Model Aviation's Sport Aviator
The e-zine for the new model pilot
www.MASportAviator.com

Those Strange Things We Call "Batteries"

Part One

By Frank Granelli

Something like this can happen to any of us if we do not understand the batteries that power our aircraft and radio equipment. There is no worse feeling than that sinking sensation an RC pilot gets when the airplane suddenly no longer responds to the transmitter's inputs. Watching your airplane either continue a dive straight into the ground or slowly continue to roll until ground and airplane meet is enough to make any RC pilot take up model trains!

Except for total receiver or transmitter failure, a very unlikely event with today's sophisticated electronics, a total loss of control is caused by battery failure. Either the receiver or transmitter battery failed or was subjected to operating loads beyond their design specifications. Those are the only battery causes of total system failure. But how to tell which is which and how to prevent it?

Answering that question is the whole purpose behind this series of articles. If you want ultra sophisticated technical battery information and specifications or want to know the step by step chemistry of an RC battery, don't read this article. This article is designed just for us non-technical RC pilots and provides the information each of us needs to safely operate our aircraft. While it provides more information than a "Batteries for Dummies" type article, you will not be getting an electronics engineering diploma in the mail after reading this article series either.

Battery Types

Photo 1

There are five basic types of batteries used in most of model aviation. The chemistry used to store and release the electrical current delineates these five classes (and that's just about as deep as we get into the chemistry). The five types of batteries are:

- Non-rechargeable Alkaline
- Rechargeable Nickel-Cadmium (Ni-Cd)
- Rechargeable Nickel Metal Hydride (Ni-MH)
- Rechargeable Lithium Ion (Li-Ion)
- Rechargeable Lithium Polymer (Li-Po or Li-Poly)

Alkaline Batteries:

This power source is about as simple to understand and manage as batteries can get. Alkaline batteries, like Duracell or EveryReady Alkaline, are used to power a few RC transmitters. The lowest cost RC transmitters sometimes use eight "AA" alkaline power cells. These batteries provide 12 volts to the transmitter since each cell contains 1.5 volts. Whether the transmitter actually "sees" 12 volts, instead of the more conventional 9.6v, in operation may vary and is not really important here.

What is important is to know that alkaline batteries have only the amount of energy put into the cell by the manufacturer. They cannot safely be recharged. Once the stored current is gone, so are the batteries. Another important thing to know is never to use any other dry cell than an alkaline in an RC transmitter. Conventional batteries, like the ones that came in the remote control of your new TV, die too quickly and suddenly to be of much use in RC no matter how "Heavy-Duty" the label claims they are. Alkalines, or the newer "Lithium Alkaline," only, please.

There is no easy way to know when your alkaline transmitter batteries are on the way out. Even if your transmitter provides a battery reading such as a series of colored lights, those lights tend to lag behind the batteries' actual decline. In other words, they may all be shinning brightly when you took off, but they can go out really fast while you are still up in the air 15 minutes later.

How do you manage these batteries? The best way is by the number of flights on the transmitter. I replace transmitter alkaline batteries every 40 flights or three months, whichever comes first. The batteries are by no means dead after only 40 flights, but replacing them is cheaper than having to hike out to the crash site and then buying a new airplane.

I use the “old” transmitter batteries that were removed to power TV and radio remote controls, RC car transmitters and flashlights. If the batteries fail, I have to change the channel by hand or light a candle. Either situation is preferable to an unmanaged air-ground interface.

Nickel Cadmium Batteries:

This is the big one. The first rechargeable batteries used in RC were Nickel Cadmium (Ni-Cd). Ni-Cds remain the most popular type of RC battery even up to today. In fact, most modern RC sets are shipped using Ni-Cds. So if you just got a new Futaba, JR, Hitec or Airtronics RC system, you probably just got new Ni-Cd batteries. All Ready-To-Fly aircraft also use Ni-Cd batteries. This is the one you want to study carefully.

