Batteries and Primitive Survival

(An e-Book that is word searchable and printable)
(3 Nov 2008)

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Introduction: Knowledge from many sources including my own research and development have been brought together to show how to intelligently use battery storage technology in a long term primitive survival situation. Lead-Acid batteries for use as primary source storage and smaller rechargeable/non-rechargeables for portability will be viewed in many different ways for practicality during primitive survival. The way to read this book is to read chapter one then jump to areas of interest, realizing that the proper storage of the correct chosen batteries and the making of efficient chargers are ideally needed before the emergency times start. This book is designed to be a reference work and is dedicated to those who wish to survive the coming pole shift. (by Mikel)

Chapter 1: Basic Battery Survival 101 (7 pages)

This chapter gives an overview summery of the basics knowledge needed to start one into primitive survival using storage cells and batteries. The remaining chapters detail and answer the questions needed to help survive in a primitive environment for an extended time.

Chapter 2: Long Term Battery Storage and Self Discharge Rates (12 pages)

This chapter details how to prepare batteries for long term storage. What are the choices of batteries and how to store them for the long term. The manufactures recommendations are detailed. A description of what to do as you take them out of storage for the first time is also detailed.

Chapter 3: Efficient Battery Chargers for Survival (20 pages)

Most of the currently efficient commercial battery chargers that I have tested have a maximum efficiency of about 20-38% of source energy delivered to the destination battery. This means you could easily waste 3 to 5 times more energy than you end up with by charging a small recharged cell. As a result I recommend making your own twice as efficient charger for use in a primitive environment. This Chapter shows how to easily construct it.

Chapter 4: Measuring State of Charge and over all Capacity (12 pages)

Easy to construct circuits are described to measure over all capacity and to determine how much charge a battery has based on its open circuit resting voltage and/or the voltage across a given load resistor. A Digital Volt meter will be one of your most valuable tools.

Chapter 5: Making Soldered Battery Packs (2 pages)

Shows how to take NiMH and NiCD cells and use them to make a soldered battery pack. When wet conditions cause connection problems due to corrosion, use this technique to keep things going.

Chapter 6: Types of Batteries with notes when to use them (13 pages)

This gives an understanding of the basic characteristic of each type of Cell and when to use each type. It will help one chouse the correct battery for each need along with what to expect from each.

Chapter 7: New Low Self-discharge NiMh cells (5 pages)

The most recommend (cost effective) rechargeable battery type for practical portable power use in a survival situation is looked at in more detail.

Chapter 8: Battery Sizes Types and History (11 pages)

This background information is included for a deeper understanding of each of the battery types and their history of when they were invented.

Chapter 9: Battery Basic Formulas and Chemistry (6 pages)

This chapter can be used to review or to learn about the basic formulas when dealing with battery power and some of the chemistry involved.

Chapter 10: Home Made Batteries (81 pages)

This is a review of what can be used to make home made batteries. For those that are caught without any batteries this information should help. Rebuilding existing lead-acid batteries has a higher probability of success. However, as a last resort this chapter should bring one up to speed quickly as to what works and what doesn’t work. One can start where others have left off.

Chapter 11: Lead-Acid Batteries (102 pages)

For the base camp or primary source of electrical storage the lead-Acid battery needs to be understood completely. Key voltages, sulfation, and how to rebuild and make repairs are explained.

Appendices (14 pages)

Battery Glossary of Terms (46 pages)

1-Basic Battery Survival 101

(11/3/2008)

Being in a long term primitive survival mode has lessons to learn to properly use what power sources and batteries you have available. Energy and battery conservation techniques will need to be practiced. This report outlines what one needs to know about batteries. The intention is to remove the confusions of what to do, and indicate common practices that need to change. Ultimately you and your group's survival will depend on evaluating what is important to know and what to do to prepare.

Background: In a 2003 report roughly 30 million dollars (8 billion kwh) is reported as lost per year nationally to inefficient battery chargers. "AA Battery Systems" have an active efficiencies from 6% - 40% (Eff= DCbatt energy/ACcharge energy). See http://www.efficientproducts.org/reports/bchargers/NRDC-Ecos_Battery_Charger_Efficiency.pdf

Thus we have something to learn about being energy efficient. In general plan to use the power as you make it. Don't store it. Storing it results in lost energy. Storing into a leaky self-discharging system would be worse yet. Yet this is now and will be in the future the most common situation.

Best practice is to use neodymium permanent magnets and make or purchase permanent magnet generators or alternators and use the power as you generate it. Water or Hydro power is most practical source. Wind is random thus depends on storage medium. Storage needs are much less for water power than wind power.

In general make batteries only to teach the young about electricity – don't plan to depend on them for power storage. For that will be a futile effort. Practicality speaking, all home made batteries are low in capacity, inefficient, and have a high internal self discharge rate.

For the common survivor it is far better and more practical to properly use and conserve what you already have than to try to make new ones. This is the main reason why these series of write ups on batteries were done.

If one is using a 12, 24, or 48 volt DC storage as a primarily source of stored power the first rule is to use it for as many things as possible. Minimize your use of rechargeable smaller cells to powering portable items. The reason for this is every time you transfer energy from one storage media to another you have significant wasted energy.

Base Camp Survival Planning

The best batteries (most economical in the long run) to purchase for primary storage before a primitive survival situation are listed in order of preference:

- 2 VOLT Sealed or valve regulated GEL cells (rated to last 20 years)
- 6 VOLT golf cart batteries (use two in series for 12 V)
- 12 volt marine service with open terminals for each cell
- 12 volt car batteries (these have thin plates and don't last any where near as long as above)

1-Basic Battery Survival 101

(11/3/2008)

Avoid purchasing used batteries. Reason, the internal leakage or self-discharge rate is already too high for the amount of recharging power one is likely to have in a survival situation. Used batteries are not cost effective going into a survival situation.

One simple way to protect your batteries during the Pole shift is to put it in a water proof plastic bag and burry it about a foot or so deep in the ground with a colored floatable rope that is about 3-5 ft long above ground. If you leave it in the car it is likely to blow away with the car or burn up when the meteorite showers hit.

What to Use for Portability

For portable needs, the most useful and cost effective size is AA. AAA to be used occasionally when lighter weight is needed. Try to use AA for as many things as possible when portability is needed.

The finding of low self-discharge rate storage is the most important attribute for rechargeable batteries in a primitive survival environment.   Bottom line is the battery will stay charged much longer. There is a growing list of manufactures making the new type "low self discharge" NiMH batteries.   Look for these (eneloop, Hybrio, etc) in preference to the currently common high self discharge NiMH batteries. They are worth the extra price.

Use 1.5 V Lithium, Alkaline, Rechargeable Alkaline, or Carbon-Zink for clocks and very low drain items where holding a charge over a long time is needed.

Use high self-discharge rate older types of rechargeables for portability, short term use, and long term low cost. The size of the rechargeable would be matched to the power needed such that the storage capacity would be used up in less than two to three weeks. Any longer and the typical internal high self-discharge rate for normal NiCD and NiMH becomes wasteful.

There are a number of companies who make shells to convert AAA into AA and AA into D and C cells. Green Batteries is one. This allows one to standardize on AA batteries and charger size, yet still be able to power D and C cell devices. This works just fine as long as one understands they are lighter weight and don't store the same amount of charge as the original size.

Standardizing on AA as the basic size has advantages of interchangeability and reusability in a long term survival situation.

Getting the most out what you all ready have

Don't always do full recharging of individual cells. Stop at 80 to 90 percent using a digital timer. Use them at a partial charge and for short discharge cycle needs.   Once the cell voltage falls below 1.0 or .9 volts then recharge.

It is not well know that Alkaline, Titanium and Zinc Carbon can be safely recharged a number of times (up to about 15 times) as long as certain guide lines for the charger are followed. See separate report on chargers. Heavy Duty and Super Heavy Duty batteries will not take and hold a charge upon recharging. Don't bother trying it is a waste of energy (I already have).

Worn out primary (only one charge) batteries of all types when they fall below 1 volt can be hooked in series to get the voltage needed for light duty use. Like running clocks. The point is "think out of the box" how can you use fully what you have.

Scrounge old batteries and try recharging or using what is left in them. Multi-cell batteries can be opened and the good or strong cell then can be wired in series with other good cells to make a usable battery.

Wiring cells in parallel always comes with a danger of wasting energy. One or more leaky cells will pull down all the rest. If you need to do this, then match the cells as best you can to age, brand and size so they all are electrically the same. Then charge and test each cells voltage after several weeks of storage to weed out the high internal self discharge rate cells. This would be the ones with the lowest voltage after that time. The rest can be wired in parallel with the provision from time to time brake them apart and test self discharge rate again as individual cells.

Water damage in wet environments

Many battery pack and cells are going to leak in wet environment. I have done some testing on this. What happens is water wicks into the cell at the seals. Actually it is pulled in by hydroscopic action due to the strong electrolyte solution in the cell. This builds pressure and leaks electrolyte thus oxidizing the terminals and sometimes also the battery holder.

In general after several weeks in a wet or near 100 percent humidity environment my test show NiMH and NiCD will have signs of swelling and leakage. Some brands are worse than others. Some brands will not leak for quite a time. It seems to take a bit longer for the water to get into primary cells (one charge type) depending on brand and quality.

One preventive measure to slow this tendency down is to first spray the cells with silicon grease. Then once that is dry, coat the ends with dielectric Tune-UP Grease, Marine grease, vaseline, battery terminal protector coating (from local auto part place) or whatever you have available that would work as a flexible water replant. Don't use anything that will turn solid to seal it. This would not allow the gasses of charging-discharging to escape and it might explode.

If a battery pack (with removable cells) is going to be exposed to water often than consider packing it with grease and hooking up wires that run to the outside of the case such that it can be recharged without taking the cells out. Some battery packs will be able to be used while sealed in zip lock bags. Another way is to make a soldered battery pack – see write up on this.

I have found that for NiMH several years of storage at about 50% humidity in room condition that about 30-50 % will have leaked and are corroded on one terminal or the other. They were not charged during this time.

Store for the long term your cells in a cool (like a refrigerator) dry sealed container like plastic bags. Every year or so take them out let them worm up and recharge them. Then put them back into storage. See “Long Term Battery Storage and Self Discharge Rates” to learn more about how to store batteries for the long term and what batteries will work best after storage.

General characteristics of all batteries

All batteries experience internal self-discharge over time.

High storage temperatures mean high internal self-discharge rates. Low storage temperature equate to low internal self-discharge rates.

Less available storage capacity (mah) at lower temperature and more capacity at higher temperatures.

Internal resistance and chemical inertial cause the charging voltage to be higher than the resting voltage. It also causes the discharging voltage to be lower than the resting voltage.

The higher the current flow of charging or discharging the greater the deviation from rest voltage and the greater the inefficiency of energy transfer to and from the battery.

Most rechargeable batteries are at there best when kept in motion (charging or discharging). Strong examples are lead-acid and NiCD. To some extent this applies to NiMH. The rest of the types it doesn’t matter that much.

Battery Do's

For the first 4 recharge cycles use new or long time in storage rechargeables in non-critical uses.

Keep working batteries in motion (charging or discharging or in use). This applies to all types of batteries. This is done until considered not fit for service. This applies to all types. Cells are most efficient when kept in motion of charging or discharging. The internal resistance is lowest when kept in motion. The capacity goes up to it’s maximum. Store the rest until you need them.

Run the device under the battery's power until it shuts down or until you get a low battery warning. Then recharge the battery. Allow rechargeable cells to discharge below 1 to .9 volts in normal use before charging them. For Alkaline, Rechargeable Alkaline, Zinc Carbon, and Lead-Acid target to not discharge below 50 percent charge. They will last a lot longer that way.

Remove the cells from the device and stored in a cool, dry, and sealed container if the battery will not be in use for a month or longer. Cells will absorb water build pressure and leak if in a damp environment. More true for NiMH than NiCd.

Store your NiMH and NiCd batteries in a closed cool container with an initial full charge.

Recharge the battery after a storage period longer than 1 to 6 months depending on the type.

For NiCd and some times NiMH one can occasionally at the end of one of the discharge cycles continue to discharge it completely down to about .6-.5 volts using a 3.6 to 5 ohm resistor clipped across it (to get rid of memory effects). If not often used, it will gain in charge capacity when then recharged.

For AA and AAA cells measure “state of charge” by measuring the voltage across a 12 ohm load resistor. See separate report later on how to do this.

A simple home made charger that works off 12 volts is twice as efficient at charging than any of the currently tested small battery chargers. See a latter chapter on this.

Battery Don’ts:

Don’t bother to fully charge individual cells – bring them up to about 80-90% on the average. Then use them again. This can be done with a timer or constant voltage charger set at a float voltage.

Don’t charge a rechargeable battery unless you intend to use it. Don’t charge a bunch and store them for later use like I and many others have done in the past. Charge it only when it is intended to be used.

Over charging can reduce capacity for most types of battery. Taking the cell to near zero from time to time is recommended for NiCD but not recommended for any other type except occasionally NiMH as it reduces capacity.

Do not short-circuit a full or nearly charged battery. A short-circuit may cause severe damage to the battery. Use a resistor that discharges at .5C or slower.

Do not drop, hit or otherwise abuse the battery as this may result in the exposure of the cell contents, which are corrosive.

Don’t use a typical fast charger on a partially discharged battery. It could damage it an lower capacity by over charging it. It is defiantly wistfully of power.

Don’t use fast chargers when you have a slow charger available. Fast chargers are generally more inefficient than slow charges. The exception is if the slow charger doesn’t turn off when charged.

Do not expose the battery to moisture or rain. Can leak past the seals to get into the battery and build pressure that then causes it to leak electrolyte and corrode the terminals.

If a Cell leaks don’t use it in a spring loaded battery holder without at least cleaning it. It could corrode the battery holder. Then don’t leave it in a battery holder for an extended period of time. In all actuality if the cell once leaked, it is better to sand the ends and Solder the cells together with a short wire and make a permanent replaceable battery pack.

Most people recommend For Nickel Metal Hydride (NiMH) batteries, conditioning (discharge fully before charging) is recommended at once for every ten charges. For Nickel Cadmium (NiCD) batteries, conditioning is recommended every time you charge your batteries. This is much over rated as needing to be done and would not be done in a survival situation with scarce power.

If one is looking at a low amount of charge capacity for a cell and this is thought to be a memory issue then and only then should one take the cell down to near zero and recharge. This would be done after all of the usable charge had been used (voltage down to .9) on a normal use discharge.

The two most common reasons NiCD or NiMH cells are damaged: Sustained high-current overcharge and cell polarity reversal (during discharge) are the main killers of NiCD and NiMH batteries: If a high charge rate is used, it is essential to terminate charge when the cell is full. If this is not done, the temperature and pressure within the cell will rise quickly as the charging current is dissipated as heat.

Cell reversal can occur in battery packs made of more than one cell in series during a close to full discharge. For this reason don’t discharge cells in series as far down in voltage as individual cells. The longer the series string the higher the per cell voltage stopping point should be set at.

The two most common reasons Lead-Acid cells are damaged: Sulfation due to setting too long discharged and cell polarity reversal. Other influences are running out of electrolyte because water in it was electrolyzed into hydrogen and oxygen and getting too hot.

Keep battery away from fire or other sources of extreme heat. Do not incinerate. Exposure of battery to extreme heat may result in an explosion.

Don’t use it if it is too hot to hold. If you can not easily hold your hand on a battery case then it is too hot to use. Let it cool off before continuing to use it.

Zapping NiCD to bring back to life

A leaky Ni-Cd cell will always have a high self-discharge rate and will re-grow internal shorts if left on the shelf without some kind of trickle charge. The symptoms are cells that go dead quickly or can not be charged at all. This often prompts the users to throw it away even though they may still be able to give nearly full A-hr capacity during discharge.

After a period of time, the insulator within a Ni-Cd battery can develop holes which allow the cell to grow crystalline "shorts" that provide a conduction path between the positive and negative electrodes of the cell (which basically shorts out the cell). If this happens, you may have to blow open this short with a high current pulse before the cell will again accept charge (a process sometimes referred to as "zapping").

