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Those Things We Call Batteries - Part Two

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The radio system's power comes from electrical storage devices known as batteries. Without power, any radio system is less than worthless. If battery power fails during a flight, your best airplane is also now just as worthless. To me, that makes batteries the as critical a component for safe RC flying as receivers and airborne switches.

If an aileron servo fails, it might be possible to safely land using the rudder instead. A bad elevator servo can sometimes be compensated for using airspeed or knife-edge tricks. There is even a video out there showing an airplane being safely flown and landed after an entire half wing fell off. If the engine quits, the airplane will still glide. But no battery power means having no control at all and no hope of saving anything.

In the first part of this battery series, we talked about all the different battery types, testing devices to determine how long they will last in the air and when to dispose of them. We also discussed field charging and when to do it. If you haven't read part one, it is still available in this section: Those Things We Call Batteries Part One.

Here in Part Two, we will look more closely at Nickel Cadmium (Ni-Cd) and Nickel Metal Hydride (Ni-MH) batteries. We will look at such subjects as why batteries age, how to fix them and how to store them.

More on Ni-Cds

Did you know that both Ni-Cd and Ni-MH batteries begin to age once they have been charged for the first time? Even if they are never used in an airplane, they do get old. I didn't know this back when I first started in RC. I thought batteries lasted forever, I mean, they can be recharged, right? So if you recharge them, they will be like new, right? WRONG!

I lost a beautiful P-39 Aircobra on its maiden flight because I used a receiver pack that had gone bad. I just didn't know that could happen. I charged it overnight, went to the field and watched the P-39 snap roll into the ground right after takeoff. That was when I started to learn about Ni-Cd batteries.

Photo 1

Battery testing equipment was not available at that time. The first one, called a “Flite Life” came out two years later. I bought one immediately. It was not very sophisticated by today’s standards. It discharged any battery at 250 mAh. You connected an electric clock to it. When the Ni-Cd being discharged, 8-cell transmitter packs or 4-cell receiver packs only please, reached 1.05 volts per cell, the Flite Life turned off the electric clock. If you kept a record of the various discharge times per pack, it was possible to tell when a battery had reached the 80% point mentioned in Part One.

While primitive, that old Flight Life tester saved me more than a few aircraft. Since then, testers have become very sophisticated as noted again in Part One. Whichever battery tester you choose from Part One, please be sure to get one.

During those early testing days, I began to notice that batteries permanently lost capacity even if they were not used. If a battery was several years old, had been put away fully charged and then tested, it gave poor results no matter how many times it was recharged.

I didn’t know what was happening so I asked Larry Scribnick of SR Batteries fame (Website) what was happening. Without getting too technical, this is what happens to Ni-Cd batteries as they age. “AA” size Ni-Cd batteries look similar to the standard “AA” dry cell. But internally, they are very different. They are composed of many small individual “plates” with tiny spaces in between. Each plate produces voltage by chemical means. The size and number of these plates determine the battery’s capacity, not its voltage which is always 1.2 volts (nominally) per cell.

As the entire battery ages, chemical deposits build up between these plates. These deposits reduce the plates’ efficiency to produce current. This reduces the battery’s overall capacity. If there are too many deposits, the battery loses the ability to maintain capacity long enough for a safe flight. Yes, this is a very superficial explanation but it is important to know about the deposits to understand the next step.

Charging a battery that has many deposits on a regular wall charger does not help much. The usual charging current for Ni-Cd batteries is C/10. “C” means the capacity of the battery in mAh. Therefore, the proper slow charge for a 700 mAh Ni-Cd battery is 70 mA. The constant slow charge does little to remove the deposits.

To restore a battery that has deposits, it is necessary to use other than a slow, constant charger. Chargers like the Sirius Pro Charger use “pulse” charging to dislodge the deposits. Again without being technical, these restorative chargers provide higher current rates and vary the charge modality to help “remove” the problem deposits.