Ni-Cd batteries offer tremendous cost savings, contain a lot of power (more on that later), and can be recharged hundreds of times. But the technology is old, probably close to 40+ years old, and therefore presents some management problems to the RC pilot. But when handled properly, these batteries offer several years of dependable service.

Let’s discuss a few terms and basic concepts before delving into Ni-Cd management. Every type of battery has a voltage rating. This is a measure of the amount of power, think horsepower here, not “power” as used in physics, that each individual cell contains. The higher the voltage, the more work that cell can perform. All the Ni-Cd cells used in RC contain 1.2 volts per cell. These cells can be linked in series to increase the voltage, and the amount of work, that a battery “pack” (groups of cells linked together) can perform.

As an example of this, look at the ratings of your servos. JR’s DS 8611SA servo provides 260 oz. /in. of twisting power (torque) running on a 4.8 Ni-Cd battery pack (4 cells in series). But the same servo provides 320 oz. /in. of force when supplied with 6.0 volts (5 cells in series). The JR DS285 servo will rotate its servo output arm 60 degrees in 0.18 seconds on 4.8 volts. The same servo will rotate its output arm 60 degrees in just 0.14 seconds running on a 5-cell, 6.0 volt pack.

Why the differences? At the higher 6.0 voltage, the motor is being provided with more horsepower to do its work. Therefore, it turns faster and with more force. Hey, that’s great. Let’s all use 6.0 volt packs to power the airborne radio system, receivers and servos, from now on. Why didn’t my radio come with a 6-volt pack? Can that one extra Ni-Cd cell cost that much? Hey I paid more than $200 for this thing. The least they could have done was to give me a 6-volt receiver battery pack!

Unfortunately, it is not all that simple. Voltage is only one measure of what a battery pack, or a single cell, can do. The other measure is a thing called milli-Ampere hour rating (mAh). The mAh rating is a measure of how much energy is stored inside each cell. Think of it as the fuel tank of your battery. The higher the mAh rating, the more fuel your battery will hold. The more fuel your airplane holds, the longer the engine will run at any given throttle setting.

It is the same for a Ni-Cd battery. The higher the mAh rating, the longer a battery will continue to provide current at a given “throttle” demand. If the “load”, the amount of energy being drawn from a battery, is 250 mAh then a 1,000 mAh battery will last, in theory, for four hours before it can’t provide any more energy. A 2,000 mAh battery will last eight hours before it is gone.

Note the “in theory” part of the preceding. There are heat loses, resistance loses, voltage changes and much more that shorten or lengthen the times mentioned, but we are not dealing with such intricacies here, only the concept of what the mAh rating means. It is the battery's fuel tank.

Unfortunately, you can't just link up several batteries together and increase the mAh rating. Unlike voltage, capacity is not cumulative. It is built into the cell itself and cannot be changed except by using two or more battery packs wired in parallel and that gets too complicated for here. So the manufacturer determines how much fuel your battery can hold. And they have improved this fuel tank a lot over the years.

Early RC Ni-Cd batteries had fuel tanks that held only 450 mAh's of energy. Today, most radio sets come with 700-1100 mAh airborne batteries. Early transmitters had only 400 mAh batteries and today have up to 1100 mAh of energy. In addition, other RC batteries are available all the way up to 4000 mAh. Ni-Cd batteries come in different sizes. These sizes are close to the alkaline cell sizes we already know: "D" size, "AA" size "C" size and the like. The batteries most commonly used in RC radio systems are "AA" size.

But the more the fuel tank holds, the larger it must be. The more fuel, the heavier the filled tank is as well. The more fuel the tank holds, the more it costs to fill it (let's not even talk about my 31-gallon Suburban tank, OK?)The same holds for batteries. The higher the mAh capacity, the larger and heavier is the battery cell and the more it costs. About the largest "AA" Ni-Cd cell commonly available holds around 1800 mAh while the most popular "after market" cell contains 1400 mAh.

