BATTERY CARE

Batteries, Cells, Chemistry, Math and Radios

Batteries are an excellent emergency power source, but require some basic information to use properly. They are electrochemical devices. They have plates, usually metallic, and either a solution or a moist compound between the plates. A chemical reaction takes place in the battery when it is discharged that produces a flow of electrons out one plate on the negative side and into another plate on the positive side.

Actually, a single unit of a battery is a *cell*. A battery is called a "battery", because it is a "battery" of cells together. Each cell will have a characteristic voltage range between charged and discharged that is set by the electrochemical nature of the metals used and the reactions that go on in the solution, gel, wet powder, etc. between the plates. Some non-rechargeable batteries contain other chemicals to absorb waste byproducts from the chemical reaction that moves the electrons along. This is what an "alkaline" battery is and why it lasts longer and costs more than a standard carbon/zinc cell. It has an excess of these chemicals to absorb more byproducts before the cell becomes poisoned. One such chemical is manganese dioxide, which is mostly what the damp black powder inside a typical dry cell battery consists.

Some cells or batteries can be recharged. In this case, a power supply is hooked up to run the chemical reaction backwards and restore the chemical makeup of the battery back to its uncharged state. Not all batteries can be recharged and attempting to recharge some non-rechargeable batteries can be quite dangerous, as pressures will develop inside the case and cause an explosion.

An example of a rechargeable battery is a lead/acid cell. Here lead plates and sulfuric acid are used and lead sulfate is generated and destroyed as the battery discharges and then is recharged. A "gel cell" is usually a lead/acid battery that has something in the sulfuric acid solution to make it less sloshy or gelled. Because they have more trouble dissipating heat and out gassing, these gel cells should be charged slower than regular lead/acid batteries.

The lead/acid battery has been in common use in automobiles since 1915 or so. It has plates of lead in sulfuric acid solution in water. One of the sets of lead plates is coated with lead dioxide. As such a battery discharges it creates two chemical reactions, one at the anode that ends up with an excess of electrons, and one at the cathode that ends up short electrons. If a wire is connected between the two, the excess electrons from the anode will travel through the wire as a current to the cathode where they are needed to complete the electron deficient reaction there.

Driving the Electrons Through Wires with Chemistry

Anode Reaction:
$Pb + HSO_4$
$^- \rightarrow PbSO_4 + H^+ + 2e^-$

This says that the metal lead in the anode reacts with the ionized sulfuric acid to produce lead sulfate, hydrogen ions in solution and two excess electrons.

Cathode Reaction:

$$PbO_2 + HSO_4^- + 3H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$$

This says that the lead dioxide reacts with the ionized sulfuric acid and the available hydrogen ions, plus some donated excess electrons from the anode via the connecting wire, to produce lead sulfate and water. When charged, the flow of electrons is forced backwards against the electro potential of these reactions and the reactions are driven backwards, changing the lead sulfate back into lead and lead dioxide on the plates and restoring the sulfuric acid to the solution, the liquid electrolyte.

Modern batteries contain calcium metal in the lead to decrease the tendency to produce hydrogen gas during charging by electrolysis of the water in the electrolyte solution. If enough calcium metal is present, the battery gassing is so well controlled that the cells can be "sealed" and their demand for replacement water greatly decreased.

Another common type of rechargeable battery is a NiCad, based on Nickel Cadmium electrochemistry. Because they are a different chemistry, they have a different voltage. Dry cells, lead/acid cells and NiCad cells will all produce a different voltage ranging from about 1.3 volts fully charged to 2.1 volts fully charged. NiCad’s are often physically the same size as carbon/zinc "dry cells" and are made in double A, and C and other common sizes. However, they will have a different voltage, a lower one. Usually this is not a problem for most electronics that are tolerant about the exact input power required.

