THE JUNIOR OPERATOR'S GUIDE TO BATTERIES, BATTERY CHARGERS, AND BATTERY CHARGING.

A Practical Compendium of All That Junk You Might Want to Know.

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Addenda to a presentation by
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1 Historical Trivia and Basics

1.1 The Ancient Days

Way back in time, in a land far, far away, the battery was born..... This most fundamental of electrical devices was the fruit of the mind and hands of one Alessandro Volta Italy, about the year 1800. The original battery was made from a stack of alternating copper and zinc disks separated by paper soaked in common salt solution. This became known as Volta's "pile" and was the original "dry battery".

Since that time, several kinds of batteries have been devised, each based upon cells of slightly different chemistry and construction. But, the principles between them are essentially the same. Most prevalent among these different cells are the Bunsen cell, the Fuller bichromate cell, the Daniell gravity cell, the Edison-Lalande cell, and the Leclanche cell. Of most importance to use in storage batteries for amateur radio use is the lead accumulator cell (known variously as the Plante or Faure cell after their inventors), the nickel-cadmium alkaline cell, and the nickel-iron alkaline cell.

1.2 Primary vs. Secondary Cells

There are two general classes of batteries. The first class is the primary battery — that battery which cannot be renewed by charging with electric current. The second class is the secondary battery — that battery which *can* be renewed by charging with electric current. A primary battery can be thought of as a disposable battery, while a secondary battery can be thought of as a storage battery or rechargable battery. The differences between the two classes relate to the chemistry of the cells. The primary cell reactions are not easily reversible. The secondary cell reactions are easily reversible.

1.3 Types of Secondary Batteries Likely to Be Found for Amateur Radio Use

There are three types of secondary battery that are likely to be found that are suited to amateur radio use. Two are relatively common, while one is uncommon. The most commonly found secondary battery type that is suited to amateur use is the lead acid battery, and its various derivatives. The other common type is the nickel-cadmium alkaline battery. The uncommon type that is a treasure if you find it, is the nickel-iron alkaline battery.

1.3.1 How Do You Know What Type of Battery it *Really* is?

How does one know what kind of battery one has? That can be a very problematic question. There are several ways of ascertaining what type of battery you may have. They are based upon reading of the labels on the battery, the type of construction of the battery, the case material, and the cell voltage. Note that this concerns rechargable storage batteries, and *not* the average flashlight size battery or the rechargable battery pack on your electric toothbrush.

1. If the battery cell voltage is 2.0 volts per cell, the battery is a lead acid battery. If the voltage is 1.2 volts per cell, the battery is a nickel-cadmium alkaline or nickel-iron alkaline battery. Note that 3 or 6 lead cells make up a 6 or 12 volt battery, while *5 or 10* alkaline cells make up a 6 or 12 volt battery. Also, rechargable battery packs in small portable equipment are almost always nickel-cadmium alkaline cells (including your HT).

2. If the battery cells have a *metal* shell, and the cells are mounted in insulating bushings, the battery is probably a nickel-iron alkaline Edison cell battery. Look for the Edison name on the cell case or for a red or black ring around the cell positive or negative terminal, or for characteristic metal flip-top cell vent caps.

3. If the battery cells have poppet valve screw caps, and the case is clear or whitish plastic, then the probability is good that the battery is a nickel-cadmium alkaline battery. This is especially true if the name is Edison. EXCEPTION — stationary batteries from phone substation installations are lead acid if the name is Exide. If the cells are unmarked they may be from a military aircraft battery and are probably nickel-cadmium alkaline cells.

4. If the battery is one of the generic Yuasa or Panasonic sealed maintainence free batteries, or if the battery is a marine or recreational vehicle battery, it is a lead acid battery.

5. If the battery is like a common auto battery, it is a lead acid battery.

6. If the battery is from an industrial vehicle or lighting or phone substation or computer UPS, it is *most* likely to be a lead acid battery but *could* be a nickel-cadmium alkaline battery, or very rarely a nickel-iron alkaline Edison cell battery.

7. If the battery name is Gates, it is probably a lead acid battery of the gelled electrolyte type. (Note: most "gel cells" are in fact gelled electrolyte cells only if the word "gel" or "gelled" appears on the label. Otherwise, they are usually just sealed, maintainence free lead acid batteries.)

1.3.2 Gel Cell Batteries

Gel cell batteries are nothing other than lead acid batteries in which the electrolyte has been thickened (much like mom thickened the gravy for the table) by the addition of viscosity increasing substances to the acid electrolyte. By analogy, think of the gel cell battery as something like a carbon-zinc battery that you put into a flashlight. The electrolyte is not a free flowing liquid, but is more like a thin paste. Gel cell batteries are very useful where a battery is liable to be inverted, or laid over onto its side, or generally shuffled about in normal operation.