Above 1800 mAh, Ni-Cd batteries get to be "C" and "Sub C" size. They are about the size of an alkaline "C" cell and weigh almost as much. Such batteries can hold up to about 3000 mAh of energy. The even larger, and heavier, "D" cells hold up to 4000 mAh and above. These last are great for boats but not much use in the average RC sport airplane.

Wait a minute, what about why I didn't get a 6-volt, 5-cell pack with my radio? While it is nice to know my airplane has two fuel tanks, one for flammable liquids and one for electrons, what does that have to do with my voltage question? That is simple, really. Doesn't your car use more fuel to go a given distance at full throttle than if you let it idle along the same distance in overdrive? The same is true for batteries.

A servo running at 6-volts provides more turning force and moves faster. But it also uses more energy, called current, but you can forget that now, to do that extra work. The higher the voltage being supplied, the faster the battery's fuel tank empties. Just like a car that can travel 500 miles on one tank of gas at 50 mph but can only travel 100 miles at 120 mph, a 1000 mAh battery can last longer when doing only 4.8 volts of work than it can working at 6.0 volts. The lower the current, the longer the battery lasts.

Over the years, RC pilots and manufacturers have found that a 4.8-volt battery pack is the best compromise of work versus capacity for sport aircraft. They have also determined that a 9.6 volt (8-cell) transmitter battery pack is a good compromise. Now, certain aspects of our sport, like Precision Aerobatics (Pattern) and Scale Aerobatic Competition (IMAC) really need to operate servos at 6 volts. These pilots not only need the extra strength and speed the higher voltage provides, but also require the extra precision; the servos center better at 6 volts than at 4.8. But that is the exception. Most sport airplanes show little, or no, performance difference at the lower 4.8 volts and their batteries last longer.

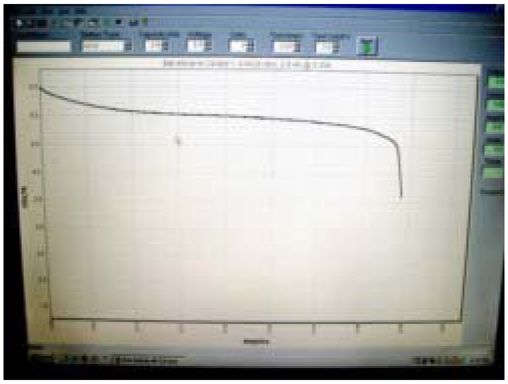

Photo 2 Photo 3

There is another important thing to know about Ni-Cd batteries. That is the manner in which they discharge. Unlike most all other batteries, Ni-Cds shed their energy in a useful, but dangerous manner.

Look at the chart above. This is not an imaginary chart but an actual Ni-Cd discharge char. The battery is an older 4.8 volt, 800 mAh pack that has seen better days. The chart was made using the CBA II, the Computerized Battery Analyzer, made by West Mountain Radio (www.westmountainradio.com). This neat little device, shown in photo 2, allows the RC pilot to study the health and performance of every type of rechargeable battery used in RC. In addition to the four rechargeable radio system battery types, the CBA II will analyze 12-volt gel cell and "wet" field box batteries.

We will discuss battery management systems later but the CBA II was mentioned here to illustrate that the charted discharge curve is real, not hand drawn. At one glance both the Ni-Cd's greatest advantage and its disadvantage become apparent. The battery pack begins with a high "surface" voltage (~5.45v) because it has just come off the charger; a Sirius Pro Series charger from Peak Electronics (www.siriuselectronics.com). The Sirius charger and battery tester is detailed in Sport Aviator's "Baggage Compartment".

This "surface" charge, no doubt called that for complex technical reasons, but we only need to know that it doesn't seem to hang around long and is not very useful, drops to 5.1v. An example of Surface charge behavior is the voltage reading on a computer transmitter. Right off the charger it will read about 11.2v. But after 20 minutes, turned off with no power drain, the reading drops to about 10.8v and there it stays for a while.

