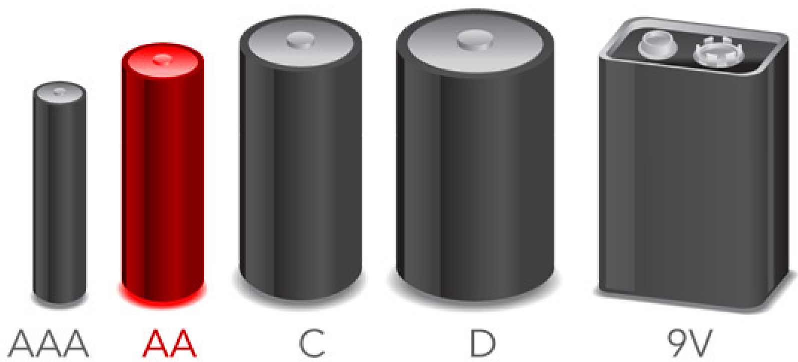
Batteries, BATTERIES, **BATTERIES**!

Batteries are the electrical lifeblood of our model boats. Whether it's power or sail, or a combination of both, we can't operate our boats without a source of electrical power, and that power is supplied by BATTERIES! In this article I will present our members with some battery basics, do's, don'ts and perhaps misspell some myths.

Types of Batteries

Batteries are divided into two basic types: wet cell and dry cell. The AA, AAA, and 9 volt alkaline batteries with which we are most familiar are examples of dry cell batteries. These batteries are not rechargeable. Other types of dry cell batteries are: lithium (disposable), nickel-cadmium (Ni-Cads), nickel metal hydride (NiMh), Lithium Ion (Li-Ion) and Lithium Iron Phosphate (LiFe). Ni-Cads, NiMh, Li-Ion and LiFe batteries are rechargeable.



Typical Dry Cell Battery Sizes

Examples of wet cell batteries are: lead-acid batteries; gel cell batteries, and lithium-polymer (Li-Poly). I am sure there will be argument from some readers as to whether "Li-Po's" are wet cell batteries. For the purpose of this article, the term Lithium Polymer (Li-Po) refers to the soft sided, pouched, multi-cell lithium polymer battery using either a liquid or gelled electrolyte.

Battery 101

How do batteries produce electrical power? To oversimplify, a battery is a container that produces electrical power by the chemical reaction between the positive and negative electrodes and the electrolyte. In dry cell batteries, the electrolyte is solid (paste). In wet cell batteries, the electrolyte is liquid, or a gel. The electrical power produced is direct current (DC) power.

The DC electrical power produced by batteries is measured in terms of voltage and capacity. Voltage is a measure of the electromotive force in the battery. Electromotive force is generally defined as the electrical potential for a source in a circuit. The other measurement is capacity. Capacity is expressed in terms of amperes/hour or milliamps (1/1000 of an amp). Amps are the rate of flow of electrons in an electrical circuit. In terms of battery capacity, the amp/hour rating of the battery means that the battery will last 1 hour at the current flow specified before it discharges. If a battery has a 1 AH capacity, it will last one hour at a current of 1 amp (or 1000 milliamps) before it has discharged. Something to remember here- if a battery is rated for 2500 milliamps, that is only a 2.5 amp/hour rating. Remember that when it comes to recharging time!

Think of batteries as a form of electrical gas tank. The voltage is analogous to the octane rating of the fuel in your gas tank. The capacity is analogous to the volume of your tank in gallons. Voltage tells you how much electromotive force you have available and capacity tells you how long you have it available at a specified rate of usage.

Series Versus Parallel

When we operate our model boats, we invariably need more electrical power than is available from a single battery or cell. For instance the alkaline batteries that we are most familiar with are rated for 1.5V (volts). The Ni-Cads or NiMh batteries in AA or AAA size are 1.2V. When we need more voltage or capacity we have to connect batteries in either series or parallel.