1.3.3 Sealed Cell Batteries

Sealed cell batteries are batteries that are closed in such a way as to prevent spillage or opening the cells for the addition of water. Most sealed cell batteries are of the lead acid type. They are designed such that the closure to the top of the cells takes the form of a rubber pressure valve the will allow the venting to atmosphere of gases if the pressure inside the cell exceeds a small value. In normal use, gassing is very limited, so that if the battery remains sealed and the cell water is not boiled away by excessive overcharging, the cell never needs to have water added. Hence, it can be effectively sealed and require no attention. These batteries find extensive use in standby power systems and emergency lighting systems. There is some use in automotive power systems.

Sealed cell batteries may be used indoors with little problem *as long as they are not overcharged significantly and caused to emit hydrogen gas in any great quantity.* Care in charging will be necessary to prevent significant gassing. But, in most homes, there is sufficient movement of air due to the air conditioning to prevent excessive explosive hydrogen gas buildup.

The commonly found Yuasa and Panasonic batteries from the surplus yards are sealed cell lead acid batteries — not “gel” cells. Generally, the cells are sealed by a rubber vent cap that forms a close-fitting seal at the vent hole. The vent hole is quite small, so that addition of water can only be done with a dropper or a syringe. There is usually a plastic cap glued over the rubber vent cap that must be broken off with a small screwdriver blade. Therefore, the cells are not maintainable, under normal circumstances. But, in the crafty arts of ham radio, they can be refilled with water with a little care, and rejuvenated if they are dried out. The usual cause of their demise is that they have been dried out by overcharging. The secondary cause of their demise is that they have been allowed to sit for longer than about a year, without recharging, and the plates have become heavily sulphated. These batteries must not sit for longer than about 3 months without a “topping off” recharge. If they do sit longer than that, they will heavily sulphate and be “dead” and of no use or not resurrectable.

1.3.4 Maintenance Free Cell Batteries

Maintenance free cell batteries are batteries in which an *attempt* at sealing has been made. Usually, maintenance free cell batteries will allow for the addition of water to the battery by removal of the top cap/cover of the cells. This is commonly done in automotive batteries. They look like they don’t have accesses to the cells, but, if you *carefully* pry up on the covers, they usually will come off in a group of three cells per cover, and *voila* you can add water the the cells. (Gee, that looks just like a normal wet cell battery with funny vent caps! It never ceases to amaze me what the sales folks will come up with next for a gimmick!) The covers usually are flat plastic about 1 cm thick and cover much of the top of the battery. There will usually be two on a 12 volt battery, so look for a characteristic line dividing the battery in half, sideways across the top. That line will divide the two covers. Some of these batteries may have a narrow channel running the entire length of the battery along the top, with a plastic cover fitting into this channel. This type of cover may need to be gently pried up with a screwdriver blade.

These maintenance free cell batteries are maintenance free only to the extent that water is not commonly necessary to be added, if the automotive charging system is working correctly. But, they do need to be checked at monthly or such intervals. Failure to do so will cause the battery to boil dry, and be good for the automotive battery salesman and bad for your pocketbook.

These batteries can be effectively used in the ham shack, if one takes care not to overly charge them to where they gas excessively or boil dry. Charge these in the ham shack only if they are being float charged. If cyclic charging is used, *charge them outside or only in a well ventilated space.*

1.3.5 Real Wet Cell Batteries

Real wet cell batteries are of any chemistry (lead acid, nickel-cadmium alkaline, or nickel-iron alkaline). They are characterized by real honest-to-goodness cell vent caps that can be easily opened for the addition of water to the cells. They come in all sizes, from several Ampere-hours to thousands of Ampere-hours in capacity. Most are in plastic cases, these days, although occasionally hard rubber cased batteries can be found in industrial installations, or for replacement automotive use.

Wet cell batteries should be used in well ventilated areas, and not in the cramped confines of the usual ham shack. They will emit hydrogen gas freely, and the Edison nickel-iron alkaline cell emits it even when not being used. Probably the best course of action is to put the cells on the back porch and cable the power into the shack.

Industrial vehicles, particularly big trucks and loading trucks use large wet cell lead acid batteries. The big 12 volt diesel truck batteries are quite good for amateur radio use as a main station battery. But, they don't have a life of more than about 5-10 years. Golf carts are a good source of large lead acid wet cells. These are fairly common, and the quality is usually somewhat better than in the diesel truck batteries. Another source of such batteries is in floor polishing machines, both pushed and riding types.

Rarely, glass cased batteries are found — *be very careful if you play around with these.* They are rather fragile, and are designed to sit in one location as a stationary battery for their entire life. Most large stationary batteries now have clear plastic cases. These are also high quality batteries that should last 20 or more years. They are also *HUGE* and weigh in at 100 and *more* pounds per cell. That is one big battery for a 12 volter to run the shack from!

If you find a metal cased wet cell battery, and the cell vent caps are flip-top caps, you may have a nickel-iron alkaline Edison cell battery. Sometimes the cells will be in wooden racks of 5 in the case. Note that the cells themselves are metal. These cells are guaranteed to last a lifetime, if well cared for. If you run across them, treasure them, or pass them *my* way. These batteries were often associated with rural farm electric systems, and with industrial signalling installations. Larger types can be found in industrial carts, in rail cars, and onboard ship.