This can be done by momentary connecting the bad cell in series (positive to positive and negative to negative) using heavy duty jumper wire from a charged decent sized amp-hour 12 volt battery. It can also be done by charging a good sized DC capacitor to a much higher voltage (110 volts for example) and using it in the same way as the 12 volt battery. Gloves and goggles should always be used when doing one of the above zapping processes.

The NiMH cell is not prone to developing internal shorts like a NiCd and Lead-Acid batteries. Zapping does not work with NiMH batteries.

Ni-Cd’s have about half the internal resistance of the newer Ni-MH batteries,
Most inexpensive NiMH packs are not really designed for discharges greater than 1C.

Next look at chapters of interest.

2-Long Term Battery Storage and Self Discharge Rates

(11/2/2008)

Using Batteries that have been a Long Time in Storage or are New

New batteries come in a mostly discharged condition and must be fully charged before use. It will need to be fully charged and discharge two to four times to allow it to reach its maximum rated capacity.

When charging the battery for the first time, they may take current slowly for the first 10-15 min. This is normal with rechargeable batteries. Sometimes the “off the shelf” chargers will stop charging a new battery before it is fully charged. If this happens, remove the battery from the device and then reinsert it. The charge cycle should begin again. This may happen several times during the first battery charge. Don't worry; it's perfectly normal. The first charge goes more slowly and at a higher voltage and for a longer time. A 1/10 C charging rate might take 15 to 20 hours to complete the first charge.

Effects of Storage

What many don't understand is that both NiMH and Li-Ion batteries go bad with age even when they are not used. You can expect them to no longer live up to their rated capacity after only one year and one expert recommends not keeping them beyond two years at room temperature. This is a good reason for not storing at reduced temperature. Instead put them in a refrigerator.

One indication that they are going bad is that they get hotter than comparable new ones when you recharge them. This is because their internal resistance increases as they age.

Several sources say the best older type AA NiMH batteries are the PowerEx line from Maha (http://www.mahaenergy.com). The best low Self-Discharge brand is Eneloop.

But don't think that all NiMH batteries are the same. Most of the batteries tested were lying about their capacities. See chapter 4 for a detailed comparison.

Long term Storage Lifetime for Batteries

If the battery is stored for a prolonged time at high temperature, the materials composing the battery will gradually deteriorate and battery capacity becomes less.

The battery manufactures recommendation for storage of less than a year to use a low enough temperature to prevent battery material from deteriorating or between -20 to 30 degree C and humidity of 65+or-20%. 30 degree C is 86 degree F.

If stored connected to a load the electrolyte fluid will leak, and the capacity will be reduced from full capacity. Avoid storage in extremely high humidity and high temperature changes, as expansion and contraction of the battery materials may cause leaks. Corrosion then forms on the metal terminals causing high resistance limiting it’s usability.

2-Long Term Battery Storage and Self Discharge Rates

(11/2/2008)

Long-term storage can cause a temporary low capacity after the first charge. Charging and discharging the battery to near .6 Volts several times will almost completely restore capacity. So in a survival situation what this means is you use it in non-critical use for the first few discharge-charging cycles. Making sure it discharges as much as you can before charging. This erases any memory effects. Otherwise you put no special attention on this.

Store batteries in a cool place, preferably refrigerated and placed in a sealed plastic bag to avoid condensation. Bring them up to room temperature before using. To store NiCads, first fully charge and then discharge them. When charged NiCads are allowed to self-discharge, they create crystals (the memory effect), which reduces their capacity.

NiCads as well as NiMH batteries need to be primed with a slow charge when they come out of storage. On the other hand, Li-ion batteries need to be stored charged. If not, they can lose the ability to charge to full capacity in as little as three months. Further, cells may leak and corrode. When coming out of storage, both NiMH and Li-ion batteries need several charge/discharge cycles for the battery to come up to its optimal capacity.

Corrosion is any darkening of metal that is not otherwise shinny silver metal color. In the extreme it turns black for NiMH. Any amount of corrosion is enough to not conduct electricity when put in a battery holder. Corrosion will not wash off with water. It will need to be carefully sanded off with fine sand paper. Avoid taking off too much metal and sanding the plastic case on the negative terminal end.

When taking NICD and NiMH cells out of long term storage check to see if slippery wet. The electrolyte for these two cells is basic and highly slippery. It does wash off easy with water. If at any time you are trying to distinguish between water and leaked electrolyte. The way to tell is – test if it is very slippery or not.

Notes on storage and leakage: I had some AAA alkaline energizer cells that have a date code of Jan 07. They have been stored at room temperature since they were new. In Dec 07 I noted about 30% had leaked. The ones that were left still had plenty of charge left (around 1.5 volts) and were still rechargeable.

No testing or recommendation is made by the manufactures for storing batteries in the 10s of years range. The bottom line is this has not been tested.

My experience with 48 Powerizer brand NiCD 2300 mah AA cells in storage for about 4 years at room temperature in the manufactures packaging of 12 shrink wrapped open at the sides. 61% leaked 39% did not leak. 17% of those that did not leak were zero volts. 50% of those that did leak were zero volts. 37% of the total were zero volts with the rest or 63% was between .6 and .7 volts. 20% were sanded on the negate terminal and 61% were sanded on the positive terminal.

Some of those that were zero volts needed zapping with a 12 volt battery to raise the voltage enough so the charger wouldn't reject it. The voltage on a slow charge was above normal and about 20% of the time quit before the time was up. I suggest doing a timed charge at about 1/10 C for about 15 hours. Bottom line these were stored too long with out cleaning, charging and temperature-humidity controlled. Inspection and cleaning and charging once a year would have been a lot better. Putting them in a sealed container in cold storage would have been even better yet. Cleaning could be done with a damp cloth and a dry paper towel as needed.

Storing batteries for a long time can cause temporary lower capacity. Recharging and discharging several times will cure most of it.

My recommendations before the pole shift would be the following. Package a small number of cells/package in air tight plastic bags (label with purchase date) and put them in preferably a freezer or a refrigerator depending on where you have the most room. Take them out once every couple of years. Let warm up naturally then open the bags and clean off any corrosion or leakage test voltage and recharge if below 40% charge. Then place back into bags sorting according to age and leakage. Place back into cold storage. The low temperature slows down the normal degrading with age. The air tight plastic bags keep the cells from loosing or gaining water thus causing leakage. The charging helps keep chemical separation from forming in the battery.

After the pole shift, keep in as cold as possible storage as many as are not going to be immediately used. Don't take out of storage any more than you can use at onetime. Every year or two check for leakage, clean, sort and repackage. Basically you do what would be done in cold storage except for the recharging unless you can afford the extra energy usage.

Long term Storage will work for NiCD, NiMH, and possibly SLA (sealed lead acid). New SLA batteries depending on quality will need to be charged at least once or twice a year. Don't bother with Li-ION Cadex tests indicated that their practical service life is only two years. They irreversibly lose 10% capacity each year whether used or not. "Li-ion batteries should not be stored for long periods of time but consumed like a perishable food."

Lithiums (non-rechargeable type) retain 90% of original service-life capacity after up to ten years in storage. Kodak also applies a freshness date on the battery cell itself. Typical freshness dates for Lithium batteries is 10 years to approximately 90% capacity.

Storage recommendation for various battery types in the manufacturer's words.

It makes a lot of sense to read what the battery manufacturers say about long term battery storage. The following is a selection of several manufacturers who have put information in their catalogs. Please read the disclaimer below:

Sealed Lead Acid Battery Storage

Power-Sonic Batteries should *not* be stored in a discharged state or at elevated temperatures. If a battery has been discharged for some time or the load was left on indefinitely, it may not readily take a charge. To overcome this, leave the charger connected and the battery should eventually begin to accept charge. Although Power-Sonic batteries have a low self-discharge rate which permits storage of a fully charged battery for up to a year, it is recommended that a battery be charged 6-9 months after receipt to account for storage from the date of manufacture to the date of purchase. Otherwise, permanent loss of capacity might occur as a result of sulfation. To prolong shelf life without charging, store batteries at 10 degrees Celsius or less.

Gaston: Lead-acid batteries previously were affected by long term storage after charging. But Gaston SLA batteries are not so affected. This battery offers longer extended storage than conventional batteries (referenced curve shows 3% per month self discharge rate at 20 degrees C.) During storage, carry out supplementary charging according to Table 3 (below 20 degrees charge every 6 months, 20 to 30 degrees C charge every 3 months, over 30 don't store). Although the self-discharge rate is low, specific precautions must be taken against the battery over discharging itself by self-discharge when in storage or not operating. In general, to optimize performance and service life, it is recommended that Gaston batteries which are to be stored for extended periods of time be given a supplementary charge, commonly referred to "top charging" periodically. The top charge referred to is a charge of 20-24 hours at a constant voltage of 2.4 volts per cell.

Spiral Wrapped Lead Acid Battery Storage
Hawker Energy Products

When a Cyclon battery is kept in storage, i.e. on open circuit, the ambient temperature should be controlled to prolong storage time and maintain maximum capacity over time. To get the best storage results, batteries should be charged at room temperature or below, and charged prior to being put back in service.

The OCV (open circuit voltage) of each battery must be monitored on an individual basis. If the OCV measures 1.93 Vpc, it has zero effective capacity and should be boost charged immediately. Even if the OCV reads higher than 2.00 Vpc at the end of 12 month's storage, the battery should be recharged before use. Thus, to maintain maximum reliability, batteries should be boost charged once every 12 months, or when the OCV reads 2.00 Vpc, whichever occurs earlier.

If the OCV is allowed to drop between 1.93 and 1.80 Vpc, some permanent damage may occur to the battery. However, if it drops to less than 1.80 Vpc, the battery will most likely be unchargable by conventional methods. Therefore, under no circumstances must the OCV be allowed to drop below 1.80 Vpc.

Just as high temperature accelerates the aging of a battery, so does it accelerate the self-discharge rate. Thus, when the storage temperature exceeds 25°C, one must monitor the open circuit voltage more frequently.

Flooded Lead Acid Battery Storage

Trojan: Periods of inactivity can be extremely harmful to lead acid batteries. When placing a battery into storage, follow the recommendations below to insure that the battery remains healthy and ready for use.

NOTE: Storing, charging or operating batteries on concrete is perfectly OK. The most important things to avoid:

1. Freezing. Avoid locations where freezing temperature is expected. Keeping battery at a high state of charge will also prevent freezing. Freezing results in irreparable damage to battery's plates and container. [Freezing can happen between -19 F (40% charge) and -98 F (fully charged)]
2. Heat. Avoid direct exposure to heat sources, such as radiators or space heaters. Temperatures above 80° F accelerate the battery's self-discharge characteristics.
3. Step by step storage procedure: 1. completely charge the battery before storing. 2. Store the battery in a cool, dry location, protected from the elements. 3. During storage, monitor the specific gravity (flooded) or voltage. Batteries in storage should be given a boost charge when they show a 70% charge or less. Completely charge the battery before re-activating.
4. For optimum performance, equalize the batteries (flooded) before putting them back into service. Refer to the Equalizing section for this procedure.

Continental Battery Storage:
Q: Will a battery rapidly self discharge if placed on concrete?
A: No, placing a battery on concrete will not cause it to discharge any faster than any other surface.
Q: Can I store a battery indefinitely?
A: No, a battery will self-discharge slowly over time. Allowing a battery to sit in a discharged state will ultimately lead to severe positive grid corrosion and battery failure. An unused battery should never be allowed to sit over 6 months without a recharge.

NiMH (Nickel Metal Hydride) Battery Storage

Duracell NiMH Battery Storage

Ni-MH batteries can give years of safe and reliable service if they are used in accordance with recommended procedures and are not abused. Batteries should be kept clean and dry both during use and storage. They can be stored for many months in a charged or discharged state without any detrimental effects as long as they are not exposed to extreme temperatures for any long period of time. After periods during which the battery has not been used, the battery should be charged before being placed in service. Extended overcharging or overheating of the battery should always be avoided.

Varta NiMH: Battery storage in any state of charge is possible. Storage temperatures between -20 and +35 are recommended, relative humidity approximately 50%. In case of long term storage cells must be recharged once a year.

Sanyo NiMH: Under the recommended storage conditions (-20 C to +35 C) the Twicel can be stored indefinitely in either a charged or uncharged state. Recovery may take several cycles. If a battery is stored for a prolonged time connected to a load, electrolyte fluid will leak, the battery will begin to deteriorate, and capacity will be impaired after storage. During long time storage battery deactivation may tend to occur, and for this reason charging may stop early during recharging after storage. This problem can be solved by charging and discharging the battery several times.

Sanyo NiMh Battery Storage: Generally speaking, a loss of voltage and capacity of batteries due to self-discharge during storage is unavoidable. The factors inducing this self-discharge of Nickel-Metal Hydride batteries is listed below:

1. The inside of the cell is a hydrogen atmosphere at low pressure, which gradually reduces the active materials at the positive electrode, resulting in a drop of cell capacity. Accompanied by this, the negative electrode which is thermodynamically unstable in its charged state gradually gives off hydrogen gas, thus reducing cell capacity.
2. The active materials at the positive electrode in its charged state self-decompose, causing the cell capacity to decrease.
3. Impurities within the cell, especially nitric ions, are reduced at the negative electrode and diffuse to the positive electrode where they are oxidized. This results in a lowered cell capacity.
4. The factors (2) and (3) also apply to Nickel-Cadmium Batteries. As discussed above, the self-discharge of Nickel-Metal-Hydride Batteries during battery storage causes a loss in stored energy. However, once recharged, this lost portion of the capacity will be almost completely restored. The self-discharge characteristics of Nickel Metal Hydride batteries is affected by storage temperature. . . If the battery is stored at high temperatures, the self-discharge will be accelerated. Also, the longer the storage period, the more the cell capacity decreases. As mentioned above, since the capacity of Nickel Metal Hydride batteries lost by self-discharge can be restored by recharging, there are virtually no noticeable adverse effects of battery storage. However, prolonged storage at high temperatures may deteriorate or deform the gasket or the separator, and should be avoided. Either fully charged or discharged, Nickel Metal Hydride (NiMH) batteries may be stored indefinitely. . . In either cased (charged or

discharged) the capacity is recovered within two or three charge / discharge cycles.

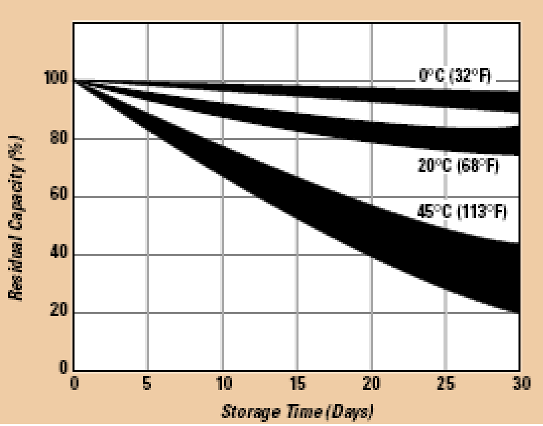
Panasonic NiMH Battery Storage

Because long term storage can accelerate battery self-discharge, and lead to the deactivation of reactants, locations where the temperature ranges between +10°C and +30°C are suitable for long term storage.

When charging for the first time after long term storage, the deactivation of reactants may lead to increased battery voltage, and decreased battery capacity. Restore such batteries to original performance by repeating several cycles of charging and discharging.

When storing batteries for more than one year, charge at least once a year to prevent leakage and deterioration of performance due to self-discharging.

In general for NiMH batteries in Storage



The state-of-charge and capacity of the nickel metal hydride battery decrease during storage due to self-discharge of the cells. Self-discharge results from the reaction of residual hydrogen in the battery with the positive electrode, as well as the slow and reversible decomposition of the positive electrode. The rate of self-discharge is dependent upon the length of time and temperature at which the battery is stored — the higher the temperature, the greater the rate of self-discharge.