Connecting batteries in series (positive to negative) will increase the voltage, but not capacity. So if we connect four 1.2V/500 MaH batteries in series, we get a battery pack that will produce 4.8V (4 X 1.2) but will have only 500 milliamp capacity. Connecting batteries in parallel (positive to positive/negative to negative) will not increase voltage but will increase capacity. Take the same pack of 1.2V/500 MaH batteries and connect them in parallel and you will have a pack that produces only 1.2V, but has a capacity of 2000 milliamps (500 X 4) or 2 amps. So when you are deciding what size pack you need in your boat, you need to look not only at voltage, but capacity requirements.

Chargeable vs. Non-rechargeable

The two additional types of batteries we need to think about are rechargeable versus non-rechargeable batteries. Non-rechargeable (such as the previously mentioned alkalines) are designated as primary batteries. Primary batteries are ready for use right out of the package, and once their capacity is used up, they are discarded. Primary (non-rechargeable) batteries CAN NOT be recharged! Don't even try! The reason why non-rechargeable batteries can't be recharged is due to the irreversible internal chemical process that occurs during discharge. One aspect of alkaline batteries needs to be remembered: they are generally of low capacity compared to re-chargeable batteries and they will begin losing voltage as soon as an electrical load is put on them. That is why alkaline batteries are not good for high load applications such as running propulsion motors, or even high torque servos (such as sail winches). Of course I wouldn't be environmentally responsible here if I didn't remind you to dispose of all batteries properly in a battery recycling center.

Rechargeable Batteries

Rechargeable batteries are known as secondary batteries. That is because they are produced in an uncharged state and must be charged before use. Examples of secondary (re-chargeable) batteries are lead-acid, gel-cell, nickel-cadmium (Ni-Cad), nickel metal hydride (NiMh), Lithium-Ion (Li-Ion), Lithium Iron Phosphate (LiFe) and Lithium Polymer (Li-Po) batteries. Notice that secondary (rechargeable) batteries may be either wet cell or dry cell. Wet cell rechargeable batteries such as lead-acid or gel cell act a lot like alkaline batteries in that they begin losing voltage as soon as a load is placed on them. It is just that they are usually of higher capacity and so the voltage drop is minimal until the battery loses 50% of its capacity. Then it will begin showing signs of discharge and loss of voltage. Ni-Cads and NiMh batteries maintain their voltage until after they have lost 90% per cent of their capacity. What this means is that if you are running Ni-Cads or NiMh batteries, they will give you very little warning that they are about to “dump”. So if you are running Ni-Cad or NiMh batteries, you either need a low voltage warning system on your boat, or you need a timer on your transmitter that will warn you when your capacity has almost reached its limit. This will require that you either measure the electrical load of your radio installation with an ammeter, by actual testing, or by computation. In the case of rechargeable Ni-Cads or NiMh batteries, most manufacturers rate capacity based on discharge down to 0.9v. However functional capacity, at which the battery loses functionality for most RC uses, is down to 1.1v.

Eneloop is a brand of 1.2V NiMh rechargeable battery developed by Sanyo and introduced in 2005. As low self-discharge nickel–metal hydride batteries, Eneloop cells lose their charge relatively slowly—approximately 15% in the first year, compared with the 0.5% to 4% per day lost by older technology NiMH batteries, which are usually not sold pre-charged and ready for immediate use. Eneloop NiMh battery packs are primarily available from sources such as Batteries America in for both AA and AAA 4 cell (4.8/6.0V) sizes and in capacities of up to 2000 MaH but they are quite a bit more expensive than standard NiMh batteries.

Eneloop AA Size NiMH

Lithium Iron Phosphate (LiFe) Batteries

One type of battery gaining popularity across the RC spectrum is Lithium Iron Phosphate (LiFe) batteries. LiFe batteries come in capacities from 200 MaH up to 2300 Mah battery packs. LiFe batteries are safer to handle and charge than are Lithium Polymer (LiPo) batteries, but currently LiFe batteries are only available in either 6.6V or 9.9V packs, so if you need more than 9.9V, you will need to connect packs in series.