If the metal cased battery has plastic cells within, and there is a tight-fitting lid, it probably came from a large commercial airplane, or a military airplane, and the cells will be very expensive, high quality nickel-cadmium alkaline wet cells. These also should be treasured, since they will have a life of at least 20 years, if well cared for. Most of the time these aircraft nicads are recycled, but often they show up in military surplus. At hamfests, most of these batteries have been broken up into the component cells for sale by the cell. Cheap private aircraft batteries are made with plastic cases looking like the high quality nicads. But, they are lead acid batteries and usually are only good for a life of 5-10 years.

Wet cells require periodic servicing. The water level needs to be checked weekly. Proper charging is a must, whether it be floating charging or cyclic charging. But, if proper care and maintenance is given, wet cells are the longest lived of the various types of batteries. It is not uncommon for the average wet cell battery to have more than a 10 year life span (excepting automotive starting batteries). It is not uncommon for industrial stationary wet cell batteries to have a life span of 25 years. Nickel-iron alkaline Edison cell batteries are the longest lived of all batteries. It is not uncommon for them to be going strong even after 50 years of service.

2 Battery Chargers

2.1 Simple Current Limited Battery Charging Systems

Current limited battery chargers are the simplest of the battery charging designs. They are characterized by a charging voltage source that is at least *twice* the voltage of any battery to be charged. A series resistance of sufficient value to limit the charging current to the battery is placed in series with the battery. The charge delivered to the battery is constant in current, and variable in voltage. As a rule-of-thumb, the charge current is limited to less than C/7 amperes, but may be as low as C/50 amperes. It should not be greater tha C/7 under any circumstances for the general sorts of batteries hams are likely to encounter.

Current limited battery chargers are the first type that were invented, and have been used for some 100 years commercially. The technology is simple, and well proven, but it has two drawbacks. First, the state of charge must be monitored in some way to prevent overcharging of the batteries. Second, if floating charging use is contemplated, then the current limiting for floating charging is very small, and the battery is not well charged if it is allowed to run down. In the first case, some history of the use of the battery is required to ascertain the amount of charge required to bring the battery up to full charge. In the second case, one needs to average the amount of charge to the battery based upon use so that the net charge per unit time (day/week/month) is maintained, while not overcharging the battery.

A current limited battery charging system is illustrated in Figure 1. This represents the fewest number of parts to make a usable battery charger. A more exotic commercial current limited battery charging system is illustrated in Figure 2. This is more complicated, but allows for charging batteries at their rated voltage by splitting the battery into two sections and charging each section at double the rated voltage. This type of system is used on ship for charging 120 volt batteries in 60 volt halves.

A practical simple current limited charging system suitable for amateur radio use is illustrated in Figure 3. It has capacity to charge several batteries simultaneously in 6 or 12 volt sizes up to about 75 Ampere-hour capacity. Note that the series current limiting resistors are household lamps. Different sizes of lamps will provide different series current limiting resistances. For example, a 100 watt bulb will allow about 100 ma charging current from a 24 volt source to a 12 volt battery, while a 25 watt bulb will allow about 30 ma charging current from the same source to the same battery. A 50 watt 12 volt RV bulb will allow about 4 amperes current to pass to a 12 volt battery from a 24 volt source. For reference purposes, lamp current values for various type of lamps is given in Figure 4. For most battery charging uses, the voltage across the lamps will be about 10-20 volts, so the lamps will glow at a very dim intensity, and pass about 1/3 their normal current. This idea of using lamps as series current limiting resistances goes back to very early in the century, but has also been proposed in amateur circles, quite recently (Figure 5).

A multiple battery system using simple current limited charging is illustrated in Figure 6. This system allows several batteries to be charged and used in parallel, for increased capacity. The diodes in the load drain lines from the batteries are reverse current protection diodes that prevent one battery from passing current backwards through another battery, if the voltage in any one battery is lower than in the other batteries. The diodes will pass the full battery current, so they will need to be rather heavily rated at approximately the load capacity.

2.2 Voltage Limited Battery Charging Systems

Voltage limited battery chargers are the most complex of the battery charging designs. They are characterized by a charging voltage source that is 1.125—1.200 times the voltage of the battery to be charged. The regulating circuitry is much more complex than a simple series current limiting resistor. In a strict voltage limited battery charging system, the starting current may be quite high, especially if the battery has been allowed to run down somewhat. As the charging cycle continues, the charge rate becomes less and less. Finally, the rate tapers off to almost nothing, as the final battery voltage is reached. One has to be very careful that the correct charging voltage is used. Not all batteries will use the same charging voltage. Depending upon the construction and chemistry of the battery the range can be, for example in a 12 volt battery, from 13.5 volts to 14.5 volts. If you use too low a voltage, the full capacity of the battery is not reached. If you use too high a voltage, the battery will gas excessively and eventually boil dry.