All batteries or cells have an internal resistance and a capacity. The internal resistance determines how many amps the battery can reliably provide in service. The capacity is measured in amp/hours. This is simply the number of amps the battery can deliver at a reasonable drain rate for that battery time how many hours it is expected to deliver those amps.

Battery Math and Amp/Hours

Most batteries are rated in electrical capacity for a discharge rate of 20 hours. A 20 amp/hour battery should provide one amp of current for 20 hours before being fully discharged. It will still show a voltage, it will no longer be functioning correctly and if rechargeable, it will be in serious need of a recharge.

Some smaller batteries like those used on HandiTalkies are rated in milliamp/hours. It is the same concept; they just use milliamps instead of amps for these lighter duty batteries. A typical rating might be 1200 ma/Hr which is the same as 1.2 amp/hours.

A standard small car battery is about 45 amp/hours. That means that it will supply over two amps for 20 hours. A battery should not be discharged at a higher current draw, or asked to deliver more amps than its amp/hour rating divided by 10 in order to get maximum capacity out of it. In the case of a 45 amp/hour battery that would mean it should not be asked to deliver more than about 4 amps for best service.

Treat Large Batteries with Respect!

A car battery can deliver up to 300 amps if short-circuited! This is very dangerous. Extreme heating can result, lots of out gassing, the plates will overheat and warp and the battery will be destroyed, often dramatically. However, this is exactly what happens when you crank a starter motor. The battery survives because these large cranking loads are short lived. Be very careful when transporting charged batteries and hooking them up. Shorting the terminals of a large battery can be quite dangerous. It is worth noting that a car battery has enough electric power in it to electrocute you many times over. The reason it does not is skin resistance. It takes about 48 volts to puncture the dry skin resistance of the human body and get current flowing in the conductive juices inside. Even damp skin will not breakdown easily at low voltages. This is why you can handle jumper cables hooked to a battery and usually not electrocute yourself, the voltage is too low to get the current inside the body where it can do damage. Still you should be careful about getting across any heavy-duty electrical power circuit regardless of voltage.

It is quite reasonable to discharge a battery at its amp/hour rating divided by six, or four, or maybe even three. So a 45 amp/hour battery could be used to power something that demanded 10 or 12 amps. *However, do not expect it to last four hours.* These higher demand currents will cause extra loses in the internal resistance of the battery to go up, and the total capacity before the battery is fully discharged will be less at these higher rates. More power is lost heating up the battery for instance.

Therefore, if you divide a battery's amp/hour rating by the current load you are going to put on it, you can estimate how long it will last. If you divide a battery's amp/hour rating by 20, you will find out how much current it can deliver and still live up to its capacity rating. If you divide a battery's amp/hour rating by four, you can estimate the maximum current you should expect such a battery to deliver and still have a reasonable life expectancy before it is fully discharged. Motorcycle batteries are handy for portable operation. A typical one would be rated at 12 amp/hours. That means it can handle half an amp easily and work for 24 hours. It should not be asked to deliver more than 3 amps maximum. My TenTec Argo 556 demands 2.1 amps on key down transmit and about .4 amps on receive. A 12 amp/hour motorcycle battery easily kept it going for 30 hours of Field Day activity. The battery was still healthy, but ready for a recharge afterwards.

An advantage to motorcycle batteries is that they have screw caps on the cells. The cells are still assessable for testing and examination, but they are less "spillable" and will withstand more sloshing about and reasonable amounts of tilting during transport. When the same motorcycle battery was asked to power a rig that demanded six amps, it strangled, the voltage dropped dramatically and the power output from the rig was mediocre. For a discharge rate of six amps, something more like a 28-32 amp/hour battery is appropriate.

Things to Know About a Battery

The three most important things to know about a battery, regardless of whether it is for an HT, a large HF portable station or just an AA size NiCad, are its amp/hour rating, its chemistry and its voltage. The chemistry determines the voltage of a cell and the number of cells determines the voltage of the battery. A standard car battery is six lead/acid cells in series. A standard "battery" for a flashlight is actually a single carbon/zinc cell. A typical automatic camera battery is two specially modified carbon/zinc cells in series to produce about three volts, etc.

