets the cut off voltage. This is one of the disadvantages of the new A123

cells. They have a lower voltage per cell and at the moment the controllers are very few. Some of the controllers can be set to NiCAD mode for A123 Cells. They then work on a percentage of voltage change. The NiCAD setting is similar to the A123 voltage differences from full to empty. This is the same for charging the A123 type cells. A special charger that charges Li-fe or Li-Fe4po4 is required for A123 cells. There are a few chargers about for charging the Li-Fe cells, like the cheap Schulze lipo card2. Of course the more expensive schulze chargers will charge Li-fe cells as well as nearly every thing else. However the use of A123 cells(Li-Fe4po4) in Boats has stopped and Lipo's are used in the main. So if you are investing in a new charger. Check for the following:

- Charges as many different types of Lithium cells as possible.
- Check the makers web site for up dates for the charger. If you can do it your self, send off for up dates or last of all send it away.
- If your buy a cheap charger be prepared to change it as new technology comes along.
- Built in balancers can be cheaper.
- Look for one that charges at least 8S. This will help when charging the lower cell counts
- Only buy an expensive charger if you need to charge faster than 6amps or large cell counts. Or unless it charges more than one pack at a time.
- At the lower end on price. The charger must have leds for error warning or connectors for connection to a PC for checking every now and then.
- Check to see if you can set the final charged voltage of each cell. A lot of the cheaper chargers only charge to 4.18v to 4.20v per cell. The official max voltage per cell is 4.23v. For Boat racing world wide
- Chargers for Lipo's with balancers start from around £40. I have tried a cheap one with balancers built in and it worked great. It even gave me individual voltages for the cells.
- The lower cost chargers can take several hours to charge a pack because of a number of reasons. First and most common reason is the voltage multiplier's are smaller and second reason is the balancer limits. The balancer discharge rates can be only a few milliamps. Even the expensive Schulze system has only a 1 amp discharge system on the balancer. The higher the balancing rate the quicker the balancer will work. If you are only charging low cell pack numbers. Ie., up to say 4s then you are better off using several low cost chargers with balancers included, than one expensive charger.

How to get started

When first selecting which lipo's to buy I follow these general rules:

- Always read any instructions that comes with any item used with Lithium cells
- Always take precautions when charging lipos
- Try and charge outside. If you cannot monitor the cells on a regular basis.
- Look which cell's the other racers are using. If they are not for racing then use cells with a good c rating. Ask if your not sure.
- Always check on different web sites the C rating on the cells to compare the details.
- If you know anyone using lipos ask them for info on what equipment they are using and which cells.
- Charge/discharge new cells at half rate prior to using in full race conditions, this helps get the cells "used" to the discharges that will be expected and lengthens their life.

IMPORTANT

IF YOU ARE ALTERING YOUR CELL PACK CONNECTORS IN ANY WAY, PLEASE ENSURE THEY ARE 100% INSULATED WITH EITHER INSULATION TAPE, FIBREGLASS TAPE OR KONTRONIK GOLDFIX ELECTRONIC TAPE. PLEASE DO NOT USE ANY CELLS WHICH HAVE BEEN DAMAGED IN ANY WAY.

- Buy a reasonable charger. There are good balancing chargers from around £60 upwards.
- If you already have a good charger that does lipos. Then get it up dated to the latest software if possible and buy a good balancer. A good balancer will protect you and your investments. Most balancers are voltage balancers. When the charge finishes the balancer makes all the cells the same voltage. There are different types of balancer but these are more expensive. The schulze system balances the cells during charge. If one cell increases in capacity before the other it distributes the extra between the cells. This helps at the end of the charge by not taking as long to balance the pack. The Schulze system starts at around £65 for a 4 cell charger. Also IChargers are excellent value from around £85 to £250
- Always charge at 1c. If your pack is 5 amps charge at 5 amps or less. This will help with the life of the pack. The lower the charge rate the more life you will get out of your pack. Charging at a higher rate will not give you more power.
- Always balance yours cells when you charge them.
- If you fasten them in your model with sticky Velcro then put a band of heat shrink around your pack where the Velcro is going, before sticking the Velcro to the heat shrink.

- When racing you must charge on the day if you want the best performance or you part charge the day before. Then top them up on the day. Only part charge up to 75 to 80 percent and only the day before not any longer.
- Always allow plenty of time for the balancing if you use a voltage balancer on the day.
- If your model slows down unexpectedly bring it in.

What you must not do!

Problems usually come from the following reasons:

- Charging cells that have fallen below 2.75v after usage when not on load.
- Charging cells too fast
- Charging cells that are hot
- Discharging cells when the outside temp is too low (cells need to be warm if used around freezing point) A max warming temperature of 40c is allowed. Some racers warm the cells all the time. This helps to reduce the resistance if the cells are cold.
- Discharging cells over their recommended discharge rates.
- Using cells of the same capacity together from different manufacturers or using cells together of different capacities
- Using damaged cells
- Not balancing cells
- Not using a lipo charger for Lipo's is very dangerous
- Discharging your cells on a balancer and leaving them connected for long periods. Some balancers use power from the cells. This can take them in to low voltage. So check your balancers instructions. I always do a discharge and charge when checking capacity on Lipos.