But the voltage drop is over quickly. Note that the Ni-Cd pack almost maintains its useful voltage, here ~5.05v to ~4.8v, until the pack is almost exhausted. The electron fuel tank is empty. This is great for RC use. The constant voltage means that the servos move at about same speed and provide about the same force throughout the day's flying. The airplane feels the same to the pilot on each flight. This is Ni-Cd's greatest advantage and it is a big one.

But notice what happens when the electron tank is nearly empty. The voltage drops off a cliff! It almost instantaneously disappears. When that happens in flight, that flight quickly terminates. There is little warning; the pilot does not feel the controls move more slowly. Everything just stops working and its rebuilding time again. (There actually is about a 15 second warning but unless the airplane is using two aileron servos, the pilot will not be able to see this short warning and probably wouldn't have time to save the airplane anyway.)

Preventing Battery "Accidents" in Flight

How do we manage this? What can be done to prevent this unhappy situation? Several things really do help. One is common sense and the other is some great, and inexpensive, equipment. First the common sense part.

It is just plain common sense to know your battery's specifications. If your receiver pack is a 4.8v, 700 mAh battery pack, remember that. Most glow-powered sport aircraft flying with just four standard sport servos use about 110 mAh per 15-minute flight (this is on the high side for safety reasons). This equates to 6.4 flights. But you never know if your battery really has 700 mAh of energy (Ni-Cd's lose capacity over time) and an unbalanced propeller, high throttle settings or violent aerobatics will cause greater energy consumption.

Therefore, plan on getting only five flights from a 700 mAh, 4.8v battery pack. I recharge after four flights just to be safe. If your airplane uses an extra aileron servo, it will consume about 125 mAh per flight or 5.6 flights per charge. (Doesn't that 0.6 flights nearly make your heart stop?) Modern digital servos raise energy consumption to about 140 mAh per flight.

Larger aircraft and scale machines with electric retractable landing gear can use up to 200 mAh per flight. My Prophecy 2-meter Pattern airplane uses 225 mA per 18 minute flight. Using these figures as guides, do the math for your systems. Know what you have and how far it can go. Btw – hangar flying at home to see how long your receiver battery will last does not work. When not fighting the air stream loads and engine vibrations, your servos are not really working hard and therefore are using almost no energy.

Photo 4

Another thing that does not work is testing your Ni-Cd batteries at the field using a standard volt meter. Remember that surface charge? It is always there and good Ni-Cd batteries will rekindle a little surface charge once the electrical load is removed. Regular volt meters therefore give very misleading readings and that could lead even the careful pilot into mistakes.

The volt meters pictured above prevent those mistakes. The Hobbico Digital Volt Meter Mk III provides a 250 mA load on either receiver or transmitter battery packs while measuring the voltage. The i4C digital volt meter on the right side provides choices of 500, 1000 or 1500 mA loads. Putting a load on the battery gives true volt readings and prevents mistakes. The 250 mA load of the Hobbico is more than adequate for any trainer or sport airplane up to about 1.20 cu. in. size. The i4C's heavier loads are designed for high performance airplanes like Pattern and IMAC aircraft as well as for scale airplanes with lots of servos.

All you need to use these safety devices is to have the "charge" plug from your switch accessible from outside the assembled aircraft. All modern radios come with a charge plug mount just for this reason. Use it and extend your airplane's "expiration date" maybe to infinity.

It is a good idea to measure your batteries voltage before the first flight; just in case the charging process was not completed for some reason. Check it again after the third flight if you don't want to check it each time. After the third flight, check before each succeeding flight. With a 250 mA load, a 4.8 volt battery pack should read at least 4.65 volts before taking off. If not, recharge it. A 6.0 volt pack should read at least 5.8 volts.

Managing Your Ni-Cd Batteries

You can manage these things? How? Yes, you can manage your Ni-Cd batteries. Using inexpensive, well some are inexpensive, devices made just for this purpose. But no matter what they cost, if one airplane is saved, any battery management device will have paid for itself several times over.