6.6 V LiFe Battery Pack

Lithium Polymer Batteries

Oh no, not the dreaded Li-Po's! Even if you have no experience with Lithium Polymer batteries you no doubt have heard some scare stories. How they puff, catch on fire and explode. Well yes, they will do all of that if they are abused, but once again, based on my experience, the only Li-Po battery I ever had explode was a 6S battery in my Wind 50 model airplane pattern ship that exploded when I hit the ground going straight down at full throttle. Can't very well blame the battery for that! (The crash of my Wind 50 and the other 10 model airplanes I put in the ground is why I am back to running model boats!) In any case, as careless as I was in the "care and feeding" of the Li-Po's that I used for my electric model airplanes, I never had one just catch on fire. I did however have them "puff up" and I learned about how "puffed up" they could get and still be useable.

6S 5000 MaH LiPo Battery Pack

First a little Lithium Polymer basics. "Lithium Polymer" is actually a misnomer. "Li-Po" batteries are Lithium-Ion Polymer batteries. What distinguishes Lithium Polymer batteries is that the design is usually flat, and lightweight, and the electrolyte is in liquid form, although it may be "plasticized" or "gelled" through a polymer additive. This is why I have classified them as "wet cell". Except for single cell batteries, Li-Po batteries are made up of single cells that are connected in series or parallel and mounted in a soft sided polymer container. Li-Po's are rated not only in terms of voltage, and capacity, but also in terms of internal composition and their discharge rate. An example of a Li-Po battery rating would be:

3S; 5000 MaH; 40C

3S: 3 cells in series (3.7 volts per cell, 4.25 maximum charge)
5000 MaH: capacity of battery 5 amp/hour or 5000 milliamp/hour
40C: Maximum discharge rate (40 X 5 amp/200 amps).

This is the actual rating of my two battery packs that will be going into my PT boat. I will connect two such batteries in series to give me a total of 25 volts and 5 amp/hour of capacity. 3S means that the battery pack will produce 12.75 volts at full charge, will last one hour at a 5 amp discharge rate, and can tolerate a maximum discharge rate of 200 amps (significantly reducing run time). As you can see, using high capacity Li-Po's in our scale boats can offer some significant run times at low discharge rates.

Series Vs. Parallel

Like any other type of battery, Li-Po packs can be connected together in series or parallel to increase voltage or capacity. However, you need to be careful and ensure that only batteries of identical voltage, capacity and charge level are used. In addition, if you re connecting packs in parallel, a paralleling harness should be used. If you try to use dissimilar battery packs, particularly connected in series, the pack with the lowest voltage, capacity or level of charge may be overloaded and a fire could result.

Charging Batteries

Charging batteries is an area that is rife with urban legend and is where most hobbyists get into trouble. Before I launch into my advice, let me relate my experiences with charging batteries. I have NEVER had a battery explode, or catch on fire as a result of charging. There are two reasons for this. One I have always used the correct charger, and **I have always been careful about the rate at which I charged.** That is not to say I haven't come close. I have overcharged NiMh batteries to where they became very hot, but caught my error before a catastrophe occurred. In that respect perhaps I was lucky. The point is this, if you use the right type of charger, charge at the correct rate, and you monitor the charging operation, you shouldn't have any trouble.

So what is the correct type of charger? Simple, one that is specified for your type of battery! If you are using Ni-Cads or NiMh batteries make sure your charger is specific to that type of battery. If you are using AA, or AAA size Ni-Cads or NiMh batteries, you should never charge them at more than a 500 milliamp (.5 amp) rate. Sub-C size Ni-Cads or NiMh batteries can be charged using a "field charger" that the fast electric boaters use, IF you are using a minimum 6 or 7 cell pack, AND you don't charge at a rate that is more than 1.5 times the capacity of the battery pack. In other words, if your Sub-C Ni-Cad or NiMh battery pack is rated at 2500 milliamps, then you should not "quick charge" it at more than 3.75 amps (2.5 X 1.5). This will take about 45 minutes to charge, but it reduces the risk of a battery fire or rupture of the battery case. In addition when charging Ni-Cads or NiMh batteries, using a Peak Detection charger will provide another level of protection, because when the Peak Detection is enabled, the charger will sense when maximum battery capacity is reached and automatically cut off the charge, or go to "trickle charge" until it is disconnected.