Recharging a battery that can be recharged is easy to understand. You need to apply an appropriate voltage and current for an appropriate time. If a battery has a 12 amp/hour rating, you should expect to charge it at 1 amp for 12 hours, amazing how that works out! The correct charging rate for a battery is the amp/hour rating divided by 10. If you charge faster, you will heat up the battery. Fast charging is OK as long as it is not overdone, like at the amp/hour rating divided by ONE. The amp/hour rating divided by four is OK if the battery is monitored or if a special, charging circuit that limits the current and maximum voltage is used.

The correct charging voltage is determined by the chemistry of the cells and the number of cells in the battery. A typical car battery has six lead/acid cells. Such a cell puts out about 2.1 volts when fully charged. *SURPRISE!!* Six of them in series cause it to be called a 12.6-volt battery! However, when really fully charged and just off the charger, such a battery can be closer to 13.8 volts. Most car battery eliminators such as the Astron regulated power supplies will crank out a fixed 13.8 volts.

Keep in mind that *AMPS times VOLTS equals WATTS.* Therefore, for a fixed amount of watts required or desired, if the volts go down, the amps have to go up. For that reason, rigs designed to work on "12 volt" power supplies, specifically for Car battery systems for mobile use etc., work better on 13.8 volts since they require fewer amps to get the same power input demand. This is why most battery substitute A/C line driven power supplies, even though called "12 volt supplies" actually crank out a fixed 13.8 volts.

For the same reason, if a battery drain is excessive, the internal resistance drags down the voltage. The net result is that the amps demanded goes up in a vicious cycle. This is why there is a reasonable maximum drain you should expect from any battery, based on its amp/hour capacity.

The power in a battery can be impressive. Take a standard car battery. It is rated at 45 amp/hours. That means it can crank out 2.25 amps for 20 hours. In addition, it will start out at about 12.9 volts and drop to about 11 volts, averaging about 12 volts during the period. 2.25 amps times 12 volts equals 27 watts. 27 watts times 20 hours equals 540 watt/hours, a half a kilowatt/hour, not bad at all for portable power.

How Large a Battery is Needed

It is important to know how many amps your rigs draw in order to estimate how big a battery you are going to need. The manuals will give you a wild guess. It really needs to be measured. Such measurements are best done with the rig connected to an adequately rated, voltage regulated power supply like an Astron.

If you meter has a heavy-duty amps scale, it can be hooked in series with the rig and you can read it directly. If not, you need a series resistor. Remember that AMPS times OHMS equals VOLTS, so if one knows how many ohms the resistor is and you measure how many volts of drop there are across it, you can easily calculate the amps.

You do not want a lot of voltage drop or resistance in series in this application. In addition, you need a beefy resistor for the high power measurements and a DVM with an accurate scale that can measure millivolts. I use a 200 watt, 0.01-ohm precision resistor. It is a huge thing with big lugs on the end and can easily measure current draws of 50 amps or more.

A typical 100 watt HF transceiver is going to demand 20 to 25 amps. You can see at once that you are going to need a BIG battery for this. In a car, the alternator and not the battery power the rig when the motor is running. Using the HF rig without the battery running at these power levels will strand you beside the road fairly fast. You can also make a wild guess at the power required for any rig if you have a good idea of its transmit power.

Take the rated power output, assume about 33% total efficiency so take that times three, and compute how many amps are needed to make that many watts at 12.6 volts. For instance, a rig designed to crank 100 watts is: 100 * 3 = 300 watts; 300 watts/12.6 volts equals about 24 amps. If you are lucky and the rig is well designed, it should need a bit less than this on key down CW transmit.