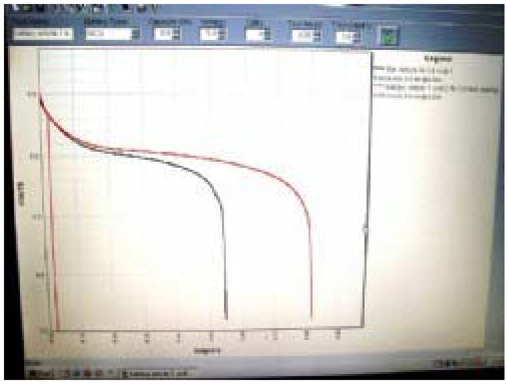

Photo 2

In Part One, we showed the graphic discharge curve for an old 800 mAh Ni-Cd battery pack. You may have wondered why we used an old pack for this example. Because, now we can show how a restorative charger works on this old pack to revitalize it. Look at photo 2 above. The black curve is the first discharge of the 800 mAh pack that yielded a capacity of just 560 mA. The pack has just 70% of its original capacity remaining and would be on my “ground work only” list.

After the discharge illustrated above, the same pack was put on a Sirius Pro restorative or “conditioning” charger. This “fast” charger recharged the battery in less than two hours. Then it switched to its “restorative” mode that pulse charges the pack somehow. (Each such charger uses slightly different, proprietary restorative techniques.)

The old pack was left on the Sirius charger for two full days. Then the CBA II (Website) was used again to discharge it. The result is the red curve in photo 2. The battery pack now had a capacity of about 810 mA! That is probably just what it had when new. The Sirius Pro restorative charger made the old battery almost new again. I not only saved some money, but probably an airplane as well.

But nothing is for free and this restoration “miracle” has a cost. Once a restorative (also called “conditioning”) charger is used to give life back to an older pack, then it needs to *alway*s be charged on that type of charger. If charged with the slow wall charger a few times, the problem seems to quickly return. This is usually not a problem for a very human reason. Once a pilot gets used to not having to charge overnight before flying but rather just on the way to the field, it becomes a very easy habit to acquire.

But some caution here as well. Regular “Peak Detecting” fast chargers should not be used as the only charger. Peak Detecting chargers build up some heat during the charge process and sometimes push the battery too far. Heat damages a Ni-Cd pack and removes some of the life from it that can never be restored. If you are constantly going to fast charge, then use a restorative charger like the Sirius Pro. Less expensive “Peak” chargers are designed for field use to extend flying time, not for constant maintenance.

Photo 3

During the above discussion, the C/10 charge rate was mentioned for Ni-Cd. packs. All the battery experts seem to agree that this is the best slow charge rate for Ni-Cd battery packs. As proof, enlarge photo 3. The left side wall charger came with a radio set that used a 550 mAh receiver and transmitter battery. The one on the right was packed with a radio set using a 1 amp hour (1000 mAh) receiver battery and a 700 mAh transmitter battery. It is no coincidence that these two wall chargers from different companies both use the C/10 charging rate.

Why slow charge at all when fast chargers are available? There are probably many reasons but two stand in the forefront. Fast chargers discontinue the charge when the entire pack reaches about, stressing “about” hard here, 90-95% of the rated voltage. Stopping “early” like this usually protects an individual cell in the pack from being overcharged while the other cells are still coming up to full charge.

Yes, each individual cell in a pack is different. They charge and discharge at individual rates and do not act as a team. You may have heard about “matched” battery packs. This means that the company or individual constructing the pack has made an honest effort to include only those individual cells that have similar charge/discharge curves. Note the key word here is similar as no two cells are identical in every respect. Matched packs live longer and produce more usable capacity, but are more expensive.

But slow charging a pack, especially the first time, allows all the cells to reach full capacity without damaging any individual cell. The charge rate is low enough that the fully charged cell is not damaged by the small amount of extra current being used to bring the other cells up to full capacity. Slow charging a pack at the start helps to prolong its useful life because all cells are undamaged and more balanced to each other.

Secondly, slow charging does not heat the cells as does a fast charger. Lower temperatures mean longer battery life. Slow charging also insures that the battery pack is at 100% capacity before you leave for the field. My suggestion is that you slow charge before most flying sessions, if you do not use a restorative charger, and fast charge those few times at the field when you just have to get airborne a few more times than usual. (See Part One for suggested flight times per battery capacity.)

What about charging at less than C/10? Getting too low a charge rate, C/100 for example, approaches the “trickle charge” area. This is used to maintain a battery pack at nearly 100%. (Some pilots swear this is the best way to preserve Ni-Cd batteries. Many experts agree.) But C/100 only maintains the battery at its present voltage, whatever that may be. A Ni-Cd battery will self-discharge at a given rate while in storage. The trickle charge is designed only to make up that lost charge. It will not charge a half-charged battery pack back up to its full capacity.