For the Yuasa sealed lead acid batteries commonly found in surplus, the charging voltage rating is often printed on the side of the battery. If it is not, the charging voltage rating is 2.25—2.30 volts per cell *for floating charge use*, and 2.35—2.50 volts per cell *for cyclic charge use.* This means that a 12 volt battery for floating charge use should be floated across a charging line voltage of 13.5—13.8 volts. This means that a 12 volt battery for cyclic charge use should be placed across a charging line voltage of 14.1—15.0 volts. Note that the charging time required is not given as a fixed number of hours in the cyclic charging method, but is actually continued until the voltage stabilizes. Normally this will take about 15-24 hours.

An easy way to find out if the charging voltage is correct is to first fully charge the battery, then second measure the current through the fully charged battery, while it is on charge. If the current is about C/400, then the voltage is correct. If the current is greater than C/100, then the voltage is too high for continuous floating charge use, but may be fine for cyclic charge use. If the current is greater than C/10, then the voltage is too high even for cyclic charge use. To properly utilize this charging method, the voltage control should be finely variable within the required range. The tolerances are rather narrow. Too much voltage will boil the battery dry, over time, while too little voltage will never allow the battery to take full charge.

2.3 Combination Current—Voltage Limited Systems

Current-voltage limited battery chargers are also relatively simple battery charging designs. They are characterized by a charging voltage source that is 1.2—2.0 times the voltage of the battery to be charged. A current limiting resistor is still used, but a the characteristic charging current to the battery starts off somewhat large and tapers off to a small value approximately equivalent to the floating charging value. The final voltage across a 12 volt battery will be in the range of 13.5-14.5 volts at the end of the charge. This represents an intermediate charging method, and if the charging voltage and series current limiting resistance are chosen correctly, the method is self regulating and not stressful on the battery.

3 Battery Charging

Battery charging is the renewing of a secondary or storage battery by passage of a reverse current back through the battery. Normally there is a fixed charge associated with any given size of battery, and that charge must be replaced after use, before the battery deteriorates.

There are several different ways to recharge a battery, depending upon the rate of the charge, and the current—voltage characteristic of the charge. There is a "quick charge" that will force a high rate of current through the battery in a short time (usually about 3 hours). This is basically a bad way to recharge a battery, because it stresses the battery by making it dissipate an inordinate amount of heat. Unless the charging circuitry has been specially designed to handle "quick charging" and the battery design will dissipate the heat buildup satisfactorily, *you are better off staying away from "quick charging"*. There is a standard charge wherein the battery may be recharged in approximately seven hours. This is the usual battery charging rating. There is a finish charge in which a battery is "topped off" or recharged in about 10 hours. This might be considered an "overnight" charge. There is a trickle charge, wherein the battery is charged in 24 hours. This is the minimum charging rate, and will insure the least amount of heat buildup in the battery on charge. There is a floating charge, wherein the battery is kept charging permanently on a very miniscule charging rate, that just overcomes the natural open circuit discharge of the battery, plus any load on the battery. Sometimes it is advantageous to combine charging rates so that the recharging may be done in the least amount of time, while not stressing the battery. This is sometimes called a tapering charge or stepped charge. All of these ways to recharge a battery have their use. Likewise, all can be abused or be abusive to the longevity of a battery.

3.1 Basic Principles

For any given size battery there is a fundamental value C which is the net charge that the battery contains. Since most batteries have a standard rated charge value for a 7 hour load cycle, the standard rate of discharge of any given battery is C/7, in Ampere-hours. Nearly all batteries are labeled as to the capacity of the battery in Ampere-hours, or that information can be gotten from manufacturing tables. If one is going to charge the battery, then it needs to be charged for 7 hours at the C/7 hour rate. In actual practice, a certain amount of overcharge is necessary to maintain the battery at full capacity. This overcharge is usually about 20% of the rated Ampere-hour capacity.

The above is true assuming that the battery is used/recharged in a cyclic manner, and not floating charged. For floating charging, the battery needs to be first fully recharged, then second allowed to float across the charging line at some small charging rate value, indefinitely.

3.1.1 Sizing the Charge to the Battery

For a particular battery, the calculations for obtaining the required charge are very simple. First, you need to know the capacity of the battery in Ampere-hours. Second, for any given battery, knowing the rated battery capacity in Ampere-hours, the standard charge/discharge rate can be readily ascertained as being C/7. If one is going to charge the battery, then it needs to be charged for 7 hours at the C/7 hour rate. This does not include the 20% overcharge capacity required. So, for a 7 hour charge, 1.2 times the amount of energy needs to be put back into the battery. This can be done for a period of 1.2 x 7 = 8 hours of charge, or, the rate of charge can be increased to 1.2 x C/7 for 7 hours. Either way is satisfactory.

As an example, consider a 65 Ampere-hour rated battery. Assume a constant current charging method. If the desired time of charge is overnight at 12 hours, then the calculations are:

1. Calculate the rate of charge required for the time involved. For 12 hours, C/12 = 65/12 = 5.4 Amperes.
2. Calculate the overcharge required at 20%. For 12 hours, the rate would be 1.2 x 5.4 = 6.5 Amperes, or for the 5.4 Ampere rate, the time would be 1.2 x 12 = 14.4 hours.