As illustrated in the above figure**,** cells stored at 0 degree C (32 degree F) retain more of their capacity than those stored at 20 degree C and 45 degree C (68 degree F and 113 degree F), particularly after 30 days.

Generally, long term storage of a nickel-metal hydride battery in either a charged or discharged condition has no permanent effect on capacity. Capacity loss due to self-discharge is reversible and nickel-metal hydride batteries can recover to full capacity by proper recharging. For example, full capacity of a nickel-metal hydride battery that was stored at room temperature for up to one year can be restored by cycling through repeated charge/discharge cycles.

As with operation at elevated temperatures, however, long term storage at high temperatures can lead to deterioration of seals and separators and should be avoided. The recommended temperature range for long term storage of nickel-metal hydride batteries is 10 to 30 degree C (50 to 86 degree F).

Nickel Cadmium

Linden: Handbook of Batteries and Fuel Cells

The sealed nickel-cadmium cell can be stored in the charged or discharged state without damage. It can be restored for service by recharging (one or two charge/discharge cycles). [Ed. note: or three charge/discharge cycles].

Panasonic NiCad Battery Storage

Store NiCad batteries in a dry location with low humidity, no corrosive gasses, and at temperature range of -20°C to +45°C. Storing batteries where humidity is extremely high, or where temperatures fall below -20°C or above +45°C

Because long term storage can accelerate battery self-discharge, and lead to the deactivation of reactants, locations where the temperature ranges between +10°C and +30°C are suitable for long term storage.

When storing batteries for more than one year, charge at least once a year to prevent leakage and deterioration of performance due to self-discharging. When using a rapid voltage detection charger carry out charge and discharge at least once ever 6 months.

Lithium Ion

Moli Energy Lithium Ion Battery Storage: Storage temperature range is -20 to 60° C. Recommended storage voltage range is 4.1 to 2.0 volts per cell. For prolonged storage periods, store discharged [i.e. 2.0 to 3.0 volts per cell] and at -20° to 25° C.

Panasonic Lithium Ion Battery Storage:
The batteries should be stored at room temperature, charged to about 30 to 50% of capacity. We recommend that the batteries be charged about once per year to prevent over discharge.

PowerStream Note: Test data confirms that storage of lithium-ion batteries is best if the cell is partially discharged. In one test by Cadex Electronics (http://www.buchmann.ca) after 1 year storage at 25°C the non-recoverable capacity remaining is 96% when stored at 40% initial charge level, but only 80% if stored with 100% initial charge level. This effect is reduced at lower temperature and is a non-issue at 0°C. At higher temperatures the effect is much worse. Cadex's recommendations are to store below 15° C at 40% of full charge (2.5 volts per cell).

Storing Primary Batteries

Varta Alkaline Battery Storage

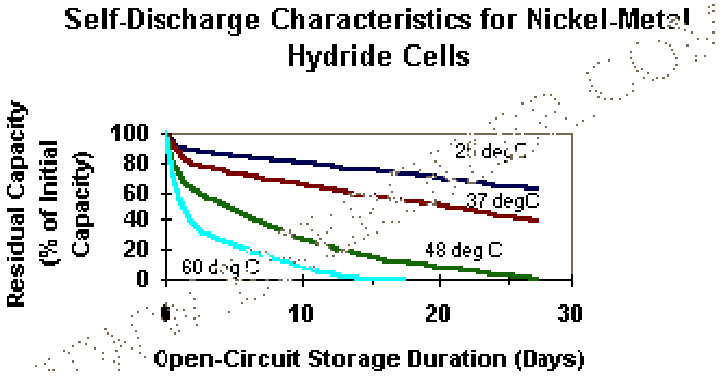
A refrigerator, with a temperature range from 0°C to 10°C [32°F to 50°F], is a good place for storing batteries, especially primary batteries. The refrigerator may, of course, also be used to store secondary batteries, but since they are rechargeable, their loss of capacity during storage may be better compensated by recharging, particularly as they can take up substantial space in the refrigerator (e.g. automotive batteries).

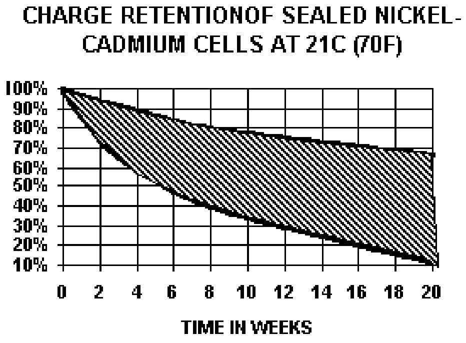
What impact may a "special" environment have on primary batteries? When storing primary batteries over several years in a refrigerator, it is important to remember that a refrigerator exhibits a rather low relative humidity. This phenomenon is familiar from uncovered food which is stored for a couple of days or longer: The food (e.g. cheese, meat) will loose moisture and dry out. This also happens - even if only slowly - to unpacked batteries if stored over an extended period of time (years). The water-vapor permeability of the batteries' plastic seal determines how quickly they dry out. The rate at which the water vapor permeates the plastic seal depends on its cross-section and surface and on the relative humidity of the battery's hydrous electrolyte.

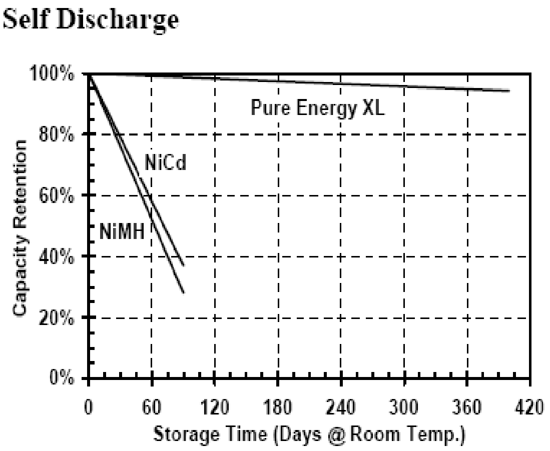
Generally this rate is very, very low. Nevertheless it cannot be ignored over extended periods of time, leading finally to a noticeable increase in the battery's internal resistance, while reducing its load capability. Thus, if anyone has to store primary batteries for a longer period of time in a refrigerator, they should be stored in a vapor-proof packaging, such as plastic-laminated aluminum foil. This precautionary measure is only necessary where batteries are stored for several years in a refrigerator or an extremely dry environment. Before use, primary batteries should be removed from the refrigerator soon enough to allow them to adapt to the ambient temperature.

Another tip: During the summer months, the glove compartment of an automobile is a quite unsuitable place to keep a flashlight. If the sun shines down on the car, temperatures may rise up to and even exceed 60°C. Consequence No. 1: The internal resistance of the batteries increases and the batteries dry out. Consequence No. 2 : When it is needed the flashlight may provide only a dim flicker. The same applies to a battery-operated emergency light in the car's trunk. This too should be checked regularly to ensure that it is functioning properly, and if necessary, the batteries should be replaced in good time.

NiCd and NiMH Self-Discharge Rate

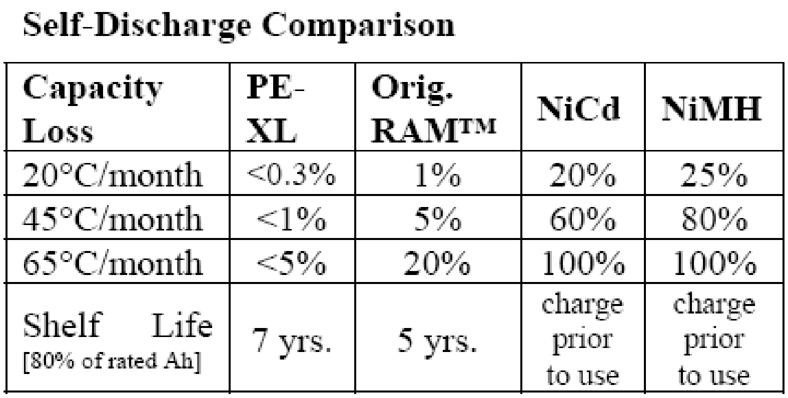






2-Long Term Battery Storage and Self Discharge Rates

(11/2/2008)



Self-Discharge Comparison

Capacity Loss	PE-XL	Orig. RAM™	NiCd	NiMH
20°C/month	<0.3%	1%	20%	25%
45°C/month	<1%	5%	60%	80%
65°C/month	<5%	20%	100%	100%
Shelf Life [80% of rated Ah]	7 yrs.	5 yrs.	charge prior to use	charge prior to use

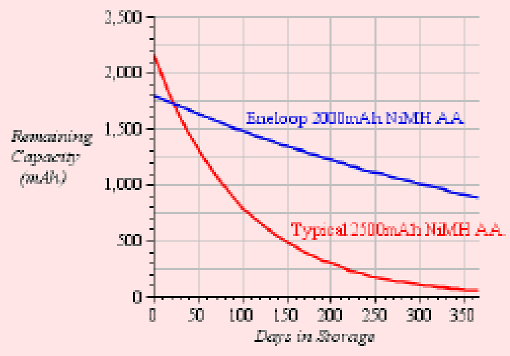
Recharging				
Type	Cycles (to 80%)	Charge time	Discharge per month	Cost per kWh
Alkaline	50 (50%)	3-10h	0.30%	$95.00
NiCd	1500	1h	20%	$7.50
NiMH	300-500	2-4h	30%	$18.50
Li-ion	500-1000	2-4h	10%	$24.00
Polymer	300-500	2-4h	10%	
Lead acid	200-2000	8-16h	5%	$8.50

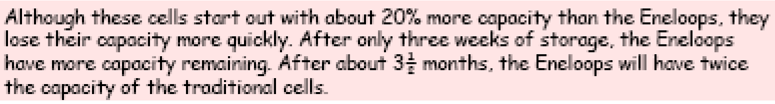
Sanyos Eneloop Low Self-Discharge NiMH

From a user group: About a month after first posting this review, I received a very nice e-mail from Mr. Taetow, Vice President General Affairs at SANYO Component Europe GmbH, expressing appreciation for my independent review and addressing a few points, which I've summarized below:

1. The Eneloop batteries are sold charged, but not necessarily 100% fully charged. In Europe we charge them about 75%. I am not sure to which degree they are charged before being sold in Canada. Thus it is rather vague to estimate the discharge rate by calculating backwards to the production date. Also, the storage conditions (transport, warehouse, shop, etc.) are unknown (see point 3 below).
2. Several long term tests have shown that the self-discharge rate decreases over time. This means that Eneloop batteries discharge relatively fast at the beginning and relatively slower the longer you store them. To get real (long-term) test results, you have to store them and wait. An estimation of long-term discharge rate by extrapolating short term storage results is not correct and leads to rather poor results. This may explain the differences you have seen.

3. Storage temperature is of high importance if you measure self-discharge rate. Higher temperatures substantially increase self-discharging. It is best to store Eneloops as cool as possible to keep the charge in the battery. As a rule-of-thumb, every 10°C increase in storage temperature is equivalent to doubling the storage time. Some R/C pilots in Europe put Eneloops in the freezer, with rather good results.





Although these cells start out with about 20% more capacity than the Eneloops, they lose their capacity more quickly. After only three weeks of storage, the Eneloops have more capacity remaining. After about 3½ months, the Eneloops will have twice the capacity of the traditional cells.

Links for more information:
http://www.powerstream.com/Storage.htm

3-Efficient Battery Chargers for Survival

(11/3/2008)

Many of the modern battery chargers use a small transformer that plugs into the wall (called wall warts) and this changes 120 V AC into 12 V DC. So, if in a survival situation all that is needed is to cut the adaptor plug that goes to the charger unit off the wall wart and using the proper polarity hook it into a 12 Volt storage battery as a source of power. These chargers are a quick an easy way to go, however they are not very efficient. They range from 6 to 40 percent of the source energy actually ending up being used to charge the battery.

A much better alterative is to make several much more efficient chargers (60% to 80%) for use now and when it is really needed. In an emergency situation electrical power is scarce and needs to be conserved. This report will show how to make simple, efficient battery chargers. We will assume the most common battery sizes needing to be recharged as AA, AAA and 9 Volt. Other sizes can be made from these building blocks.

The Basic Principles of Efficient Charging

The industry is going in the direction of faster and faster charging rate. This has by observation tossed efficiency out the window. The higher currents equate to higher internal losses and more energy lost as heat. In a survival mode time to recharge is not the issue and should not be the major concern.

Not wasting energy is the issue. Also fast charging does not leave the battery fully charged. Some tests show fast charging leaves the battery around 85% charged. Fast charging also shortens the life of the battery. Bottom line – take your time charging any battery and the process will be more efficient.

Most efficiency in changing takes place at slow charging rates of between .1 and .01 C (a full charge in 10 to 100 hours). C is the capacity in Milliampere (mA) times hours or (mAh).

Most recommended commercial charging procedures are based on something like the following.

Charge Rate Termination Technique when changing between

- 1C to C/2 use voltage or temperature based termination
- C/2 to C/4 use voltage based
- C/5 and below use time limited
- Trickle charge at a C/300 rate

The above is based on the ability to make electronics that properly stops charging when charged for a public that expects zero time to charge. In a survival situation when slow charging for efficiency is a necessity, one should use the timed approach or constant float voltage approach and stay around C/10 or below.

Most current rechargeable batteries have a high internal discharge rate and will not stay charged for very long. Thus the typical user leaves it on charge all the time. This is so it will be fully charged when needing to use it. For most current off-the-shelf chargers this is very wastefully of energy and significantly shortens battery life.

Current off-the-shelf chargers are mostly current limited. Stopping the charging typically occurs at a dip in voltage or rapid change in temperature of the cell. These methods waste energy as heat in the last 10% to 20% before fully charged.

As mentioned earlier the circuitry in current charges are highly inefficient being designed to only transfer about 6% to 40% of the input energy to charging the battery.

Shifting to a voltage regulated charger where the current tapers off and you don't care how long it takes to charge is a much more efficient strategy.

If the right constant voltage is chosen, when the cell is full there is virtually no charging current flow. The only current left would be equal to the self-discharge rate at this voltage. This would be then the ideal float voltage for full charging. This voltage is found to go down as the battery ages.

An optimum voltage can be chosen that will charge new batteries to 95% capacity and old ones to 100%. Along with minimizing self discharge. For the average cell and efficiency, my testing shows the proper constant voltage to charge NiMH and NiCD new and old batteries at is between 1.35 to 1.36 volts.

For new and old Alkaline, Zinc Carbon, Titanium and rechargeable Alkaline Manganese (RAM) batteries the proper constant voltage to charge at is between 1.55 to 1.56 volts. As a side note, tests showed that 1.38 volts to be maximum float voltage for new NiMH cells. However, I don't recommend designing around this voltage.

Using the above recommend float voltages to charge batteries the current will end up when charged at a minimum trickle charge rate depending on the age and type of cell. This voltage is lower than the maximum that these cells can be charged to but the small amount more than this that the cell will hold is almost like a surface charge in that it is a very low percentage of the overall battery charge capacity. I found maintaining a float voltage at a higher value than recommended above is wasteful of energy.

Current chargers that go into a trickle charge mode are wastefully in that they deliver many times more current than is needed to maintain a fully charged float voltage. Most commercial chargers use a constant current .03 to .05 C trickle charge rate.

The typical rate to match self discharge is about .001 C. So .002 to .004 C would be plenty and work for older cells as well. My tests show a minimum trickle rate of about 1 ma for AAA and 2 ma for AA to be needed for the typical good rechargeable cell.

An alterative way to charge is to use a constant current for a given time using a timer to bring the battery up to say 70% or less of it's maximum capacity. Then put it on a trickle charger for the rest of the way. This can be accomplished in a primitive environment with the use of a series resistor of the proper size.

Pulse charging works well with batteries that are prone to crystal formation such as lead acid, and NiCD. It tends to break up the crystals. It is not needed but will work for other types of batteries. These types of chargers are generally not as efficient at transferring energy as one can build using DC only. In a survival situation use what you have or build an efficient DC charger as shown further into this report.