I know a few pilots that keep all their batteries on trickle charge. Their claim is that it prolongs the battery life by many years. One has batteries more than 10 years old and they still work great. I am not recommending this, but it may be worth a closer look. Trickle chargers are available and could save both money and airplanes. But I suggest still checking the battery pack before flying by using a full discharge/recharge cycle.

Even more critical than trickle charging a half-full pack is the opposite situation where a pilot buys a larger capacity battery and uses the radio system wall charger to charge it. This happens very often and it is not a good idea. Trying to charge a 1500 mAh battery pack on a 50 mA wall charger just doesn't work. Most of us would think that we could just charge the pack for 30 hours and have it reach full capacity. For various reasons, this does not work. What happens is that eventually the 1500 mAh battery begins to act more like the 500 mAh pack for which the charger was originally designed.

Photo 4

When purchasing larger capacity batteries, you will also have to purchase an after-market charger capable of charging the new battery at least at C/10. This includes transmitter and receiver packs. Since most aftermarket chargers are fast chargers, it makes sense here to buy a conditioning or restorative charger, like the two shown above) for the new larger battery.

What about storage of Ni-Cd batteries? Again I checked with Larry Scribnick about this. His answer surprised me. I had always been taught to store unused Ni-Cd battery packs fully charged. But the answer is that Ni-Cd batteries self-discharge which means that there is always some chemical action taking place. The more charge in the pack, the more action happening. Therefore, it is best to store the batteries discharged, but at the safe level; not under 0.9 volts per cell.

This means checking the pack's voltage on a regular basis and then using a slow charger to bring the pack back up to about 1 volt per cell. This provides the longest battery pack life but is the difference large enough to make a difference? Today, it costs between $15 to $25 to buy a new receiver pack and about $20 for a new transmitter battery pack. For me, and this is just my opinion, I would rather cycle (charge, discharge then slow recharge back to ~1.05 volts pre cell) the pack every 90-120 days. If that means the pack lasts four years instead of five, I can almost afford that.

It is a good practice to date each battery pack, transmitter and receiver, with the month and year of purchase. This helps to keep track of the older batteries for more careful checking. Keep a list of the date for each battery "in the plane" and check the older ones before flying. How old can a pack be and still be good? This depends as much on the number of charge/use cycles as on the years involved.

It is not feasible to record every cycle, including flight cycles, for every battery pack once your hangar grows much beyond five aircraft. Some can do it, but I have never managed it. Instead, I rely on the 90-day testing outlined in Part One. My own notes show that once a battery pack reaches around 400 cycles or about four years, it starts to decline. The conditioning chargers help here, for a while. But eventually, the batteries wear out.

In aircraft that fly a lot, the batteries are replaced every two years regardless of test results. "Fly a lot" means more than 200 or more flights per season. Those that don't fly much are cycled and tested every 90-120 days using a conditioning charger. If the batteries still test above 80% capacity but are more than seven years old, they are replaced anyway.

Finally, does the Ni-Cd "memory" phenomenon really exist and what is it? The "memory" concept says that if a Ni-Cd pack is *always* fully charged and then *always* discharged the exact same amount, say a full charge and then always only two 10 minute flights made each time, then eventually the battery will only stay charged for just 20 minutes and then drop to zero.

Does this actually happen? It is possible that this concept started back when there were no testing devices available to RC'ers and older packs couldn't be restored. But many batter experts say this is a very real concept while others say not true. It is not up to us newer pilots to evaluate this problem. We only need to know that if we charge and then safely discharge a Ni-Cd pack every 90 days as recommended in Part One, then "memory" just can't happen and we are safe from its ravages.

Nickel Metal Hydride Batteries

Nickel Metal Hydride (Ni-MH) batteries are identical in appearance to Ni-Cd batteries and similar in construction, but use a different chemistry. Ni-MH batteries have two distinct advantages over Ni-Cds. First, for given cell size, "AA" for example, Ni-MH batteries have more capacity. About the largest capacity Ni-Cd "AA" cell is around 1600 mAh. But some Ni-MH "AA" cells reach over 2000 mAh (2 amp hours). The battery packs weigh about the same but the Ni-MH pack will last longer.