Hence, the total charge would be 14.4 hours at 5.4 Amperes, or 12 hours at 6.5 Amperes.

3.1.2 Charging vs. Use Application of the Battery

One needs to consider the use application of the battery to be charged. The way in which it will be used, can affect the way in which the battery should be recharged.

If the battery is subjected to heavy cyclic use, then the charging should be cyclic in nature, accomodating any vagaries in the desired times of use of the battery. The battery packs in your HT are cyclic use batteries.

If the battery is required for standby use, and only comes on line if the power fails, then cyclic charging is not the most effective method of charging of the battery. This is because the battery will lose charge on open circuit standby, if it is not used. The battery will discharge due to high resistance leakage across the battery case. This amount of leakage discharge will vary with the type of battery, but as a rule of thumb, a battery should not be let stand more than 90 days without topping off the charge. The standard topping off charge rate is C/10, for 4 hours. If the battery is permanently off-line and put into storage, it should be recharged every 3 months or so with a topping off charge. Failure to do so, will result in heavy sulphating of the battery and loss of capacity, if it is a lead acid battery.

If the battery is required for floating use, and is used occasionally for powering the rig, but generally left on the charging line most or all of the time, the use is not cyclic and not standby, but somewhere in-between. Hence, the rate of charging for such a battery should be somewhat higher than standby floating charging, but not as high as the C/7 hour rate. You will need to look at your usage of the battery and do long-term calculations of the charge usage to determine the best charging rate. A weekly or monthly log of daily activity will quickly show you the amount of charge required on the weekly or monthly basis. The rate of charge will be the average weekly or monthly rate plus the overcharge factor. In non-cyclic use, the overcharge factor is only about 5% of the charge rate. So, if the battery is used on a weekly basis of say 20 Ampere-hours, then the charge required to maintain the battery is 21 ampere hours over a week, or a floating charging rate of $21/168=0.125$ Amperes.

3.1.3 Charging vs. Type of Battery

The type of battery has an effect on the charging of the battery. Standard lead acid wet cells that allow for replacement of water are generally more forgiving of overcharging than sealed lead acid cells. Nickel-cadmium alkaline wet cells are more forgiving of overcharging than are lead acid cells. Nickel-iron alkaline "Edison" cells are virtually immune to overcharging, as long as sufficient water is maintained in the cells, and the heat buildup is dissipated.

Generally, the sealed lead acid cells or sealed nickel-cadmium alkaline cells are best suited to floating or standby use service. The wet cells are suited to any type of service and any type of charging.

3.1.4 Gassing of the Battery During Charging

Gassing of the battery during charging is detrimental to the battery, if done to excess (especially in the non-maintainable sealed cells). Some gassing will occur during any charging of the battery, but, if the charging rate is kept below the required charge plus any overcharge, *and* the rate of charge is kept within manufacturing specifications, then the amount of gassing will be minimal.

The gases that are evolved from the battery are diatomic oxygen and diatomic hydrogen. *The mixture of these gases is* **highly explosive** *if ignited.* Exercise due caution when charging batteries, *and* charge them in well ventilated spaces if cyclic charging, or charge them outdoors. In floating charge service, the gassing is minimal, so it should generally be of no great concern. *Keep open flames away from the batteries at all times.* For non-sealed cells, *be careful not to spill the battery acid or alkalai on your person. It will burn severly. Wash immediately and thoroughly with running water for at least 15 minutes, if you spill the electrolyte on your skin.*

3.1.5 Tricks for Resurrecting a Really Dead Battery

What does one do if one has a *really, really dead as the ol' doornail* battery? There are certain tricks that one can try to resurrect a "dead" battery. But, bear in mind that if the battery is a lead acid type, and it is heavily sulphated from misuse or longstanding disuse, it may be almost impossible to resurrect the battery into useful capacity. Sometimes only one cell in a battery becomes heavily sulphated, or develops a high internal resistance that prevents taking charge. If this happens, the only recourse is to us a long, slow trickle charge to try to reverse the sulphation, first, before trying any other method.

Tricks to try are:

1. Check the water in the battery first. It is amazing just how dry the battery can get, and still be somewhat operational. Be careful not to overfill with water, but make sure just enough water to cover the tops of the plates is present, even after the battery has been tapped or rocked from side to side to dislodge any trapped air between the plates.

2. Try a very slow low value constant current charge rate for a week or so. Make sure that you cannot exceed the maximum safe charging current for the battery, even under dead short across the charging source terminals. A charge rate of C/150 on dead short should be satisfactory.