Survival Efficient Charging Guide Lines

1. Make your own charger over using off the shelf in-efficient chargers.

2. To preserve the life of the battery and to increase efficiency use only slow charging at 10 to 100 hours for near full charge.

3. Plan to stop charging at less than 5% of full charge. Only full charge when equalizing (bring all cells up to the same voltage) cells in series.

4. To hold a near full charge (within 5%) on a battery, use a constant voltage regulated charger (1.35 to 1.36 Volts for NiMH and NiCD or 1.55 to 1.56 Volts for Alkaline, etc.).

5. Alternatively make a simple constant current charger using a single resistor in series and time the charging time to be less than full charge (less than 70%). To bring it up to full charge and maintain a full charge use a properly designed very low constant current trickle charger (about .002 to .004 C charging rates).

Off-the-Shelf Chargers

The Battery Xtender http://www.theweb2u.com/ with a price of $39.95 is designed to recharge so called non-rechargeable Alkaline, Zinc Carbon, Titanium and rechargeable Alkaline Manganese (RAM) batteries. For normal so called non rechargeable Alkaline Cells the number of recharges can be between 10 and 100 with extra life of between 2 and 15 times the original capacity.

Measurements on how the unit works, shows that it runs at 17.5 ma constant current and stops charging at 1.600 volts. Recharging time can be between 8 and 24 hours depending on how much it was discharged. The more it is discharged the sorter the life and the fewer times it can be recharged. Typically one wants to recharge before it reaches half charge.

A bad battery results in different ways. Recharging these types of battery one can not help but notice that they hold less and less charge (mah) every time it is charged. At some point its capacity becomes so low that it is not worth charging. It may or may not leak before it gets to that point. Some times one can clean it off and continue to use it. In this case use it for quick discharging uses, so it doesn't corrode the battery terminals and case. Other times you risk damaging the battery holder.

The more times it is charged depending on brand and batch date the internal self discharge rate will increase. This decreases charged shelf life. For this reason it is better to continue to reuse a recharged cell until completely useless than to let it sit.

Rechargeable Alkaline Manganese (RAM) Battery Charger

Grandcell Recharger (for rechargeable alkaline Manganese (RAM) batteries) can be found along with RAM batteries on ebay.com

Measurements on the unit show that is uses a tapering off current of 0.48 amp at 1.34 volt down to 0 amp at 1.637 float Volts.

Note: My recommendations are to use a much lower voltage than is found on the above chargers (use 1.55 to 1.56 volts as max). My test show a longer life and greater charging efficiency will result for both rechargeable and non-rechargeable Alkaline cells.

Wall warts (small transformer and DC rectifier that plugs into the wall)

Battery packs and tools that recharge using wall warts as source can be improved. They typically are designed to recharge all the time at full charging rate. This tends to fry or rapidly burn out the battery and wastes power if left plugged in all the time (the typical use). A resistor put in series will fix this. The charging cord between the transformer and battery pack is split and one of the wires is cut. A resistor of proper size that will recharge the pack in about 300 to 400 hours is chosen. This produces a trickle charge rate that will recharge the battery in about a week. One can leave this on recharge full time. The result is the tool is ready to use when you need it and the battery pack lasts years instead of months and the power wasted is very much less. This strategy will work before and after a Pole Shift. The leads for the resistor are bent so they just about touch each other.

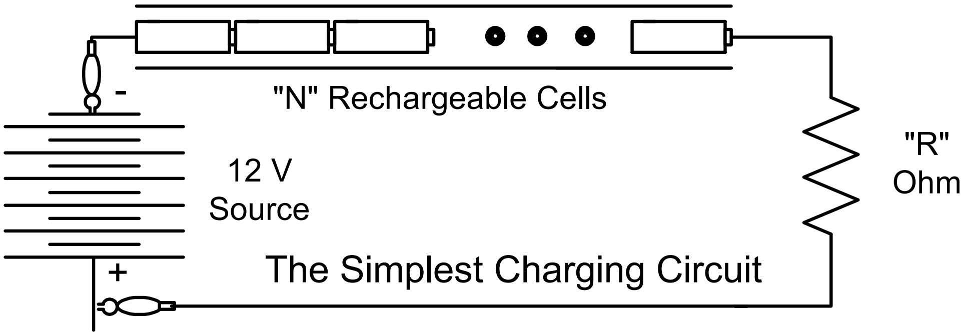
When fast charging is needed the resistor leads are connected together and the resistor is effectively taken out of the circuit. In the above example we used a 220 ohm resistor. One way to find the right value of resistance is to temporally hook up a digital amp meter and a variable resistor (pot) and adjust the flow to be about 100 times less current than what is measured when the pot is zero ohms. Then measure the resulting resistance using a digital ohm meter.

3-Efficient Battery Chargers for Survival

(11/3/2008)

How To Make the Simplest of Chargers

The simplest charger is one or more cells in series with a resistor connected to a DC source. If 12 volts is used as the charging DC source then the circuit might look like the following.



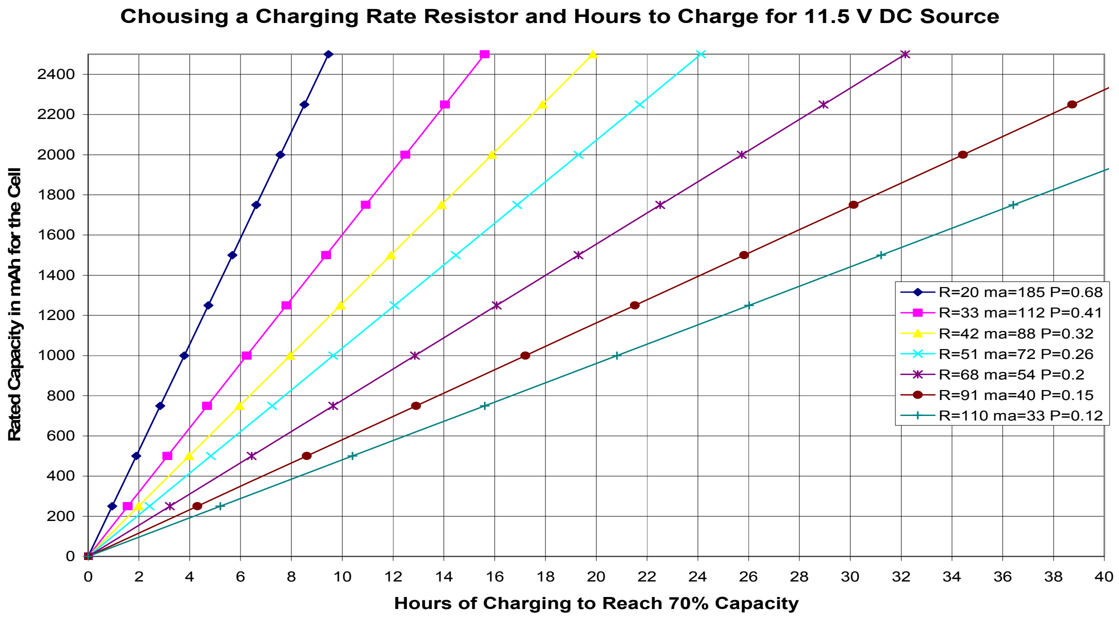
The higher the value of “N” cells the more efficiency of transfer of energy from the 12 V source to the cells being charged and also the lower “R” will be. The lower the value of “R” the more out of control the circuit can get if the source voltage changes due to different states of charge. I found by “trial and error” that six cells is about the right number to maintain charging control as the source voltage varies. Seven or eight cells in series might be able to be used in special cases where the charging voltage is not very high.

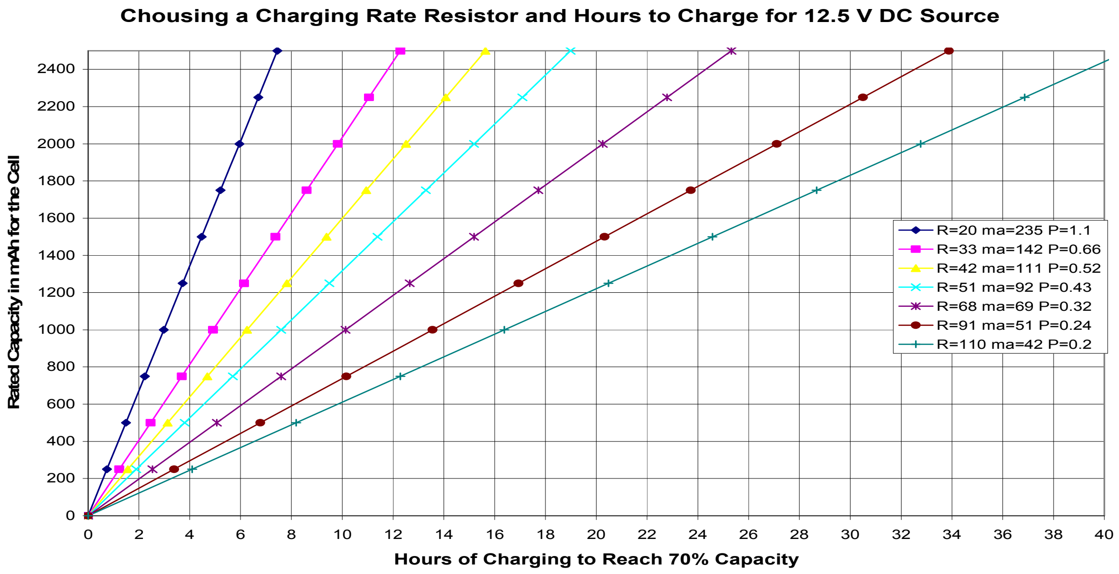
For each type of chemistry and size of cell, there is an optimum number of cells and an optimum R value. See the following formula and tables to get the details of how this works. A timer should be used to change it to about 70% of full charge. Designing for over night or 12 hour charging time is what could be most usefully for the majority. Typically one would design for about 1/10 to 1/20 C maximum charging rate and after the time ran out a trickle charging rate to maintain a float voltage and bring it up to full charge over a given time would be used.

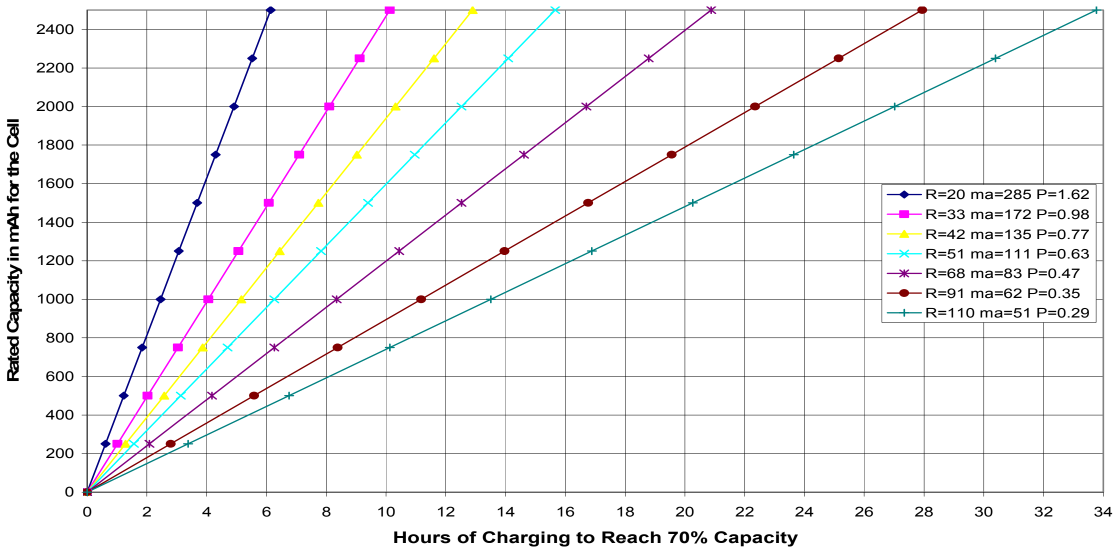
$R=(E-N*V)*(H/C)$ or
$H=(R*C)/(E-N*V)$
Where:
C = mAh capacity rating for each of the individual cells.
N = The number of cells in series being charged.
H = The hours it takes to charge to full C capacity at planned charging current.
V = Single Cell Charging average Voltage at a Given (C/H) rate. An average would be about 1.3 volts (NiMH or NiCD) or slightly less for longer charging times.
R = The resistance is calculated in ohms.
E = Voltage of DC source. This could range from 11.5 to 13.5 volts or higher for a typical 12 Volt lead acid battery.

The following graphs can be used to chouse a series resistor and determine the charging time to reach 70% of capacity for any given size cell. For example if 12 hours for a full

70% charge is chosen for a 2000 mAh AA cell then the best resistor to use is 42 Ohms at 12.5 average volts for the source. Another example; if 12 hours for a full 70% charge is chosen for a 900 mAh AAA cell then the best resistor to use is 91 Ohms at 12.5 average volts for the source. Once the charger is built the following curves can then be used to determine changing time for any given source input voltage and size of battery. Other values of resistance can be found by interpolation between of the given curves. First choose the Voltage range. Then based on planned hours of charging and capacity find the resistance value that gives the best fit to your situation. Efficiency of energy transfer to the charged cells is of the order of 60% to 80% depending on source voltage.