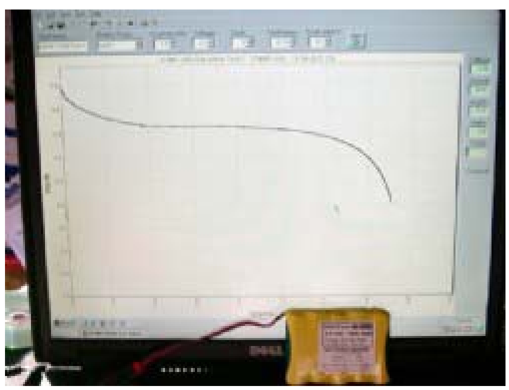

Photo 5

But there is another, even more vital, Ni-MH advantage that can sometimes save aircraft. This advantage is its discharge curve. Like a Ni-Cd, the Ni-MH battery discharges at a constant rate for most of its charge. Yes, it does have a "surface" voltage, here over 7 volts. Like a Ni-Cd, the voltage drops quickly to its useable amount, here about 6.1 volts. Also like a Ni-Cd battery, the voltage stays in the useable range for a long time.

The important difference is at the end of the discharge curve. Remember how the Ni-CD battery's voltage "fell off the cliff" at the end (see photo 2)? But the Ni-MH final discharge curve is much less abrupt. This can, and has, saved airplanes.

Photo 6

How? The pilot gets a warning as servo response starts to slow due to lack of battery power. Everything takes longer to happen and the controls become sluggish. Sluggish yes, but they still work. Ni-MH batteries saved the Prophecy pictured above.

While practicing the Advanced Precision Aerobatic maneuver sequence for the second time that day, I began to notice that the rolls were slowing down a little and that elevator response was late. At first, I thought it was just me and continued flying for another 6-7 minutes. But then the roll rate *really* slowed and I knew something was wrong. I thought I had lost one of the aileron servos.

This was only the second flight so I never gave the battery a thought. It had to still have a lot of power left. After landing, I checked the ailerons for the bad servo but both ailerons moved. I then held right aileron and pushed downwards on the right, up, aileron. To my surprise, just a gentle pressure moved the aileron all the way back to neutral despite the right aileron control being inputted.

I checked the battery using the i4C tester discussed in Part One. The 6-volt Ni-MH pack read 4.6 volts at no-load. Applying a 500 mA load made the numbers disappear! The battery didn't even have enough power left to light the digital screen! I later found out that I had charged the battery on the charger's "trickle charge" setting and therefore never really charged it after flying six flights the day before.

The point behind this little epic is that the Ni-MH battery was still able to fly the airplane while alerting me that something was wrong and then continued working enough to make a safe landing. If the battery had been a Ni-Cd, my expensive Pattern airplane would have been converted into fiberglass dust.

Ni-Cd batteries are great for trainer and light sport applications. But as your airplanes get more complex, read expensive here, and have more than four servos, you may want to consider using Ni-MH batteries instead. The Ni-MH's larger capacity handles additional servos better and the discharge curve helps protect the expensive airplane against loss.

Photo 7

As your aircraft get more expensive and harder to replace, you should also be looking at the on-board switch. While this is a battery article, it is also about protecting your aircraft. The switch that comes with your radio is fine and usually works well. But if it should fail, then so does your flight control.

In more valuable airplanes, I suggest you consider using a “Mil. Spec.” (military specification) switch. There are several Mil. Spec. switches available like the MPI switch pictured above. How does it differ from standard on-board switches? If the regular switch fails, power is cut off from the receiver and servos. But the Mil. Spec. switch defaults to “on” if it fails. This means that the broken Mil. Spec. switch continues to supply full power to the on-board system even though it itself is broken. This is nice insurance to have.

However, again nothing is free and the Mil. Spec. switch always is slightly “on” even when in the off position. The current draw is small, around 10-20 mA, but it does exist. Therefore, if you are going to store an aircraft using this type of switch for more than a few weeks, unplug the battery from the switch.

Most Mil. Spec. switches usually have a resistor as shown above. The resistor regulates the voltage reaching the on-board radio system from a 6-volt, or more, battery pack, here to 5.3 volts. The servos now produce more output torque than when operating at 4.8 volts and also center more precisely. Just as importantly, the servos move at the same speed during successive flights because the voltage reaching them is always 5.3 volts. The airplane always responds the same flight after flight and this helps the pilot to fly better.