3. If 2 does not work, try a heavy current charge rate of C/3 on dead short across the charging source. *Be VERY CAREFUL when doing this as you can cause the battery to burn up if it takes hold and clears its high resistance and begins to charge normally. Check it every 5 minutes or so. If the battery begins to feel warm even slightly, stop immediately.*

4. If the battery can accept sufficient charge to develop full voltage (indicating that there are no shorts in the battery or cells sulphated beyond resurrection), then cycle discharge/charge the battery through 10 cycles of slow charging, slow discharging at a C/20 rate. The battery should recover capacity after a few cycles, or if not, it is only

of scrap value. After the 10 cycles are completed, and, if the battery appears to be usable, cycle it for 5 more cycles at a C/7 rate.

3.2 Normal Charging

Normal charging is cyclic charging at a constant current rate of C/7 for 7 hours, plus a 20% overcharge factor. The overcharge rate may be the same as the normal rate or may be somewhat reduced to approximately C/10 for two hours. If the overcharge rate is reduced, it is known as a finishing charge.

3.3 Topping Off Charging

Topping off charging is charging after a period of idle storage or off-line time, so that reduced capacity of the battery due to leakage currents is restored. The constant current rate of a topping off charge is C/10. Normally the topping off charge is given for 4-5 hours.

If constant voltage charging is used, the voltage should be 2.40 volts per cell, for a lead acid battery, over a time period of 24 hours. This is 7.20 volts for a 6 volt battery or 14.4 volts for a 12 volt battery. For a nickel-cadmium alkaline battery of the sealed type, the charging voltage should be 1.40 volts per cell. This is 7.00 volts for a 6 volt battery or 14.0 volts for a 12 volt battery. For a nickel-cadmium alkaline battery of the wet cell type, the charging voltage should be 1.48 volts per cell. This is 7.40 volts for a 6 volt battery or 14.8 volts for a 12 volt battery. The voltages are critical, and should be kept to very close tolerance.

If the topping off charging rate is used for regular charging, then the time required to recharge is 12 hours (10 hours plus a 20% overcharge factor).

3.4 Trickle Charging

Trickle charging is a long term charging cycle of 24—60 hours. The usual trickle charging rate is C/20 — C/50. The additional 4 hours beyond 20 or 10 hours beyond 50 provides the 20% overcharge factor.

3.5 Floating Charging

Floating charging is the maintenance of the battery permanently across the charging line. Care must be taken to insure that the battery is *not overcharged.* This is done by careful selection of the charging voltage, if constant voltage charging is used, or by careful selection of the series current limiting resistance if constant current charging is used. The fully charged battery should be floated across the charging line such that the current through the battery is equivalent to the load drawn from the battery over time plus the leakage discharge current plus an overcharge factor of approximately 5%.

If constant voltage floating charging is utilized, then the values given earlier (2.25—2.30 volts per cell for a lead acid battery, 1.40 volts for a nickel-cadmium alkaline sealed cell, and 1.48 volts for a nickel-cadmium alkaline wet cell) should be the voltage across which the battery is floated.

If constant current charging is utilized, then the charging current should be calculated based upon the expected charge usage. For a given installation, the rate of charge usage should be ascertained as a value of so many Ampere-hours on a weekly or monthly basis. For example, consider a 38 Ampere-hour battery floated across a charging line and a load of 25 Ampere-hours per week is drawn from the battery. This might represent 10 hours of usage at a mean load of 2.5 Ampere-hours. This might be typical for a ham using a small 2 meter mobile rig in the shack. The charge to be restored into the battery over a week would be 25 Ampere-hours used plus approximately 1 Ampere-hour leakage current plus approximately 1.5 Ampere-hours overcharge current. This would require that 27.5 Ampere-hours be restored into the battery over each 168 hour week. The net charging current required would be 27.5/168 = 0.163 Amperes constant current charging rate.

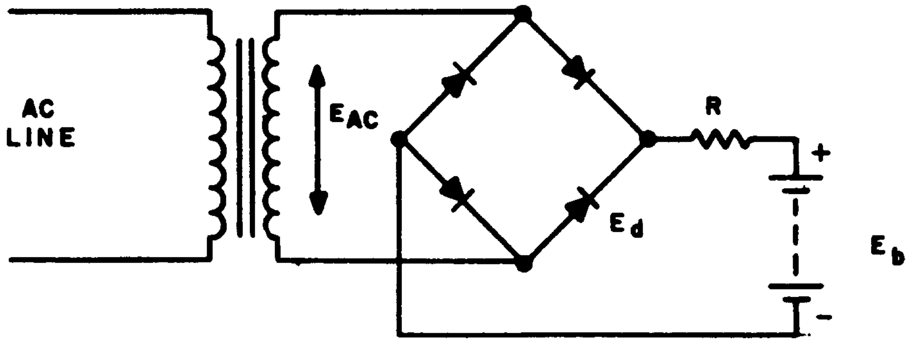

Figure 1: A simple current limited battery charging system.