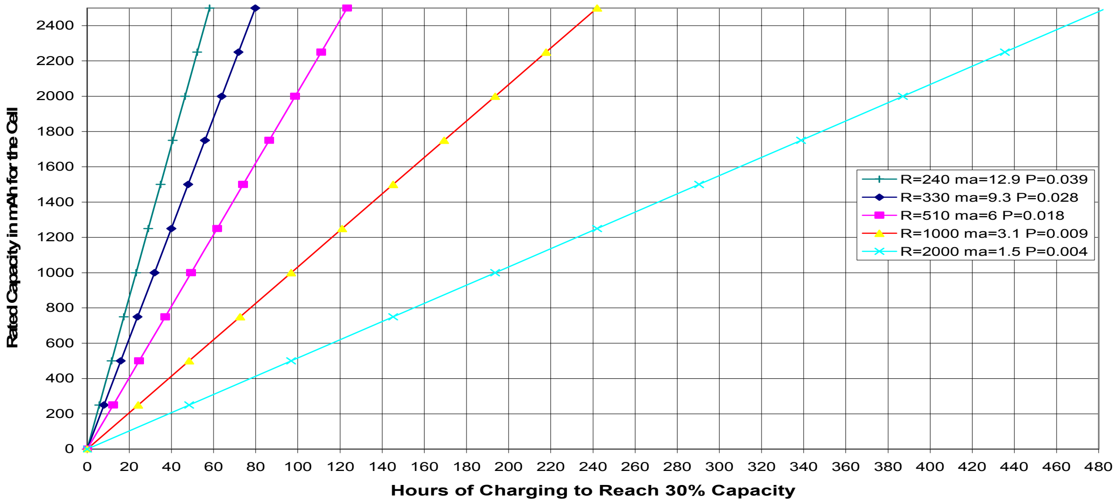


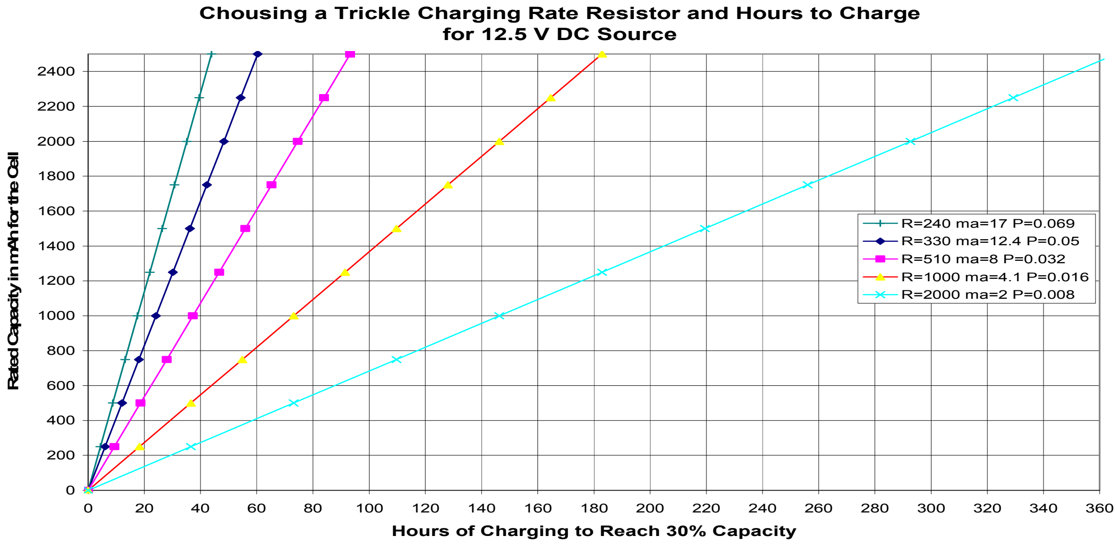

Chousing a Charging Rate Resistor and Hours to Charge for 13.5 V DC Source

Selecting the Trickle charging Resistor

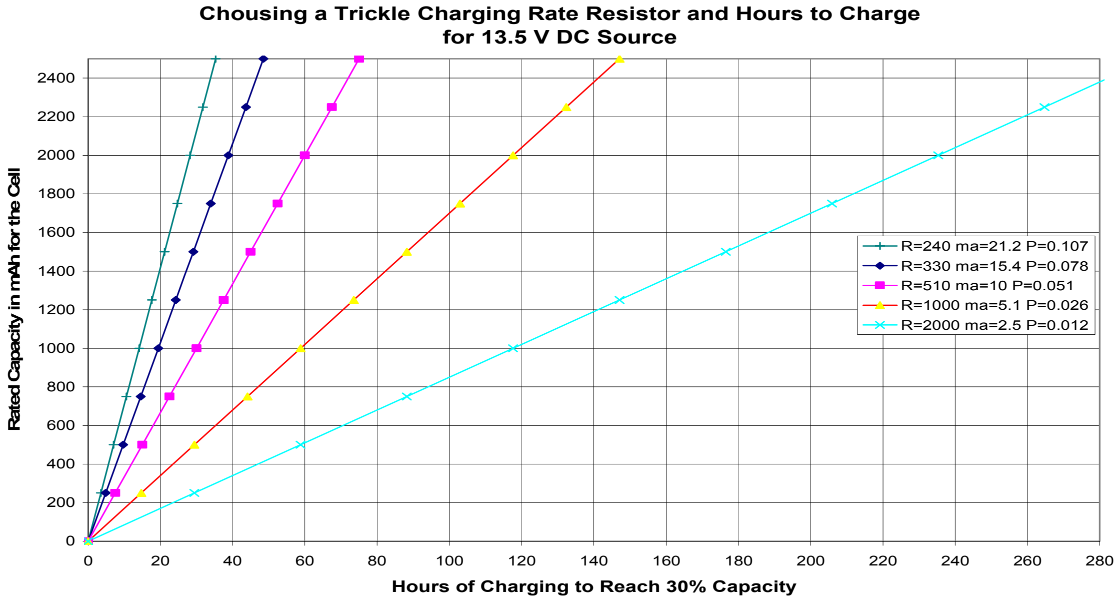
Once your batteries are charged to 70% C then the rest of the way (last 30%) can be done using a trickle charge mode. If the unit is properly designed it will also efficiently keep the batteries from loosing charge, as a result of self-discharge over time. The series resistor charging the six cells can be a pot (variable resistor) or a fixed resistor.

For example if you need a fully charged battery once every two weeks then this would be the time for full charge for the last 30% of the charge. Given the typical source voltage capacity size and hours to charge, the following curves will help determine the best resistance value to use.


Chousing a Trickle Charging Rate Resistor and Hours to Charge for 11.5 V DC Source



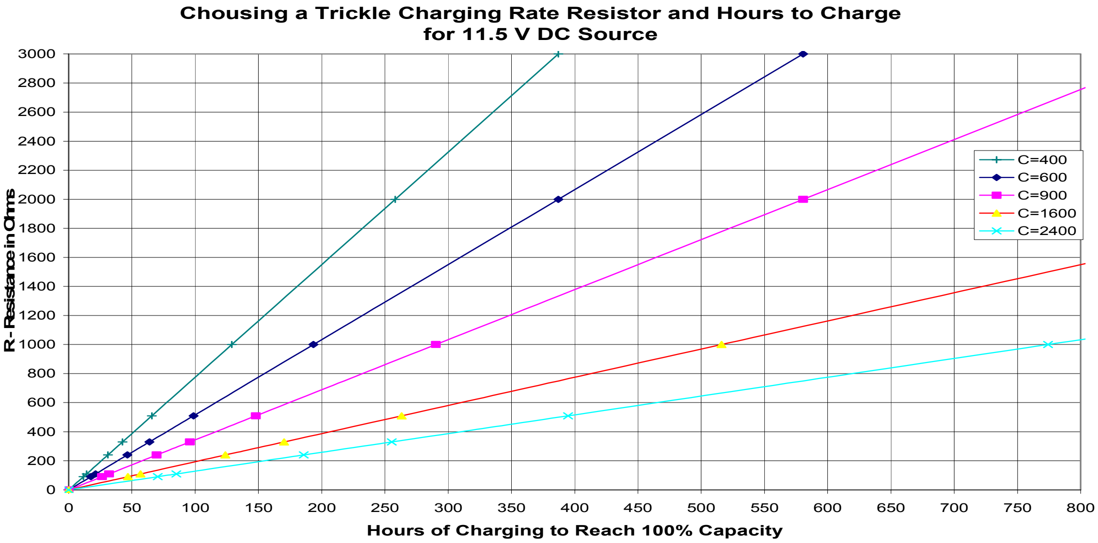
Chousing a Trickle Charging Rate Resistor and Hours to Charge for 12.5 V DC Source



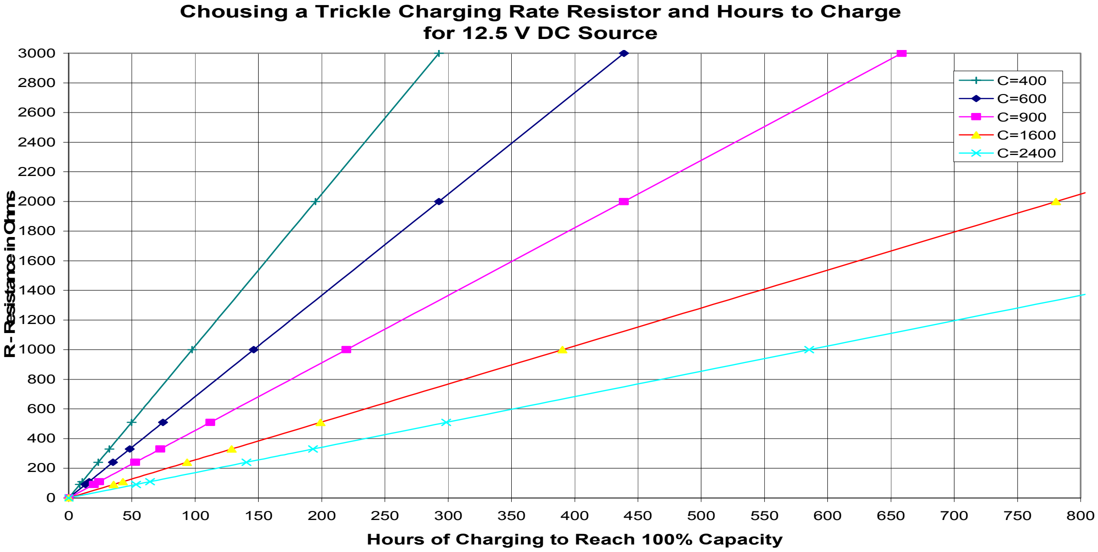
Chousing a Trickle Charging Rate Resistor and Hours to Charge for 13.5 V DC Source

Given enough time, one can trickle-charge all the way to a full charge.

One can also use this method to fully charge a discharged battery. Use the curves above and multiply the time by 3.3 to get the total time it would take for a full charge starting with a discharged battery. The best choice of resistance can be determined from the following curves once one has arrived at the capacity and average hours planned for a full charge.



Chousing a Trickle Charging Rate Resistor and Hours to Charge for 11.5 V DC Source
R - Resistance in Ohms
Hours of Charging to Reach 100% Capacity
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
C=400
C=600
C=900
C=1600
C=2400



Chousing a Trickle Charging Rate Resistor and Hours to Charge for 12.5 V DC Source
R - Resistance in Ohms
Hours of Charging to Reach 100% Capacity
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
50
100
150
200
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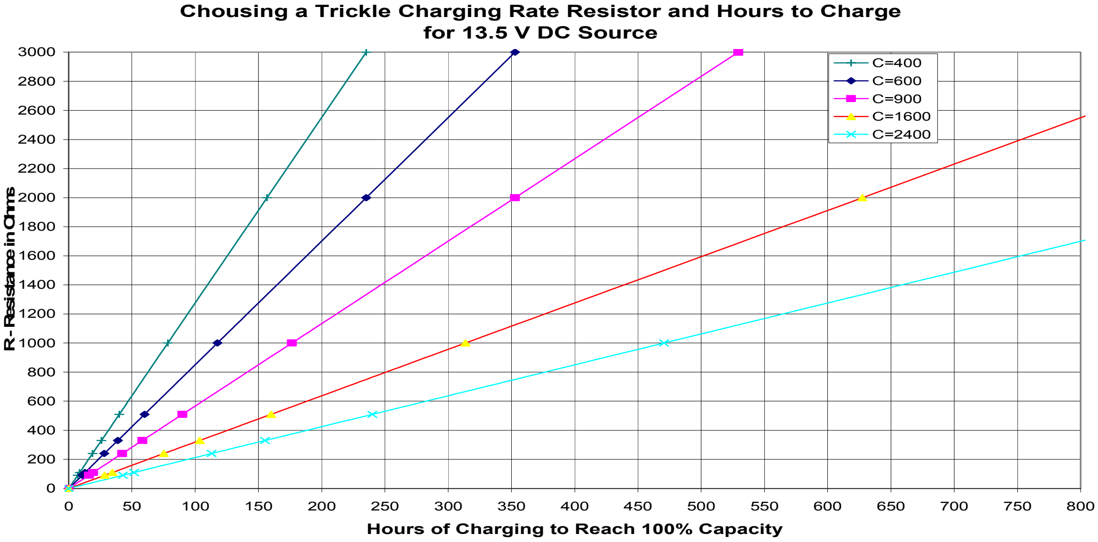
C=900
C=1600
C=2400



Chousing a Trickle Charging Rate Resistor and Hours to Charge for 13.5 V DC Source
R - Resistance in Ohms
Hours of Charging to Reach 100% Capacity
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
C=400
C=600
C=900
C=1600
C=2400

If a 2000 mAh battery takes one year to self discharge then the average rate of discharge is 2/365*24 or .22 ma leakage. A trickle change that is greater than this would eventually charge it up.

How to Make an Efficient AA and AAA Charger using a 12 V DC Source

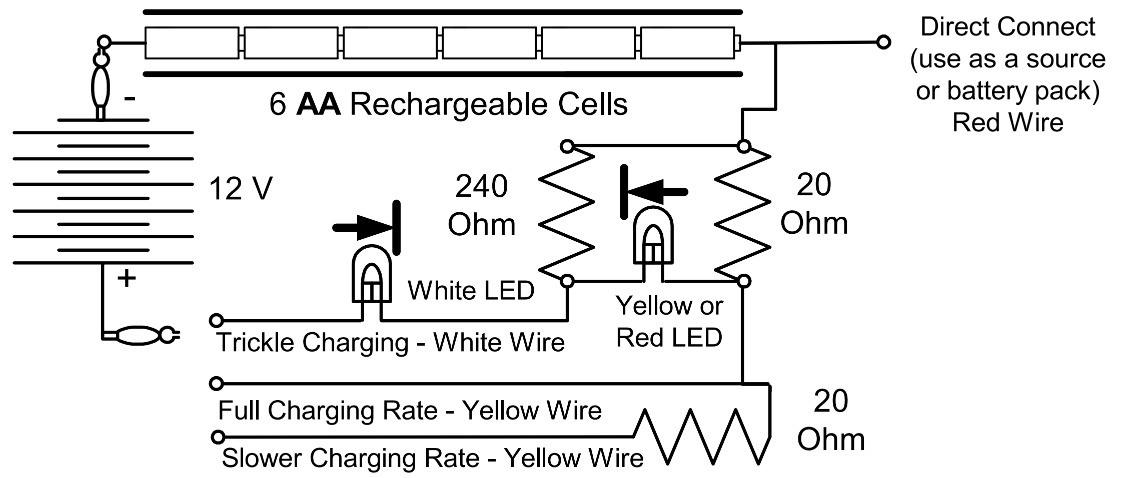
A simple series AA or AAA charger can be made using common plastic plumbing supplies, resistors and super bright LEDs. For 6 AA rechargeable cells use a ½ PVC pipe that is 11.5 inches long and two slip on end caps. One end can be glued on permanently or pined on. The other end is pressure fit and removable so the individuals cells can be added or removed.

For the 6 AAA rechargeable cell use a 3/8” I.D. Flexible Tubing that is 10.25” long. At Home Depot this is called Torro Funny Pipe and comes in 24” long model 53365. It uses pressure fitting funny pipe fittings.

For safety: A .25” hole can be drilled into the pipe sides to let off gas pressure due to a possibility of over charging. If no hole is drilled there is a possibility of pressure popping off the end cap. The hole can be covered up with electrical tape so that under pressure it will release (like a pop-off-valve) to keep the inside near atmospheric pressure. But will seal if exposed to wet weather.

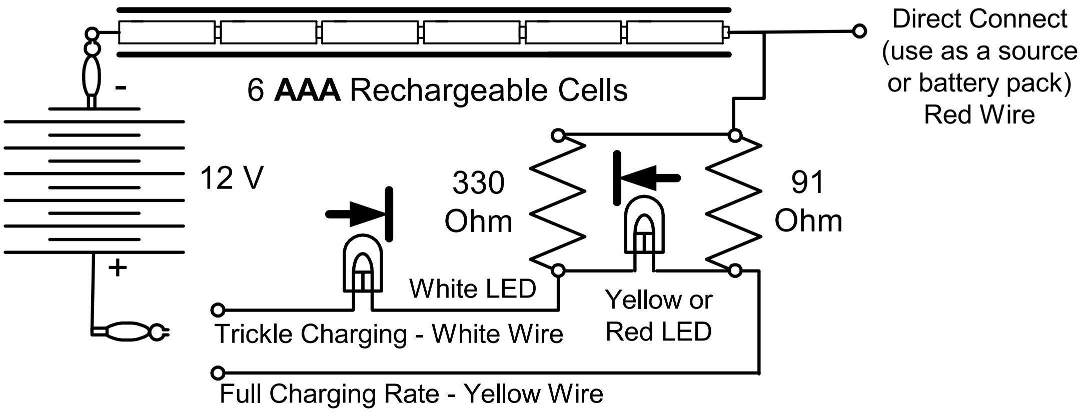
A small machine copper, stainless steel, or Zink plated screw will work for the positive and negative terminal connections. Use around the size of 6/32 and ¾” long with two nuts and one number 10 washers. A spiral spring can be salvaged out an old battery case.

Efficiency of energy transfer to the charged cells is of the order of 60% to 80% depending on source voltage. The circuit below shows how it is wired for 6 series rechargeable AA cells.