To take such a rig to the field you are looking at 80 to 100 amp/hours of battery minimum, two Car batteries in parallel, or one really beefy heavy equipment battery. I have seen batteries easily available at up to 120 amp/hours each, but they are whoppers and back breakers to pick up. I recently purchased a heavy duty, deep cycle Marine battery at Sears. It is about 84 amp/hours and weighs in at 53 pounds.

Typical Motorcycle Batteries will be in the 6 to 12 amp/hour range. The larger batteries for big motorcycles and lawn tractors will range from 12 to 32 amp/hours. The smaller foreign car batteries start in about this area, about 30 amp/hours.

Many batteries now days are rated in CCA or RC. CCA is Cold Cranking Amps. CCA is approximately equal to the RC of a battery times five. [1000 CCA is about 190 RC]. RC is Reserve Capacity. You can convert RC to amp/hours by the following formula:

Amp/Hours = (Reserve Capacity / 2) plus 16

One solution to battery mass is to turn down the power on the rig for portable service [QRP]. Few will notice if you reduce power from 100 watts to 50 or 25 watts, but you will decrease the power demand on transmit and the size of the battery sharply. This is a case where the FCC precept that you use the minimum power required to communicate makes a lot of sense.

In an emergency, a few S units on someone's distant receiver sacrificed for additional hours of operation on your end could be crucial. Remember battery life is not linear, if you half the power demand you may well more than double your operating time. Also remember that reducing power six DB, or to one fourth the transmit power; will only cut your received signal strength by one S unit on the other end.

Charging Batteries and Battery Chargers

Battery chargers are usually very simple things. The average manual charger is just a beefy transformer, a few large diodes and not much else. They often have less than wonderful internal connections and always benefit from a case removal, some soldering of the crimped connections and maybe some extra heavy wire. They usually have a circuit breaker somewhere and may have an alleged amp meter which imagines it can read current, more or less, approximately, somewhat related to reality. They produce pulsed DC with no filtering at about 15 volts. Some have a "fast charge" setting that really abuses the battery with even higher voltages. They are designed for occasional use, expecting the battery to be routinely charged by a car's regulated charging circuit, not to be the only source of recharge for a battery. Such chargers are good for pounding on batteries. They will easily overcharge batteries of the lead/acid type they are designed to work with. This causes electrolysis and gassing which damages the battery and makes an explosive gas (hydrogen).

There are some "automatic" chargers available at places like Sears for just a bit more than the equivalent manual ones. They are well worth the extra price when your primary use for the battery is portable or emergency power and a lot of recharging will be done off this charger. They are highly recommended over the manual versions.   The best battery charger is a power supply that can be current and voltage regulated. There are some super fancy automatic ones that incorporate these features. Based on the chemistry of a battery, there is a *MAGIC* voltage where it can be left connected and it will not overcharge, and its internal leakage will be compensated for, keeping the battery fully charged all the time. This is called trickle charged or *"floated"*, but most so-called trickle chargers are junk, not voltage regulated and really just slowly boil away the electrolyte with electrolysis, making certain it will be a *"late"* battery when you actually need it.

To properly charge a battery, you should apply a voltage that causes current to flow *(being careful to get the plus and minus hooked up properly!)* at about 1/10th the amp/hour rating of the battery to a maximum of about 1/4th the amp hour rating of the battery.

For instance, for a 45 amp/hour battery you should not charge much faster than 5 amps. For a 12 amp/hour motorcycle battery you should not charge faster than about 1.5 amps, etc. When the voltage required to maintain this charge rate exceeds 14 volts, you should turn it down and regulate it at 13.8 volts. Just let the charge rate drop naturally while the voltage is held constant at the battery terminals. Eventually the current into the battery will drop to practically nothing at 13.8 volts if it is lead/acid. Different chemistries will have different magic voltages. This is what is called *"float"* charging a battery. Maintaining it at a voltage which just balances the electrochemical potential of a fully charged series of cells, just below where they will start to perform electrolysis on the battery solution. If done correctly such a float can go on for a very long time and the battery will stay healthy, just compensating for the internal discharge rate of the battery.