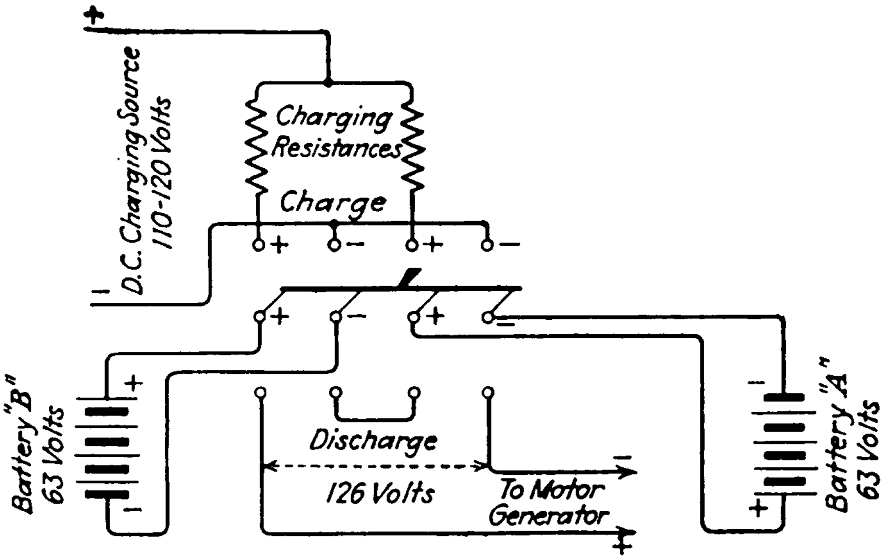

Figure 2: A commercial current limited battery charging system.

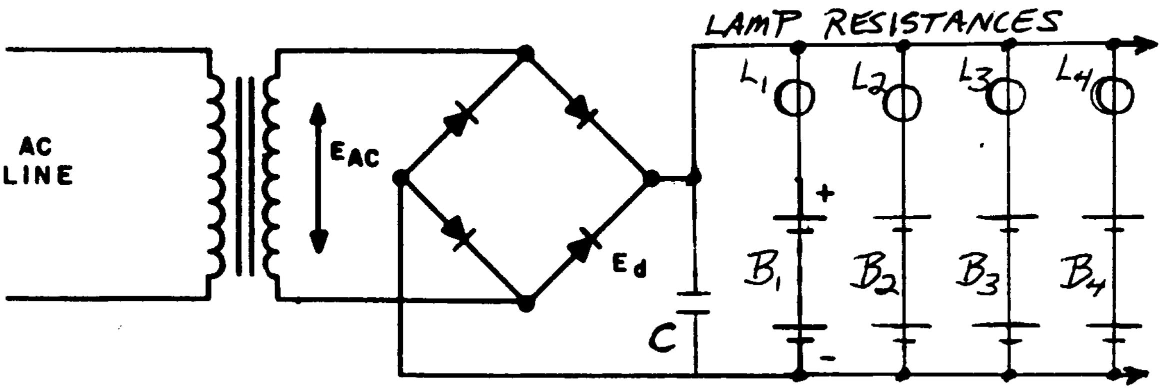

Figure 3: A simple current limited battery charging system with multiple battery charging capability, suited to amateur radio use.

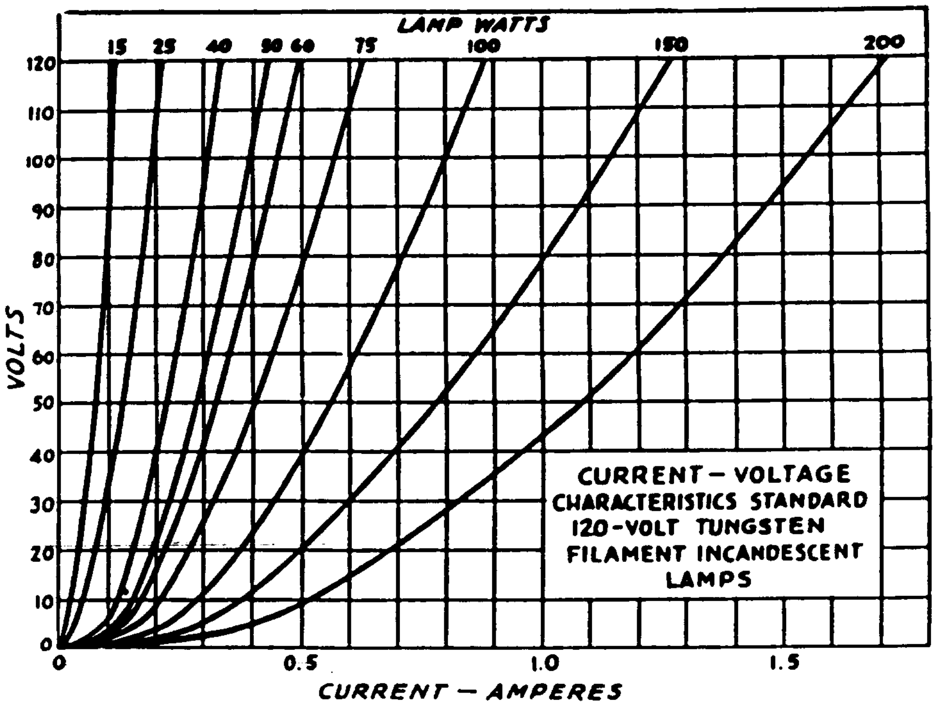

Figure 4: Current-voltage relations of tungsten lamps of standard manufacture (after F. Hamburger, Jr., "The Incandescent Lamp as a Resistor", QST, July, 1934, page 31).