Efficient 12 Volt charger for Rechargeable AA NiMH and NiCD Cells

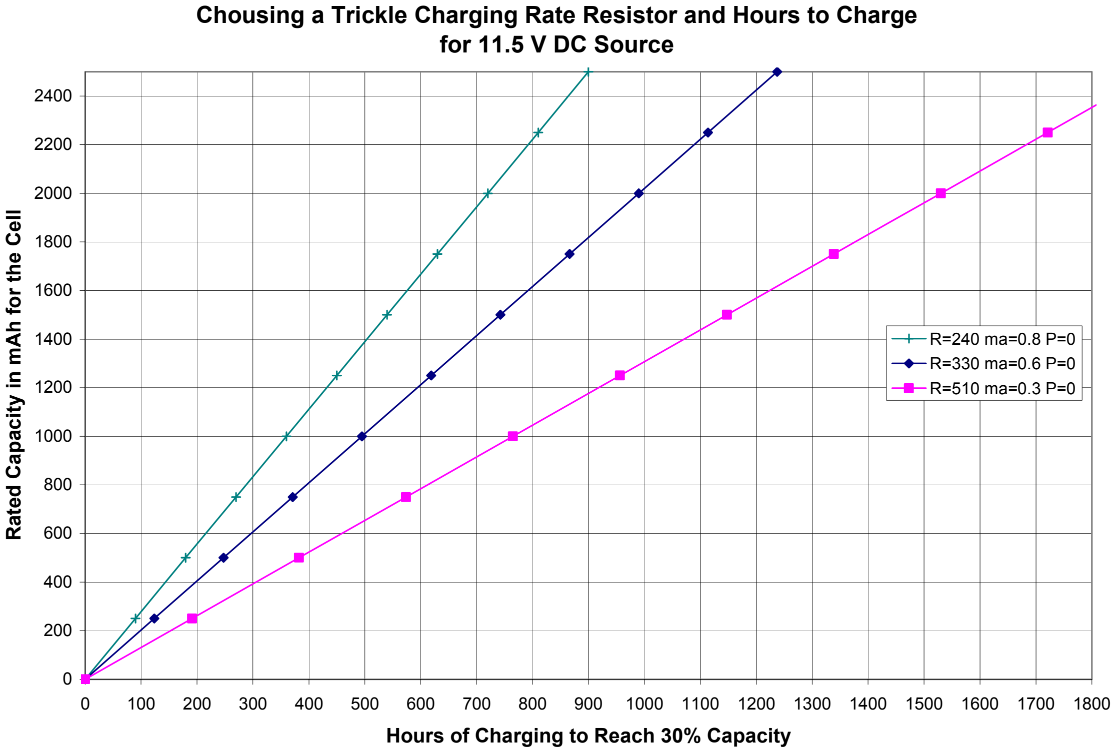
This next circuit shows how it is wired for 6 series rechargeable AAA cells.

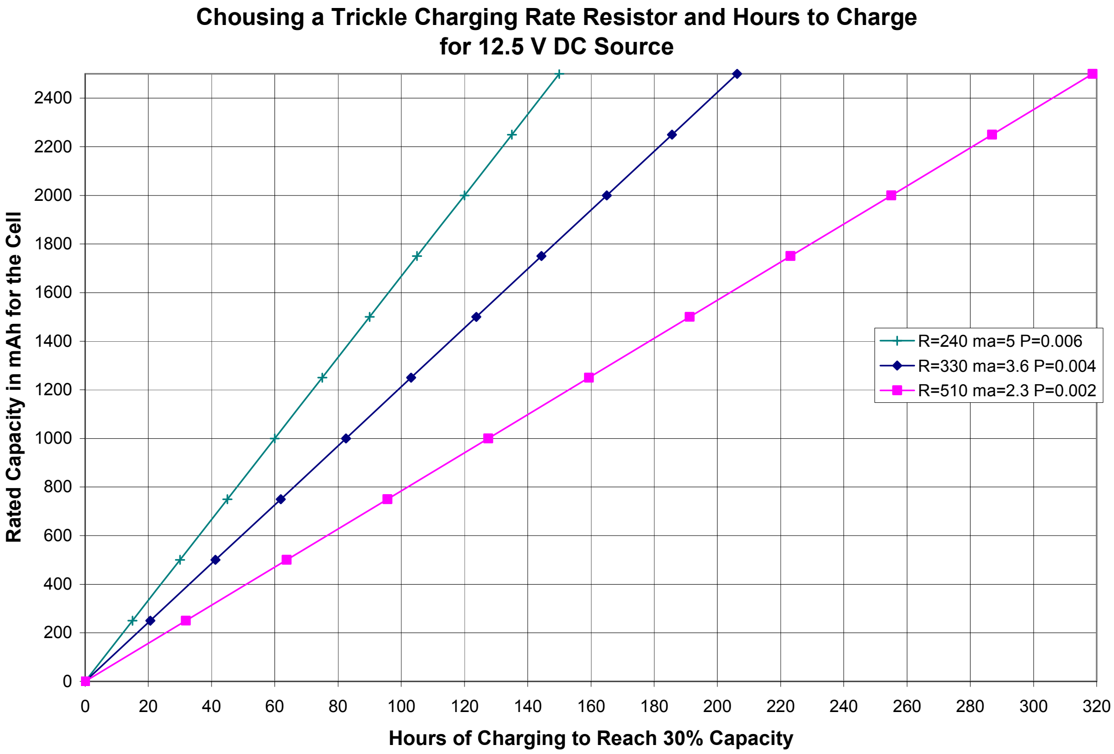


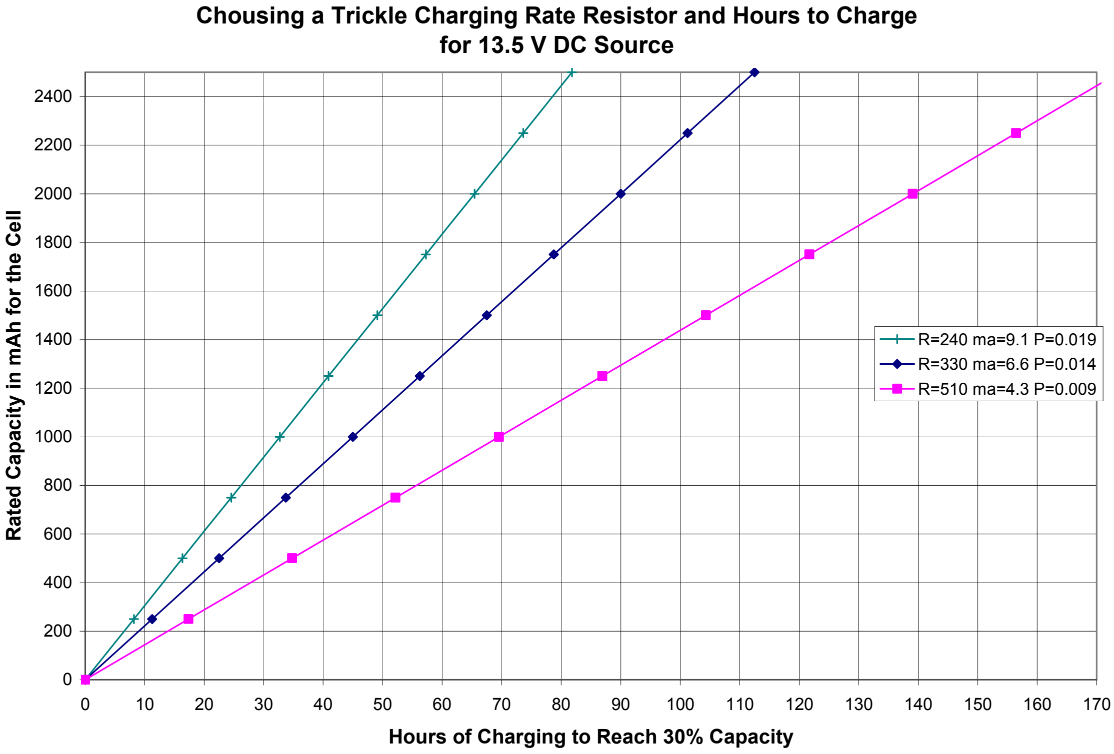
Efficient 12 Volt charger for Rechargeable AAA NiMH and NiCD Cells

The charging curves given above for series connected use 20 ohms (fast) or 40 ohms (slower) AA and 91 ohms (AAA) can be used to determine the charging time.

The following trickle charging curves apply to the above circuits when a white LED with voltage drop of about 2.9 volts is in series with a given resistor 240 or 330 Ohms is used.

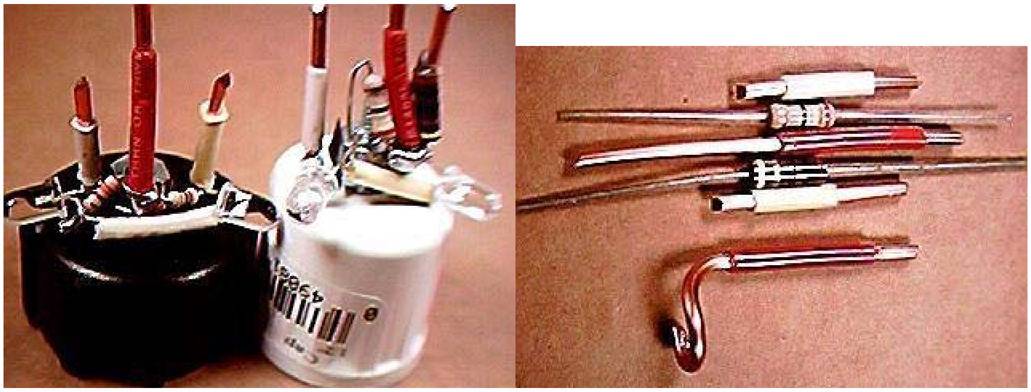



Chousing a Trickle Charging Rate Resistor and Hours to Charge
for 12.5 V DC Source
Rated Capacity in mAh for the Cell
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
Hours of Charging to Reach 30% Capacity
R=240 ma=5 P=0.006
R=330 ma=3.6 P=0.004
R=510 ma=2.3 P=0.002

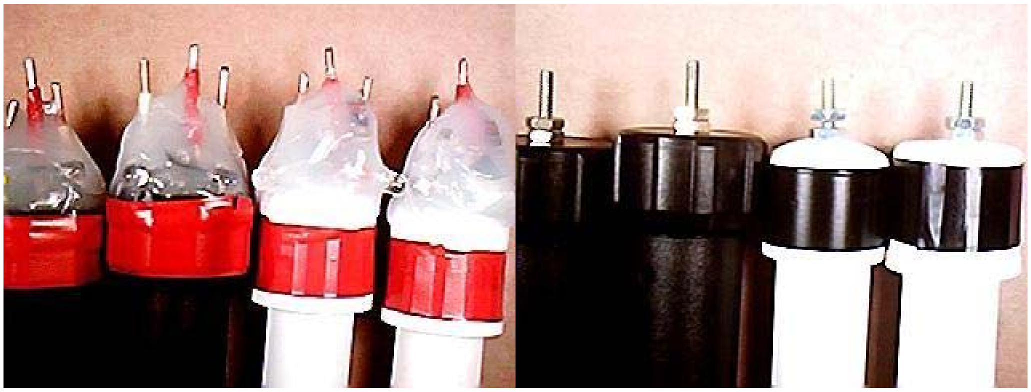

Chousing a Trickle Charging Rate Resistor and Hours to Charge
for 13.5 V DC Source
Rated Capacity in mAh for the Cell
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Hours of Charging to Reach 30% Capacity
R=240 ma=9.1 P=0.019
R=330 ma=6.6 P=0.014
R=510 ma=4.3 P=0.009

How it’s made

Number 12 gauge wire was used for the terminal leads. Red for the direct connect. White for the trickle charge and yellow for the full charging rate lead. The red lead was cut to be 2” long with 1” insulation striped off one end and about .25” off the other end. The yellow and white wires were about 1.125” with about 3/8” insulation striped from one end and 1/8 striped from the other end. A loop is bent in one end of the 2” red lead. The nut will hold this onto the end cap. Depending on space, the resistors are located vertically if needed when soldering them. See below.

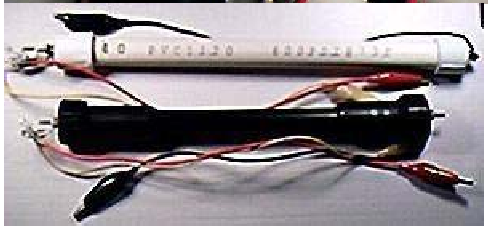


The positive and negative ends when finished then look like the following. Silicon rubber sealer was used to encapsulate the ends to add strength and durability in wet environments. Note the spiral spring in the negative cap. This came from an old battery pack.



The red direct connected wire is used when this pack is used as a source of power. It is connected directly to the light or portable item needing to be powered.

Another way to go is wired with clip leads. I believe without clip leads are easer to store and use. No wires to get tangled up. Can keep jumper clip leads separate and use when needed on each end. The follow was an earlier version documented for it's lessons learned.



If you have a bunch of these stored the leads tend to get tangled. Better to build it with out the clip leads.

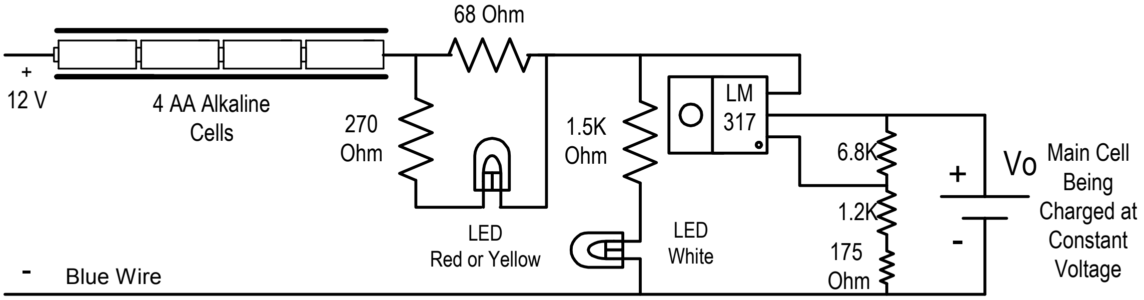
Constant Voltage Charger

This charger is designed to recharge so called non-rechargeable Alkaline, Zinc Carbon, Titanium and rechargeable Alkaline Manganese (RAM) batteries.

For so called non-rechargeable alkaline batteries adjust to 1.55 to 1.56 volt maximum for Vo. A variable resistor 10 turn trim pot from 5 to 10 k ohm can be used instead of the individual resistors (6.8 k and 1.375 k) that determine the output voltage. Turn down the voltage using the variable resistor (pot) as your batteries get older. The ratio for the voltage divider resistors is about 1.375/6.8 = .2022.

Given 5 cells that need recharging, the cell with the highest voltage is used to control the process and is put in the Vo slot. Once this one is charged it will then trickle charge the rest until Vo cell is removed and replaced with the next highest voltage cell. In this way all the cells can be charged as long as one has a supply of cells needing charging.

The characteristics of the circuit: Still charges down to 9.5 volts source voltage. Charging current ranges from 68 ma at source 13.5 volts to a trickle charging rate of 3.4 ma depending on voltage Vo. The red light goes off when the current flow is less than 20 ma. The white light is on all the time and trickle charges the 4 cells at about 3.4 ma when Vo reaches a maximum.

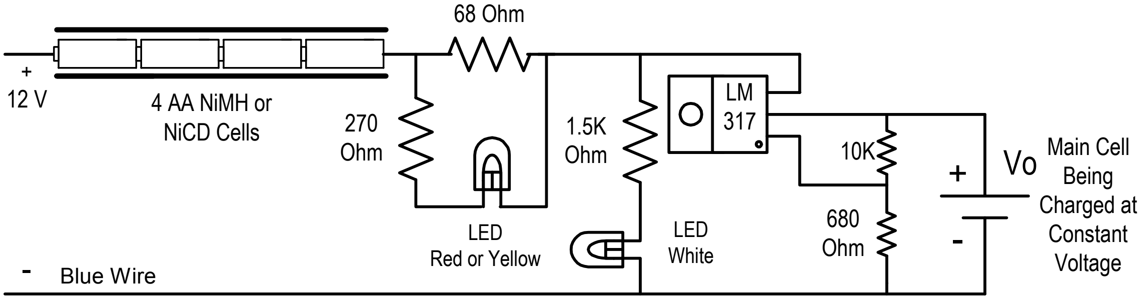


Efficient Charger For Non-Rechargeable and Rechargeable Alkaline AA Cells (Constant voltage Vo = 1.56)

For NiMH and NiCD rechargeable cells use a slightly different set of resistors adjusted to produce 1.35 to 1.36 volts. The ratio for the voltage divider resistors is about 680/10,000 = .068.