Summary

Some times we have to make decisions we don't want to, unfortunately Nimh cells are too fragile for competitive use. They are costing between 4 and £10 per cell. This was killing our sport. The us of Lipo's has brought our sport to new levels. The Lipo system has had hundreds of millions of dollars thrown at it and with the latest safety features making them easier for everyone to use them safely. Batteries with the same power will be available to everyone. No one will be faster just because they have better cells. If you look after your cells you will get lots of charges from them. The transformation that fast electric racing has taken over the last few years, has see our sport grow to be even more exciting. Links for info:

- www.kokam.com
- www.tenshock-motors.de
- www.hydromarine.de
- www.overlander.co.uk
- www.plettengberg-motoren.de

Update September 2013

The info above was updated Sept 2013. Some parts have been left as the are the basic info that anyone running Lipos should know. Some info has been changed with the lipo's getting better.

Update August 2008

To date Lipo cells have come in leaps and bounds. There are a large number of retailers now selling cheaper cells. But I still stick to the main info in the article. Kokams are still by far the best value for long term use. However with the cells now going to 25c and some up to a questionable 33c, for competition use you may be better getting several cheaper packs and changing them as the rules may differ over time. Hopefully this will be settled at the Nats and give us 2 years of the same rules. 30c Kokams give hundreds of charges when used correctly. Some of the cheaper makes that quote a supposed 25c can be killed off in a hydro 1 or 2 within a few runs. They may give great power. But be prepared to change them regularly. I run a well know make of Lipo's and the power is really good and you will get a lots of runs, however as I run at the max temp towards the end of each run (55c+), I have to watch the prop and motors I run. At one lake a few months ago I had a faulty controller and the only spare controller I had was a Kontronik F5B aeroplane esc, this caused the pack to degrade. The Kontronik is a 150amp switch no speed variation to speak of. So I had to run flat out for nearly all the race. The lake is known for being very sticky as well (Burton Water then? - Ed. Some waters get "thicker" due to the constituents of the run off into them. that's a no - it was Elmbridge.) . The pack still works but the power is not there anymore. It is about 2 to 3 laps slower. So the pack is now only used for club running. It had been run for 27 times before.

Individual cell selection

One area I did not cover was individual cell capacity. If all manufacturers matched their cells, then balancers would not be needed to the same extent, I have a 9s4p pack of Kokams 1500mah cells (yes a 36 cell pack) where the cells were put together with exactly the same voltages to 3 decimal places 5+ years ago. They give me around 1.4kw output in a 1/3rd scale aeroplane. To this date they have been charged as one 9 cell pack and all are still in balance. For competition use you will see over this winter at least one UK importer mentioned bringing in single cells and matching them on capacity. These types of pack will give you even more power throughout the full length of the race and most of all the pack will last even longer. This is because you will find in all budget packs a variance the capacity between the individual cells. This is because the makers of the cells need a special machine which cost 1.8 million dollars to make every cell the same. The most advertised lipo importer in the UK said he would need 6 of these machines to keep up with demand and the cost would probably double at least the prices. Some importers have their own smaller testing equipment which costs about a £1000 for testing the cells and can match the individual cells. Therefore giving an even better pack. A pack I got in April from the same importer (4s 5000mah 25c) had the following:

- Cell 1 4473mah (Ouch! - Ed)
- Cell 2 4987mah

- Cell 3 5006mah
- Cell 4 5308mah.

Luckily I had a Schulze LiPODimatic in when I ran my Hydro 2. This monitors each individual cell and if the voltage under load drops below 2.8v (this can be set for different voltages) it cuts the power. I must point out that at this point I am waiting for a warranty exchange (27-08-08)

New Summary

With manufacturers putting more and more of the chemical pastes into the cells we will see the higher C rated cells going up in weight, however the lower Capacity cells will be giving more power out and more capacity out, which overall will be good for the high power applications that are weight critical. But most of all we should see good lipos being more readily available. The old story of very high selected NiCads and Nimh's will be long gone and it will down to your thumbs and setups not who you know. Most of the fast electric lads are now looking forward to a brighter and more competitive future. (Just goes back to you get what you pay for through reputable dealers. I'd like to add that my supplier does not add Cadmium to cells and some others still do so take care. Cadmium is proscribed under the rule Pete mentions above.

NB. The data in this article was supplied when the article was written and as example data, please bear in mind that data can and does move. This is a guide to what you should or need to know and not necessarily the most up to date information. Certain cells coming from certain countries may have substances that are prohibited in the uK - you should therefore check that the supplier has the necessary certificates