Peak Detection Charger

Speaking of “trickle charge” you should not leave your Ni-Cad or NiMh transmitter or receiver pack on “trickle charge” full time, unless it is programmable or a battery cycler. If you look at most “trickle chargers” they charge at 25 to 50 milliamp rate. That is a high enough rate, that it will actually overcharge your batteries, and even though they won’t overheat, the internal chemistry of the battery will change, and they will not only discharge more quickly but they won’t fully charge next time. This is the infamous “memory” that you may have heard about that Ni-Cads develop. In addition Ni-Cads, over the course or their useful life need to be periodically cycled, which is discharging them then re-charging them, otherwise they will develop the “memory” previously described. Most chargers that cycle, discharge to 1.1v and re-charge so that actual charge may be less than total rated capacity. The level of discharge and re-charge should be done only according to the battery maker’s instructions and using a charger which has a cycling (charge/discharge) mode.

If you are charging a lead-acid battery, always remove the battery caps, and charge in a well ventilated area. Cells should be filled to the appropriate level with distilled water (not tap water), and be careful not to let them boil over. Most automotive chargers have selectable charge rates or ether 2 or 6 amps. Automotive lead-acid batteries must always be monitored when charging. If you boil off the electrolyte, you will short out one or more cells, not to mention generating toxic gasses.

The underlying fault with all lead acid batteries is the requirement for an excessively long charge time arising from a two-stage process: bulk charge and float charge. All lead acid batteries, irrespective of type, are quick to charge to 70% of capacity within 2 or 3 hours, but require another 9 to 10 hours to "float charge" after the initial charge.

Charging gel cell batteries is fairly straight forward but should be done very carefully. Compared to flooded lead-acid batteries, VRLA gel cell batteries are more vulnerable to thermal run-away during abusive charging. The electrolyte cannot be tested by hydrometer to diagnose improper charging that can reduce battery life. Most hobby gel cell batteries aren’t rated for more than 7 amp/hours, so avoid charging rates that are more than more than 50% of the battery capacity and only with chargers rated for Pb batteries. I have had good luck using a Hyperion programmable multi-charger that I bought for my Li-Po's, selected to the correct battery type (Pb).

Charging Lithium Ion Batteries

<u>Charging Lithium Ion (Li-Ion) batteries must only be done with chargers specific to Li-Ion batteries.</u> That is because the charging process for Li-ion batteries is in three steps,

1. Constant current
2. Balance (not required once a battery is balanced)
3. Voltage source

Top charging is recommended to be initiated when voltage goes below 4.05 V/cell.

All three of these steps are automatic in chargers designed for Li-Ion batteries that have balancers.

Failure to follow current and voltage limitations can result in an explosion!

Lithium Ion Battery Pack (3.7V)

<u>Care of Li-Po's</u>

So what about the scare stories concerning Li-Po's? First, because they are wet-cell, Li-Po's need to be handled more carefully than dry cell batteries. If the case is punctured, or if a fully charged battery is dropped on concrete, it can cause an internal short and then a fire can result. If you do drop a Li-Po on hard surface, do not use that battery until you have monitored it in a safe area and see if it will start smoking or smoldering. A wise precaution when working with high voltage and high capacity Li-Po's is to have a Class C fire extinguisher handy that is rated for electrical fires. Li-Po's should not be discharged to less than 3.25 volts per cell. If you don't already have one in your boat, you should install a low voltage warning device on either the balance tabs of your battery pack, or to one of the unused channels of your receiver (if you have telemetry) to warn you of low voltage on your battery. One thing to remember about Li-Po's, at full charge, the battery has about 4.25 volts per cell. If you are thinking about using a 2S Li-Po in your boat as a receiver pack, you may need a voltage regulator, as a fully charged 2S Li-Po will be producing over 8 volts. That could overload your receiver or servo(s) which may only be designed to run on no more than 6 to 6.5 volts.

If you have not been very conscientious about maintaining your batteries, they will start to “puff”. Puffing happens over the life cycle of the battery, particularly if the batteries are not kept at a 44-54% level when in storage. Why do I say 44-54%? Because that is the level that brand new Li-Po’s are charged to when they are in storage awaiting sale. That is the level you should keep your Li-Po’s stored at when not in use.