The characteristics of the circuit: Still charges down to 8.5 volts source voltage. At 12 to 13.5 volts source the charging current ranges from 70 ma to a trickle charging rate of 5.2 ma depending on voltage Vo of the cell being charged.

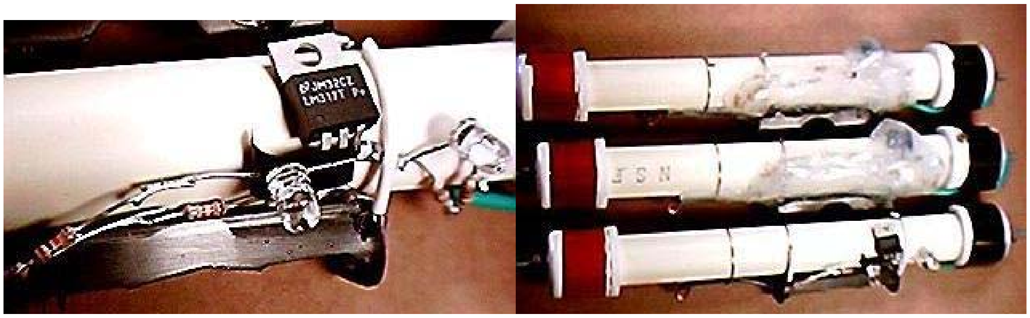
The main advantage of this type of circuit over the previous series resistor circuits is that the current tapers off to zero flow when charged and is maintained at full charge with minimum flow just to take care of self-discharge. In other words it is impossible to over charge.



Efficient Charger For AA NiMH and NiCD Rechargeable Cells (Constant voltage Vo = 1.35 volts

The holder for the 4 AA cells can be made from a 7 and 5/8" section of ½" PVC pipe. A single cell hold is wired to the side of the pipe as shown below. The circuitry is covered in silicon rubber sealant that gives durability and water proofing.

Basic operating instructions: Charge the cell with the highest voltage first by putting it in the Vo holder. Once this is charged then move the next highest voltage cell into the Vo holder.



9 Volt Battery Charger

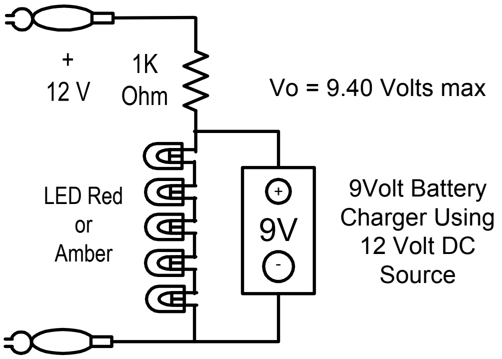
Charging of 9 Volt Alkaline or NiCD or NiMH is easy and reliable to do with the following circuit. It also works as a night light that does not attract bugs. It will charge at a trickle charge rate until a constant voltage of 9.4 - 9.5 volts is reached at which time the Amber (yellow) or red super bright LEDs are lit at full strength. When the battery is disconnected the light is fully on – indicating it is hooked up properly. When a discharged 9 volt battery is connected the LEDs are off.

It is a very efficient use of electricity in that it is producing light or charging or doing both. In all my testing no matter how long I left it on I never over charged Alkaline or rechargeables. I never had any leakage with Alkaline. It has proven it’s self to be very workable.

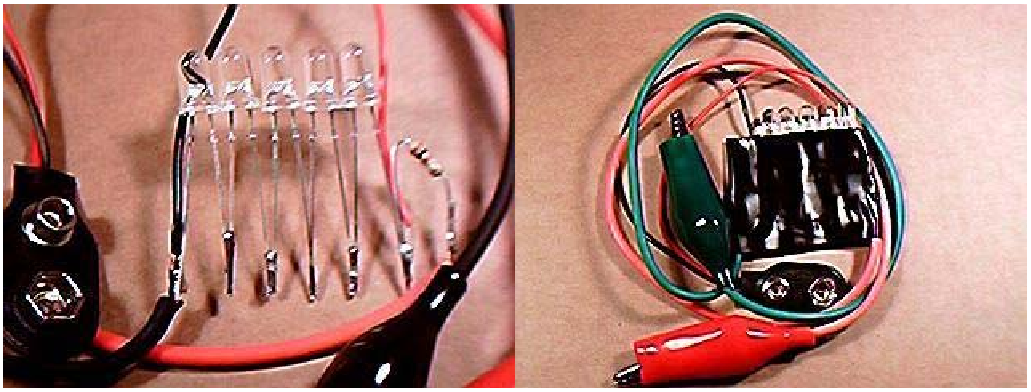
The LEDs act as a voltage limiter or Zener diode. Instead of producing heat in this case they produce usefully light. You might have to wait a day or two for a full charge depending on capacity and state of charge. The unit is extremely easy to make. It is one of the super winners in my book.

It draws 2.9 ma when fully charged at 12.5 volt source (using .036 watts) producing all nearly all it’s power as light. LEDs are just turned off at 8.00 Volts and 4.5ma charging current. For a fully discharged battery 5.4 volts (.9volt/cell) it charges at 7.1 ma.

As an example a 100 mAh battery would take about 24 hours to charge. Amber LEDs work a bit better than Red. It is a bit higher voltage drop. Amber measures 1.88 Volt/LED and Red measures 1.80 Volt/LED at 2.5 ma. White won’t work for this purpose it measures 2.76 Volt/LED at 2.5 ma. 5 amber or Red are used in series as shown in the circuit diagram.



9 Volt Alkaline, NiMH and NiCD efficient Charger



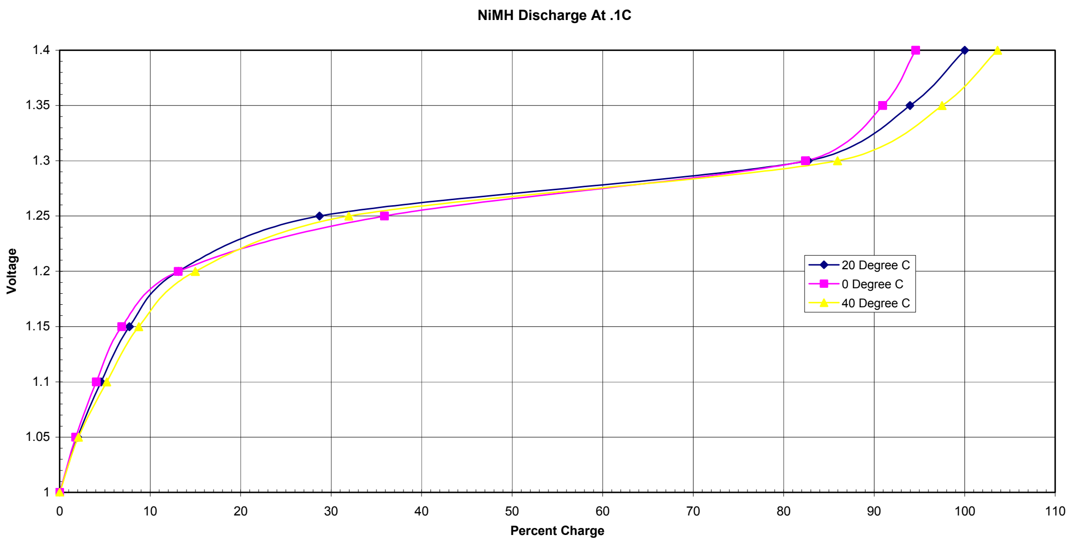
The leads are soldered as show above. Electrical tape is then wrapped around the bare leads. Out of about 10 Cells repeatedly charged and discharged on the average about 3 or 4 times. I had two that would not hold a charge after a short period of use. Both were the same brand Toshiba Alkaline. Duracell and Fuji both worked much better. Brand and possibly batch has a lot to do with rechargeablity of Alkaline cells.

Things to know about Charging Batteries

A battery should always remain cool during charging. High temperatures shorten battery life. If the battery gets hot while charging (too hot to easy hold your hands on it) then the charging rate is too high.

Trickle charge redistributes the electrolyte to remedy dry spots on the separator brought on by gravity separation of the electrolyte during long storage.

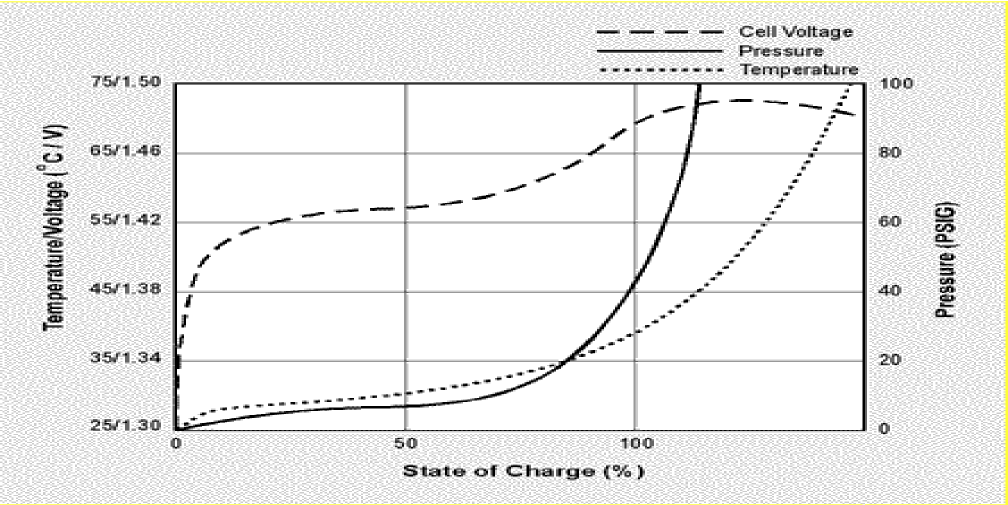
The higher the ambient temperature the more capacity it will hold, but the shorter the life time of use and the greater the internal self-discharge rate.



Some battery manufacturers do not fully form the cells before shipment. Full performance is reached after the battery has been run through several charge/discharge cycles.

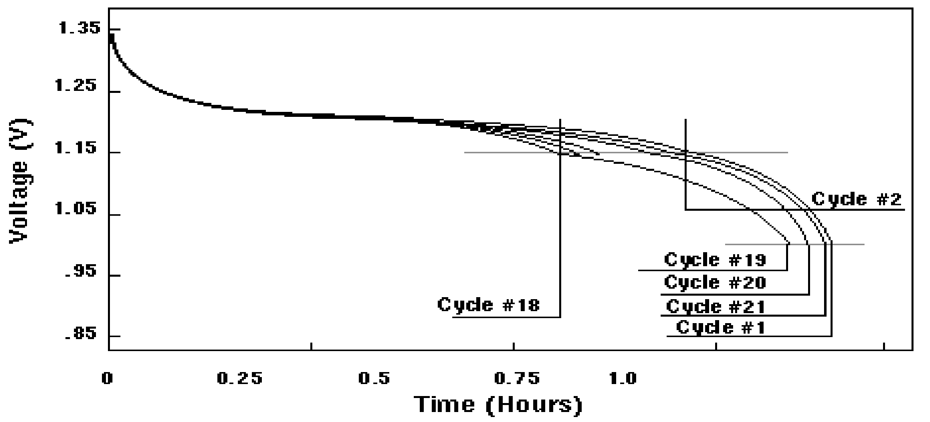
Most rechargeable cells are equipped with a safety vent to release excess pressure if over-charged. The safety vent on a nickel-based cell opens between 10-13 Bar (150-200 psi). With a resealable vent, no damage occurs after venting. Some electrolyte is lost and the seal may leak afterwards. A white powder accumulating at the vent opening indicates venting activities.

A typical voltage, pressure, temperature curve for both NiCD and NiMH would look like the following.



Most recommend sending your Nickel-Metal Hydride batteries (NiMH) and your Low Self Discharge (LSD) Nickel-Metal Hydride batteries through a reconditioning (discharge) cycle about every fourth time you charge them. Nickel-Cadmium batteries (NiCd) need more frequent reconditioning cycles. In a survival situation just use them until fully discharged before charging and you will get the most out of each. To recondition is wastefully of energy. Note: Lead acid and alkaline batteries should not be fully discharged before charging.

You may have heard that NiCd batteries develop discharge memory and that NiMH batteries do not. This is not quite true. Both NiCd and NiMH develop discharge memory, the NiCd just does more readily. Discharge memory refers to the behavior of batteries whereby if a battery is discharged, for example, only half way every time it is used; eventually the battery can only be discharged half way before it dies. So, for example, a 1,000 mAh battery begins to behave something like a 500 mAh battery. See the following for NiMH memory effects.



Effects on Ni-MH cell capacity due to repetitive partial discharges.
[Conditions: Charge: (Cycle #1 – #21)=1C to -ΔV=12mV. Discharge: Cycle #1=1C to 1.0 V, (Cycle #2 – #18)=1C to 1.15V, (Cycle #19 – #21)=1C to 1.0V; Temperature: 21°C (70°F)]

Notice that after a few complete cycles of complete discharging it that the capacity returns back to normal.

Working with battery packs: Check the voltage of each cell while the pack is discharged. Find any cells that are week less than .2 volt or often times reversed in voltage and replace them. Then recharge the battery pack. This strategy will work to weed out the weak cells. It works for large or small capacity series hook up cells. If a battery pack is fully charged and is allowed to sit around for a month or two and then the voltage is measured of each cell one can find the cells that have a high internal self discharge rate and weed them out.

The best off the shelf battery chargers have these features

- Runs off 12 Volts DC (wall wart adaptor) so it can be used in an emergency directly wired to a common 12 volt battery.

- Charges both Nickel-Metal Hydride batteries and Nickel-Cadmium (NiCd) batteries.

- Has an optional discharge cycle, more commonly called a reconditioning cycle.

- Switches to a trickle charge or shuts off automatically after the batteries are charged. This prevents you from over cooking your batteries that would dramatically shorten their life.

- Charges each battery individually and not in pairs.

Note—Use an ordinary surge protector (any type) to reduce the chances of an electrical surge acting to confuse your smart charger during a charge cycle. The internal computer that measures a small negative voltage to determine fully charged state can get confused with surges.

4-Measuring State of Charge and Capacity for Various Battery Types

(11/3/2008)

How To Make a Capacity Tester

The following circuit can be used to measure the storage capacity "C" of your AA and AAA cells. Capacity is the total milliamp-hour (mAh) storage capability of the cell.

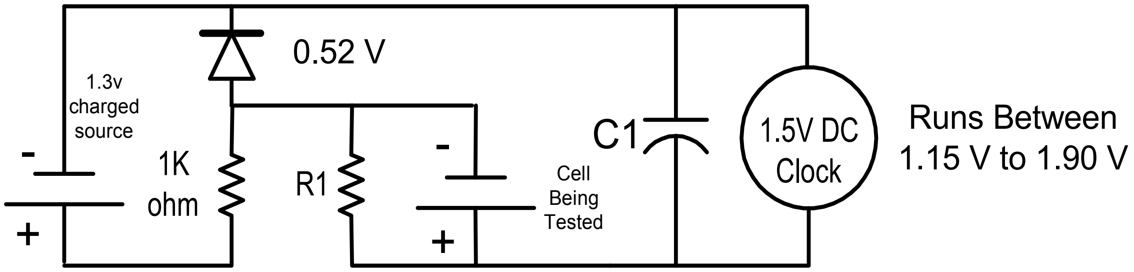
It is easy to use a standard 1.5 volt DC clock as a measuring device. One can purchase a battery clock at the local 99 cent store. In actual fact any digital single cell battery operated clock of any physical size can be used.