Photo 5

The Sirius SuperTest Precision Battery Tester will discharge just about any battery pack. The rate at which it discharges the battery pack is adjustable at either 125, 250 or 500 mA. Batteries for sport and trainer aircraft should use the 125 mA rate as this most closely simulates actual flight discharge rates. The SuperTest terminates the discharge when the cells reach about 1.05 volts to protect them from over discharging. Discharging Ni-Cd batteries too much can cause permanent damage.

The SuperTest works with 4, 5 or 8-cell (usually transmitter packs) battery packs. What it does is measure and record the actual amount of energy, within 1% accuracy, that was removed from the battery. In other words, does your 700 mAh battery pack really have 700 mAh in it? Exactly how much "fuel" is in that battery pack anyway? The SuperTest will tell you to within less than 1 mAh.

The CBA II will also record that information for you and produce a discharge graph. The graph is nice to have but the really important information is the mAh rating. The SuperTest costs $70 and is totally self sufficient. The CBA II cost $100 and requires a computer; preferably a laptop since it can be difficult to bring the fuselage to your desktop. The CBA II also measures battery temperature during discharge, an $11 option, but this is really only needed when working with Lithium batteries, not with Ni-Cds.

Once you know how much fuel is really in your battery, what do you do with the information? OK, here we go by the combined experience of many RC pilots most of whom are more knowledgeable than I about this subject. It has been written, so it must be so, that battery packs that can only contain 70% or less of their original mAh rating should not be used in flight. Write “Not For Flight “on them in big print and assign them setup duties while building new aircraft on the workbench.

If your 700 mAh pack only rates 490 mAh, don’t fly with it. The battery has lost too much capacity to be safe. Always keep that Ni-Cd voltage drop-off cliff in mind. We will discuss why Ni-Cd batteries lose capacity later. But for now know that when a battery can only hold 70% of its rated capacity, it can also suddenly fail in other ways.

Actually, *I don’t follow this advice*. And maybe you shouldn’t either. I figure that if 70% capacity is supposed to be safe, then 80% capacity is even safer. When one of my 700 mAh Ni-Cd pack falls below 560 mAh, I replace it. Why take a chance when replacing a $15 battery pack can prevent so many problems?

It is a good idea to “cycle” your batteries (measure its capacity and recharge) about once every 90 days. Don’t do it too often unless you see a problem or feel that your battery is not lasting as long at the field “as it usually did”. All rechargeable batteries, Ni-Cds included, have finite lifetimes. Too many deep discharge cycles will shorten the pack’s useful life. Measure when necessary but do not overdo it.

Photo 6

Even more sophisticated battery management devices are available. The Hobbico Accu+Cycle shown above not only simultaneously discharges transmitter and receiver battery packs but then charges these packs back to full capacity. It records the *time* it took to discharge and then automatically recharges the packs. Discharge rates can be set at either 250 or 750 mA. Use the 250 mA rate for all sport and most high-performance aircraft. The 750 mA rate is usually used only when you want to run a quick battery check before flying. Discharge readings at the high rate will show less capacity than the battery really possesses and can be misleading.

What do you do with the time reading? If it took 160 minutes to discharge your 700 mAh battery pack, multiply 250 by 2.67 (160 min / 60 min. per hour). The result is that your 700 mAh battery holds 668 mAh, not 700. Fly accordingly.

Here is where the directions for the Accu+Cycle and I differ. The directions state that the average sport RC airplane uses 250 mA per flight hour. I have flown several trainers and tested the results. For example, I charged the new 700 mAh Ni-Cd battery in an Alpha 60 using the Sirius Pro Series charger. I then discharged the battery pack with the SuperTest and got 730 mAh. Yes, Ni-Cds can sometimes exceed their mAh rating.

I did this three times and got 730, 726 and 728 mAh ratings so a capacity average of 728 mAh is reasonable. I then went to field with the battery on charge as the Sirius charger also works on 12 volts. I assembled the airplane and flew a fairly stressful 15-minute flight; lots of high throttle and constant maneuvering.