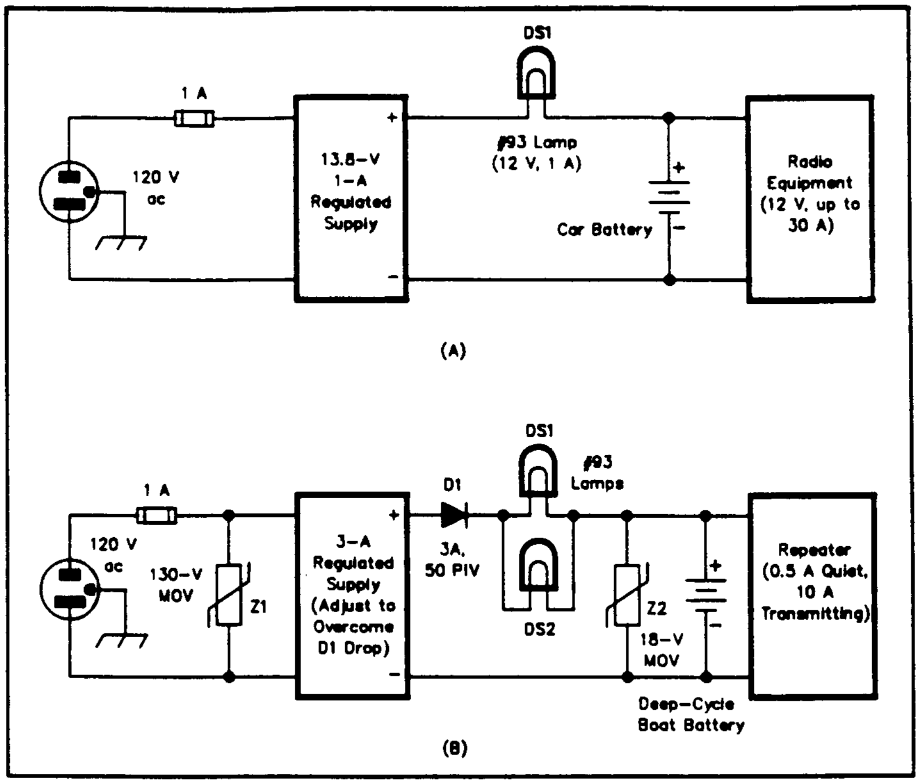

Figure 5: Incandescent lamp current limiting system for float charging battery systems in amateur radio use (after M. Covington, "Light bulb converts power supply into a battery charger", QST, March, 1992, page 85).

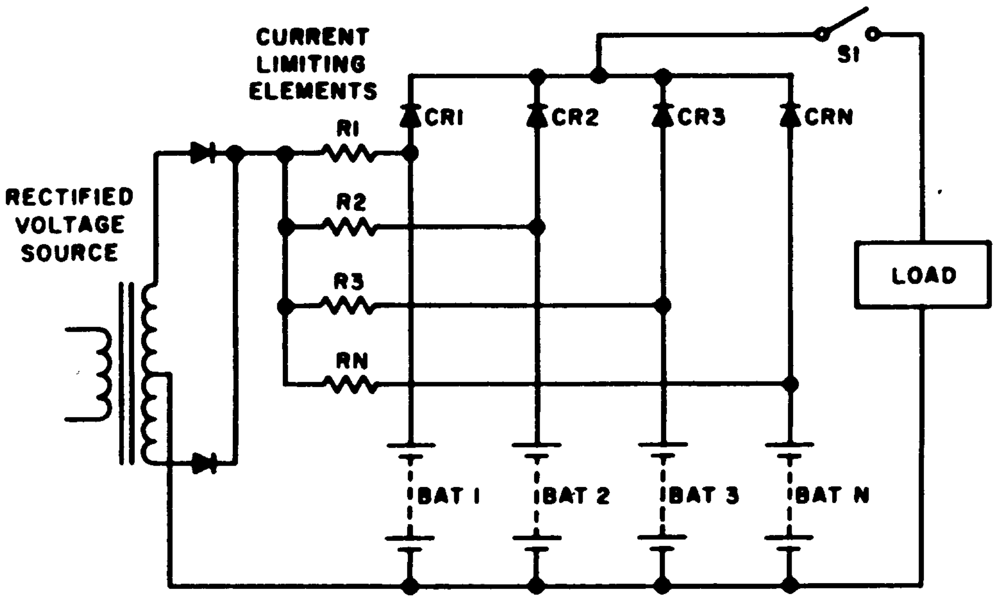

Figure 6: A simple current limited multiple battery power system.