OK, lecture over and back to Ni-MH batteries. According to the people who manufacture restorative chargers, while their chargers do a great job of safely charging Ni-MH battery packs, they can’t be conditioned and renewed as can Ni-Cd batteries. That’s what they say and I have always believed them. But the preparation for this article series now has me questioning this concept.

Photo 8

Notice the Ace Abacus pictured above. I took an older 1600 Ni-MH battery pack off the shelf to illustrate a few points to be made in this Part Two article. The battery was charged on a standard fast charger because I needed some photos quickly. To test the battery, I used the Abacus discharger, (sadly no longer available), and was surprised to get only a 25 mA capacity reading. The battery was old, true, but that far gone?

The old battery was put on a Sirius Pro restorative charger and left for two days. Then it was tested again on the Abacus. Note the small red lights in the photo. Adding them together shows that the “dead” old battery now has a 1325 mAh capacity. That is still not 80%, but quite an improvement nonetheless.

That same battery was charged again and was the subject battery used in photo 5 above. After the second restorative charge, it capacity was now 1510 mA. This is 94% of its listed capacity and very acceptable. I don’t know what occurred, and still trust the Sirius manufacturer’s experts when they say it shouldn’t be happening, but clearly *something* is going on here.

Instead of holding this entire article back for clarification, if possible, I will list here the results of my follow-up with the experts. For now, don’t depend on “bringing back” Ni-MH batteries until we find out otherwise.

Photo 9

This article is getting longer and more eyes are glazing over from all this text than from the first part of this series. But there is one more subject to cover: crash damage. This topic was not originally planned for this battery series but something just occurred to make its inclusion extremely important.

While testing another review aircraft, the transmitter output circuitry died. It happens, not often, but it does sometimes. The review airplane struck the ground while nearly vertical and in a 45 degree bank angle traveling at very high speed. Having the transmitter's "failsafe" set to low throttle doesn't much slow a vertical descent such as this. (And if you want to know, yes, I did *buy* another review aircraft to replace it since this was only flight 15 of a 30+ flight review.)

The on-board battery was a brand new 1100 mAh Ni-Cd 4-cell battery pack. Prior to the crash, it had only 14 1/3 flights on it and had just been purchased for this aircraft. But it was well wrapped in foam and seemed to have weathered the impact with no damage. The receiver and transmitter went back to the manufacturer for repair and inspection (Always return the receiver to the manufacturer for inspection after a severe impact such as this.) But the battery pack was not since no damage was apparent and it tested several times at over 100% capacity.

Using a different transmitter and receiver, work was started in on the replacement aircraft. The original battery pack was charged and used for setting up the servos during assembly. While setting up the throttle servo, I started to smell something wrong; almost like an ozone smell with a hint of burnt wires. Looking down at the battery pack, I noticed that the plastic wrap was shrinking back and curling. The battery was extremely hot. It was immediately disconnected and knocked to the concrete floor.

But the disconnected battery continued to get hotter and was venting battery fumes. The plastic wrap was now melting. Using a plastic razor knife and holding the battery in place with a large screwdriver, I cut through the plastic wrap and then separated each cell, cutting all the wires.

That solved the burning problem. It was a lucky thing that I was not somewhere else when this battery shorted out or things could have been much worse than just a scare. What happened? The force of the crash impact had caused one corner of the front cell to cut through the insulation of the positive wire leading out to the connector. However, the negative outside wall of the cell had rebounded away from the cut wire, just barely not touching the exposed positive wire.

Somehow, during the movements necessary for servo installation, the cell wall moved against the exposed positive wire. This was an instant short and the first thing every pilot learns about Ni-Cd batteries is that you never, ever short them like this. There is a lot of energy in a Ni-Cd battery and one of a Ni-Cd battery's strong points is that it can discharge its current more quickly than can most battery systems. When shorted out, all that energy is quickly released for good or ill.

The moral? If your battery is involved in a minor to moderate crash, test it out and it should be OK. My standard for now is that if I can repair the aircraft and the battery was well insulated from shock using foam, it should be OK. But when the airplane hits hard and not even the tail wheel can be saved, discharge the battery and discard it. A fire or a destroyed new aircraft is not worth the $20 savings obtained from reusing the old battery. Likewise, when you feel the need to replace the battery after a severe crash, also replace the on-board switch.

The next article in this series will discuss the new Lithium battery systems that are becoming available. With more capacity, lighter weight and increasing safety, these newer batteries are becoming popular for powering on-board radio systems.