Upon landing, the airplane was disassembled and discharged with the SuperTest while I practiced flying the Masters Pattern with my Focus II. The SuperTest removed 634 mA from the battery. That flight took about 94 mA to accomplish. I did this once more and got 101 mA for the flight. After that it was getting dark so I went home. I used this data when setting my 125 mA per 15-minute flight rule mentioned above. The extra 25 mA allow for higher strength servos and digital servos, PCM receivers, unbalanced propellers which strain the servos, and extend ground runs that also put extra loads on the servo and battery pack.

I am sure that Hobbico got their 62.5 mA per flight readings from extensive testing. But I could not duplicate them. Maybe their test airplanes were perfectly balanced and flown under ideal conditions without with my extra heavy hands on the sticks. Until you prove out your own aircraft's energy use, I suggest you go by my estimate since the higher consumption rates I outlined provide extra safety margins.

Transmitters however, do use about 250 mA per hour. So the discharge time on the Accu+Cycle is about the amount of time you can expect your transmitter to last. Remember that your transmitter is using current at this rate for the entire period it is on. So include about 10 minutes per flight for starting, engine adjustment, back taxiing and the like. Each 15 minute flight therefore uses about 25 minutes of capacity. Most transmitters can be trusted up to about 2+ hours. I recharge all of mine, regardless of battery capacity (that ranges from 600 to 1800 mAh) when the voltage reading reaches 9.2 volts. My recharge limit on transmitters without voltage readings is four flights.

More To Come Next Article

This article is getting a little bit too long. By now, your eyes must be getting dim and a little glazed over. I can't blame you. There is a lot of text here and few photos to break the monotony. But there is also a lot of vital, airplane-saving, information.

But there is still more to discuss about Ni-Cd batteries before moving on the Ni-MH type. Why do Ni-Cd batteries gradually lose capacity? What can be done to restore the lost capacity? What charge rates are best for these batteries? How are Ni-Cd batteries best stored when not in constant use? How long do these things last anyway? What chargers are available for field use?

There is a lot more to go, even in a simple battery article like this one. So, we will cover all those questions in the next article in this series. The second article will also cover everything about Ni-MH batteries.

This second part should be published in Sport Aviator before the end of September. Part Three will cover the Lithium batteries and will appear before the middle of October.

Summary

Let's outline the basic information discussed above:

1. Of the five battery types used in airborne RC, Ni-Cd batteries are the most common and require the most management.
2. Know your battery's true capacity using one of the devices outlined.
3. Plan on using 110 mA from your 4.8v receiver battery pack per 15-minute flight. Having electrically operated landing gear, PCM receiver, more than 4 servos, digital servos, unbalanced propellers, high throttle settings or performing extensive aerobatics can raise battery consumption to as high as 225 mAh.
4. Plan on using 250 mA from your transmitter battery pack per hour of operation.
5. Recharge at the field whenever your receiver pack has flown 80% of its rated number of flights. Always disregard any "half flights" like that "point six flights" your math gives you. That is a safety margin.
6. Use a "load applying" volt meter (once called expanded scale voltmeters but are now mostly digital) to measure your receiver's voltage before that first flight of the day and after the third flight and every flight after that until recharge.
7. Receiver battery voltage reading with a 250 mA load should be at least 4.65 for a 4.8 volt pack and 5.8 for a 6-volt pack.
8. Measure your battery's capacity about every 90 days. Discard any battery pack that can no longer reach 80% of its rated capacity.

The Grabber:

The most mysterious things in RC for a newer pilot are the batteries. But they are also the most important part of your radio system since in-flight battery failure always means instant vertical landings. What they are, how to manage them, how to test them, what are their limits and more are detailed in this article. Find this, the first of a series covering all RC batteries, in the Flight Tech Section.

www.westmountainradio.com – Link to website.

www.siriuselectronics.com - Link to website

Sirius charger and battery tester – Link to article.