I have personally only experienced one brand of Li-Po battery that *didn’t* puff on me. Some will start puffing very early, others will take longer. My experience was that a little bit of puffing is not a major concern. However when the case puffs up noticeably like a balloon it is time to get rid of the battery. You should cut the battery leads and put it in a container of high concentration salt water. The salt water will actually act like an electrolyte and discharge the battery to the point where it can be disposed of safely.

Charging Li-Po Batteries

This is where people get into trouble with Li-Po’s. **Li-Po’s must be charged carefully and must NEVER be charged with any charger other than one designed specifically for Li-Po batteries.** I use a Hyperion dual port charger that is programmable and can charge Li-Po’s, Ni-Cads, NiMh, and gel cell (Pb) batteries. To ensure proper and safe charging of your Li-Po’s the charger must be set to the proper number of cells (1-7S), and the charge rate should never exceed 1.5 times the capacity of the battery. Example: a 3000 MaH battery pack should not be charged at more than 4.5 amps (3 X 1.5).

Hyperion Multi-Charger

You should also have a balancer that can be connected to the balance tab on the battery pack that will balance the cells as the battery is charged to ensure that all cells charge evenly. You need to make sure that you have the correct type of plug for the balancer to connect to the balance tab. JST type connectors are becoming very common. However, if you are using a Thunder Power battery, their balance tabs are completely different from other battery packs and will require the use of a Thunder Power charger (sounds like JR radio vs Futaba). When you are using a balancer make sure you have programmed the charger correctly for the cutoff. Most chargers have either a time, voltage, or TCS capacity cutoff or all three. This is a safety feature to avoid overcharging your battery which could cause a fire.

For scale and sail boaters, there just isn't a need to quick charge Li-Po's at the pond since unless you are running a fast electric, you should have plenty of run time on a single charge if your battery pack has enough capacity. If you have a power boat with a high amp propulsion system, bring more than one battery pack, so you can run your boat while the other pack is charging.

When charging Li-Po's make sure that you charge them in a fire resistant area or have your Li-Po's in a charging bag. And don't forget to have a class C fire extinguisher handy. **Never, never leave Li-Po's connected to a charger overnight!**

Charging Lithium Iron Phosphate (LiFe) batteries.

Conventional lithium iron phosphate (LiFe) batteries need two steps to be fully charged:

Step 1 uses constant current (CC) to reach about 60% State of Charge (SOC);

Step 2 takes place when charge voltage reaches 3.65V per cell, which is the upper limit of effective charging voltage.

This means that a 6.6V LiFe battery pack will actually charge to 7.3V, but when the pack is removed from the charger it will drop down to 6.6V. This is why you **only use a charger specific to LiFe batteries for charging**, (or a multi-charger that has LiFe capability) and is why you won't need a regulator to run receivers and servos that are rated for maximum 7V input.

Battery Selection

So what kind of battery or battery pack should I use in my boat? The volume and type of hull, the purpose of the boat (racing versus cruising), the energy and capacity density and power and current drain required to run all the servos and propulsion system, combined with the desired run time will dictate what type of battery to use.

For instance in smaller sail boats, the weight to capacity ratio is critical so the relative weights of different battery packs and types is important. Straight NIMH batteries AA cells with 1500 Mah capacity weigh less than AA cells with 2500 MAH capacity for instance. This tends to be true for all battery types except wet cell automotive batteries. Whereas if you are running a 1/96 scale battleship, battery size and weight isn't as important as is voltage, and capacity. In fact for a displacement hull such as a warship or cargo vessel, having a heavy battery means you won't have to use as much ballast to get down to the design waterline.

Another important consideration is battery pack shape and configuration. You need to fit a battery into a confined space and sometimes be able to move it fore and aft to control weight distribution to balance the boat, especially if you are running a boat with a planing hull, such as a speed boat or PT boat.

Finally, if you are running a high speed power boat with a motor that draws high current (in excess of 25 amps), you will probably need to use either Ni-Cad, NiMh, or a LiPo battery pack(s). As of the date of this article, these types of batteries are still the primary types of batteries available to the model boater that can tolerate high discharge rates and are available in higher capacities (up to 5000 MaH in the case of LiPo's).

Well, that's about it for batteries. Smooth sailing, fair winds and following seas!

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