Exercising Batteries

All lead/acid batteries like to be exercised at intervals. To do this you should discharge them at a rate of $1/10^{th}$ to 1/4th of their amp hour rating. For a standard 12-volt lead/acid battery, you can usually find something at the NAPA Parts Store that is just right. I like truck tail light bulbs for small batteries and headlamps for larger ones. You can use just the backup filament, or the turn signal filament or both. With the headlight, you can use normal or high beams. Just wire up some clip leads from the battery to this "load". Monitor the voltage on the battery and when it tries to drop below 11 volts under load, stop. The battery is now ready to recharge. This evens out the distribution of the lead sulfate on the lead plates of the battery and the sulfuric acid strengths in the cells. This in turn helps insure that the battery will have its full charge capacity. How much to discharge the batteries depend on the exact battery and its chemistry. Lead/acid batteries should not be over discharged. A standard car or motorcycle "12 volt" battery should not be discharged below 10 volts. NiCad’s need deeper discharges to condition them and avoid "memory effects" where the battery capacity is dramatically reduced, causing them to appear to charge just fine, but rapidly go flat when a load is applied.

Battery Dangers

Be careful around bubbling batteries, the gas is hydrogen and it will explode if you make a spark or open flame. There should NOT be a lot of bubbling. That is a symptom of too much voltage on the cell during charging or too rapid a discharge. The solution is being broken down into gas and that is NOT supposed to happen. It is NOT a normal part of the charge/discharge cycle.

PLEASE do NOT be one of the sad idiots who checked his battery fluid levels while charging a battery with his BIC lighter!   **No flames around a charging battery.** It should not be heavily out gassing but do not take a chance. Some out gassing is inevitable, a small amount, due to difficulties in getting the same voltage across all of the cells in a battery. Also, watch the liquid levels in a battery. The non-sealed ones will evaporate. **Replace the fluid with distilled water only!** Never add more sulfuric acid, you will unbalance the battery. The replacement needed is distilled water.

Many batteries come "dry", at least the lead/acid ones. You will get a bottle of sulfuric acid with it. Add it carefully up to the indicated line. Purchase of dry charge batteries is highly recommended. You are certain they are new and fresh. **Watch out for sulfuric acid.** The acid will burn skin. It will cause very serious damage or blindness if you get it in your eyes. If you come in contact with it, rapidly wash it off with lots and lots of water. If you get it in the eyes, flush with water and get medical attention at once.

Sulfuric acid will make cotton cloth *disappear as you watch*; eating holes in everything cotton you are wearing. It is poisonous and would cause hideous internal damage if swallowed. The stuff inside a battery is even worse. It also contains dissolved lead. Any spills of lead/acid battery contents or battery acid can be neutralized with ordinary baking soda from the kitchen. Do not get any baking soda inside the battery. You will destroy the battery. The soda will fizz like crazy until the acid is neutralized then the entire mess can easily be cleaned up with water.

A lead/acid battery that has access, the old fashion type with the pukas on top with plugs that allow you into the liquid in the cell, has one advantage. You can measure the specific gravity of the liquid inside. Since this liquid is sulfuric acid solution that changes strength as the battery charges and discharges, and sulfuric acid is very heavy, the density of the battery fluid changes as it charges.

A hygrometer will measure the specific gravity. You can get very portable and easy to use ones that have a series of colored balls inside an eyedropper like device. You suck up some of the acid and how many balls float shows the state of the charge on each cell. Again, be careful, and wash off any such equipment after use since it will be covered with the acid. It is an excellent method of accessing charge state on Lead/Acid batteries.

Lead Acid Battery Specific Gravity for Various Charge Levels

Specific Gravity	Percent of Charge
1.265	100%
1.225	75%
1.155	25%
1.120	Discharged

Information courtesy of the University of Hawaii Ham Club