Typically if the voltage drops below about 1.15 volts the clock will stop. So to test the time it take to discharge a cell down to .9 volts a bit of help in terms of extra voltage and circuitry is needed from another charged helper cell.

The following circuit show how this is done. The diode is used as a voltage drop of about .52 volts. This .52 volts is added to the cell being tested. The result is one is measuring the discharge down to about 1.15-.52 or .63 volts. This is below .9 volts and the taper off in time is really rapid so that the time it take to discharge to .9 volts is about the same as to discharge to .63 volts.

This circuit will work even if the clock stops running at about 1.4 volts. It is very flexible in this respect for choice of clock need not be the same electrically as my choice and it will still work fine. The 1k ohm is to limit the discharge rate of this helper cell.

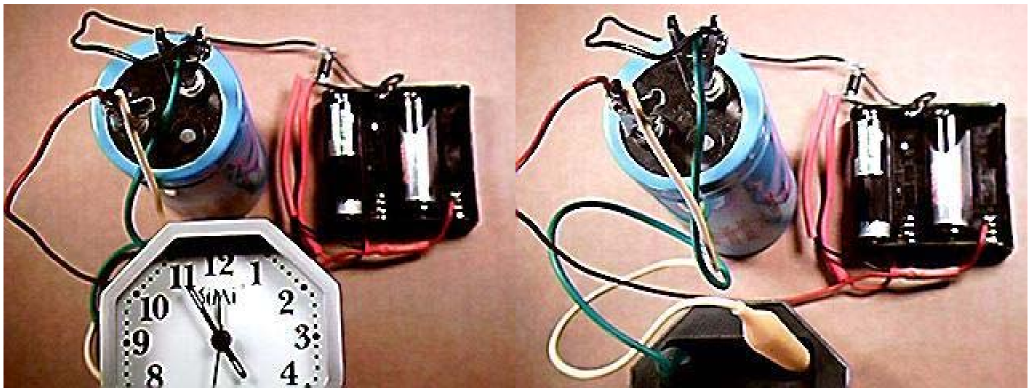
R1 is the discharge load resistor and will determine the cell being testeds current flow and how long it will take to discharge. Its size and the time for discharge will determine the state of charge. The capacitor C1 needs to be as big as possible. I used 29,000 mfd 25 volt electrolytic capacitor. This was much bigger than it needed to be.



Easy to make mAh cell Capacity Tester

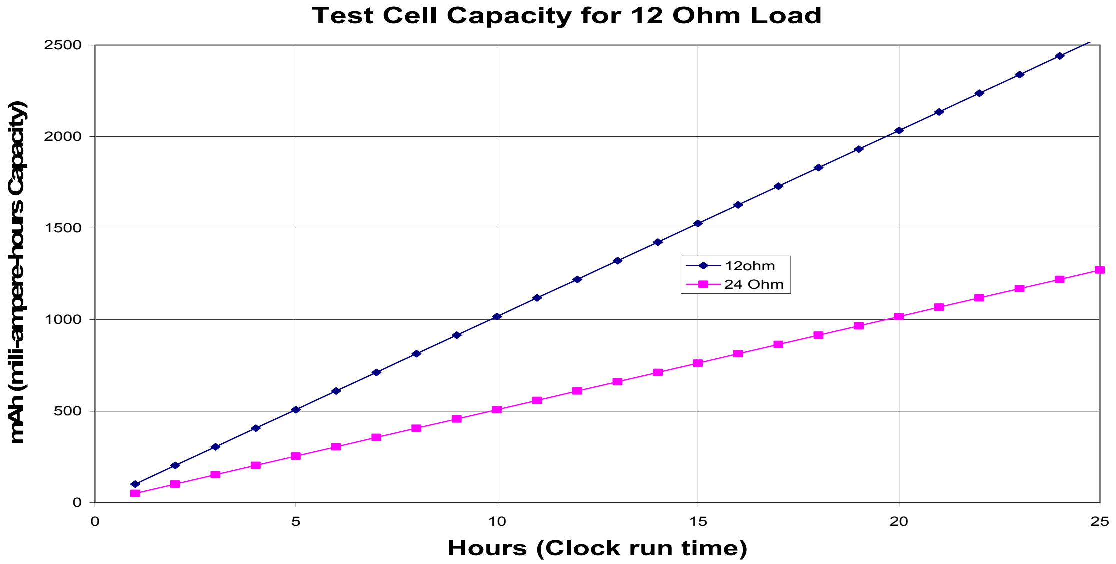
4-Measuring State of Charge and Capacity for Various Battery Types

(11/3/2008)



The cell with the black tape around it in the above picture is the helper source cell. The one being tested is next to that. The holder will work with AA or AAA cells being tested. Determine measured capacity "C" from measured discharge time and R1 the load resistor.

The time is converted from for example 7:15 hour to 7+15/60 or 7.25 hours (decimal). A relative good average voltage of 1.22 volts can be used for NiMH and NiCD batteries. Measured Capacity C = Hours*1.22volts*1000/R1. R1 for my measurements was 12 ohms. The results were repeatable within plus or minus 3% and were as accurate as the resistor and chosen average voltage. Typically compared to other methods of measurement the results were within plus or minus 5 to 10%. The following curve can be used to determine approximate capacity for NiMH and NiCD.



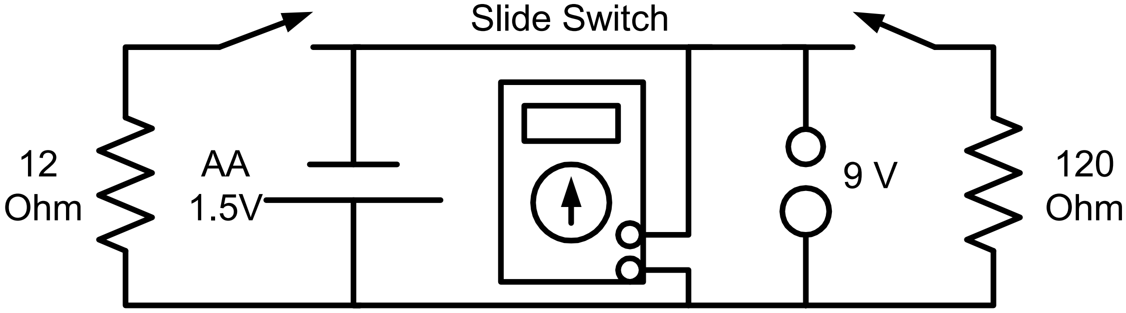
As a rough order of magnitude if you are using 12 volts as the load resistor, then measure the hours, and multiply by100 to get the capacity. Most of the time one is comparing one type of cell to another in terms of capacity. Thus absolute accuracy is not needed.

4-Measuring State of Charge and Capacity for Various Battery Types

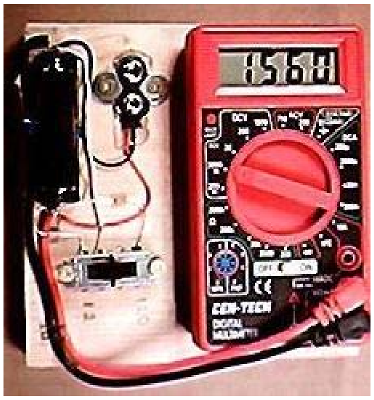
(11/3/2008)

Voltage-Load measurements to estimate state of current charge

One simple way to estimate remaining stored energy of a battery that is partially charged is to put a load on it and measure it's voltage. Then look up the result in a table to find the remaining charge. The following circuit can be used to measure an estimated remaining charge left in AAA, AA and 9 volt batteries. The slide switch is used to attach different sized load resistors depending on the look up table being used.



Battery State Of Charge Tester



Any digital meter can be used. I used a low cost Harbor Freight meter that cost $3.00 witch typically has less than a plus or minus 5% voltage reading. The switch is a single pole double through as a minimum. Fasten a small bit of ribbon (type used for x-mass packages) under the bottom of AA cell holder and such a way that it would fold over the top and be beneath the AA or AAA once the battery is inserted. By lifting this ribbon it becomes an easy way to pull the cell out of the battery holder.

The following table where the load resistor is 12 ohms can be used for AA and AAA cells to estimate capacity by measuring voltage. This measurement does not give an accurate result. It depends on brand or type of chemistry, how old the cell is, temperature and accuracy of the digital meter to name a few of the main variables. One is encouraged to make your own table based on the cells you have. All this being said I believe it worth while to attempt to publish a common result so that in the time of need (primitive survival) there is something that can be used to the extent it match the current cells you are measuring.

Lead Acid Gell Cell Discharge Voltages					
	75 deg F	Lead Acid 2.8 ah	Lead Acid 2.8 ah	Lead Acid 6V 2.8ah	Lead Acid 12V 2.8ah
No of Cells		1	1	3	6
R ohms/bat =		14.3	40	120	240
Discharge Hrs =		21.0	62.0	62.0	62.0
mAh =		2955	3137	3137	3137
ma avg =		140	51	51	51
Avg Volts =		2.019	2.031	6.092	12.185
Watt-hr =		5.97	6.37	19.11	38.22
Rechargeable times		650	650	650	650
Energy Cost Factor					
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	2.253	2.253	6.760	13.520
5	95	2.137	2.157	6.470	12.940
10	90	2.123	2.143	6.429	12.858
15	85	2.112	2.133	6.399	12.798
20	80	2.102	2.123	6.370	12.740
25	75	2.090	2.110	6.330	12.660
30	70	2.078	2.097	6.290	12.580
35	65	2.066	2.083	6.250	12.500
40	60	2.053	2.070	6.210	12.420
45	55	2.041	2.053	6.160	12.320
50	50	2.027	2.040	6.120	12.240
55	45	2.013	2.023	6.070	12.140
60	40	1.999	2.010	6.030	12.060
65	35	1.983	1.993	5.980	11.960
70	30	1.968	1.977	5.930	11.860
75	25	1.952	1.960	5.880	11.760
80	20	1.935	1.940	5.820	11.640
85	15	1.913	1.920	5.760	11.520
90	10	1.890	1.897	5.690	11.380
95	5	1.857	1.863	5.590	11.180
100	0	1.800	1.800	5.400	10.800

9 Volt Battery Discharge Voltages						
	75 deg F	NiCD 9V 100mah	NiMH 9V 180mah	Super Heavy Duty 9V	Alkaline 9V	Alkaline 9V
No of Cells		6	6	6	6	6
R ohms/bat =		979	666	300	300	666
Discharge Hrs =		10.0	10.0	8.8	18.9	28.6

4-Measuring State of Charge and Capacity for Various Battery Types

(11/3/2008)

mAh =		88	133	203	465	302
ma avg =		9	13	23	25	11
Avg Volts =		8.531	8.518	7.002	7.434	7.130
Watt-hr =		0.75	1.13	1.42	3.46	2.15
Rechargeable times		2000	750	1	6	6
Energy Cost Factor		0.0115	0.0202	12.0862	0.8291	1.3310
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	9.600	9.850	9.580	9.370	9.190
5	95	9.221	9.450	8.160	8.465	8.246
10	90	9.046	9.295	7.912	8.202	8.010
15	85	8.971	9.189	7.742	8.029	7.850
20	80	8.914	9.100	7.617	7.887	7.730
25	75	8.878	9.034	7.506	7.769	7.631
30	70	8.850	8.986	7.414	7.670	7.545
35	65	8.830	8.950	7.321	7.587	7.457
40	60	8.810	8.920	7.238	7.517	7.366
45	55	8.790	8.860	7.153	7.455	7.271
50	50	8.760	8.827	7.047	7.395	7.180
55	45	8.721	8.787	6.939	7.328	7.080
60	40	8.672	8.735	6.812	7.260	6.960
65	35	8.613	8.663	6.671	7.195	6.832
70	30	8.542	8.551	6.528	7.115	6.704
75	25	8.470	8.380	6.367	7.030	6.580
80	20	8.369	8.237	6.204	6.930	6.450
85	15	8.241	8.049	6.017	6.830	6.290
90	10	8.059	7.742	5.828	6.696	6.110
95	5	7.763	6.236	5.612	6.533	5.846
100	0	5.040	5.030	5.380	5.845	5.400

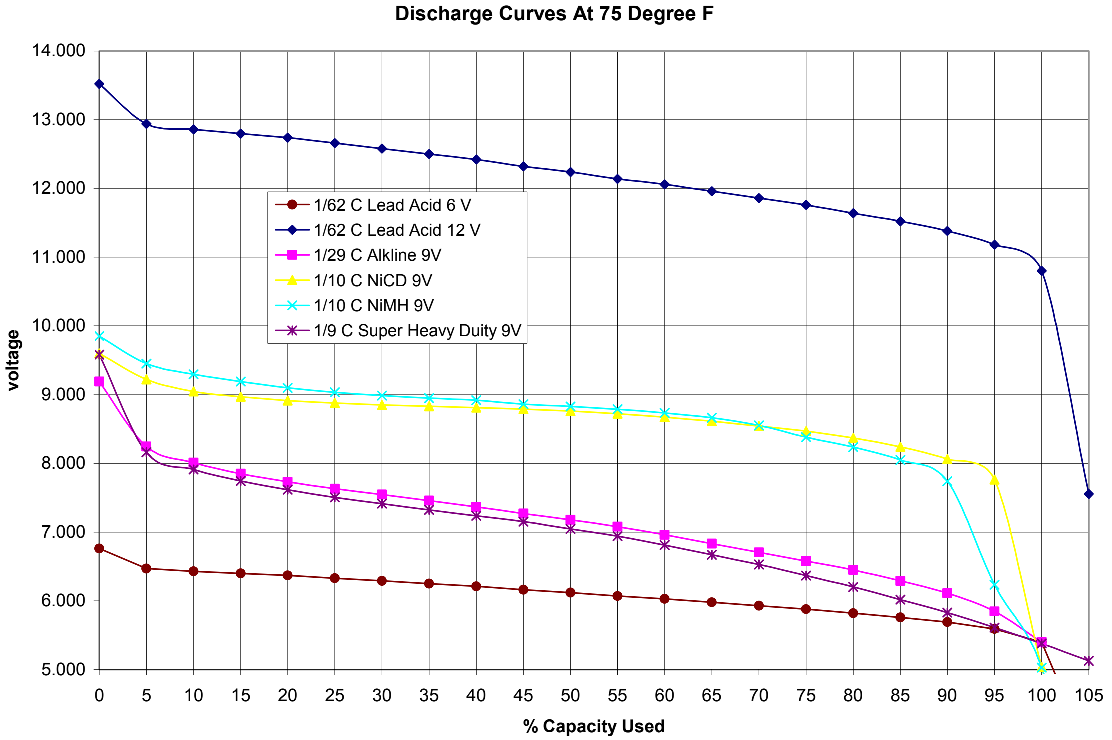
AAA Size Cell Discharge Voltages							
	75 deg F	AAA-NiMH 750mah	AAA-NiMH 900mah	AAA-NiMH 900mah	AAA-Super Heavy Duty	AAA-Alkaline	AAA-Alkaline
No of Cells		1	1	1	1	1	1
R ohms/bat =		12	12	118	12	12	12
Discharge Hrs =		5.0	5.8	53.3	2.8	7.8	5.1
mAh =		505	593	561	263	759	477
ma avg =		102	103	11	95	97	94
Avg Volts =		1.220	1.225	1.258	1.159	1.184	1.142
Watt-hr =		0.62	0.73	0.71	0.30	0.90	0.54
Rechargeable times		750	750	750	1	6	6
Energy Cost Factor		0.0373	0.0316	0.0325	56.5128	3.1911	5.2634
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	1.341	1.359	1.425	1.639	1.516	1.460
5	95	1.280	1.292	1.353	1.367	1.352	1.321
10	90	1.262	1.268	1.316	1.299	1.310	1.285

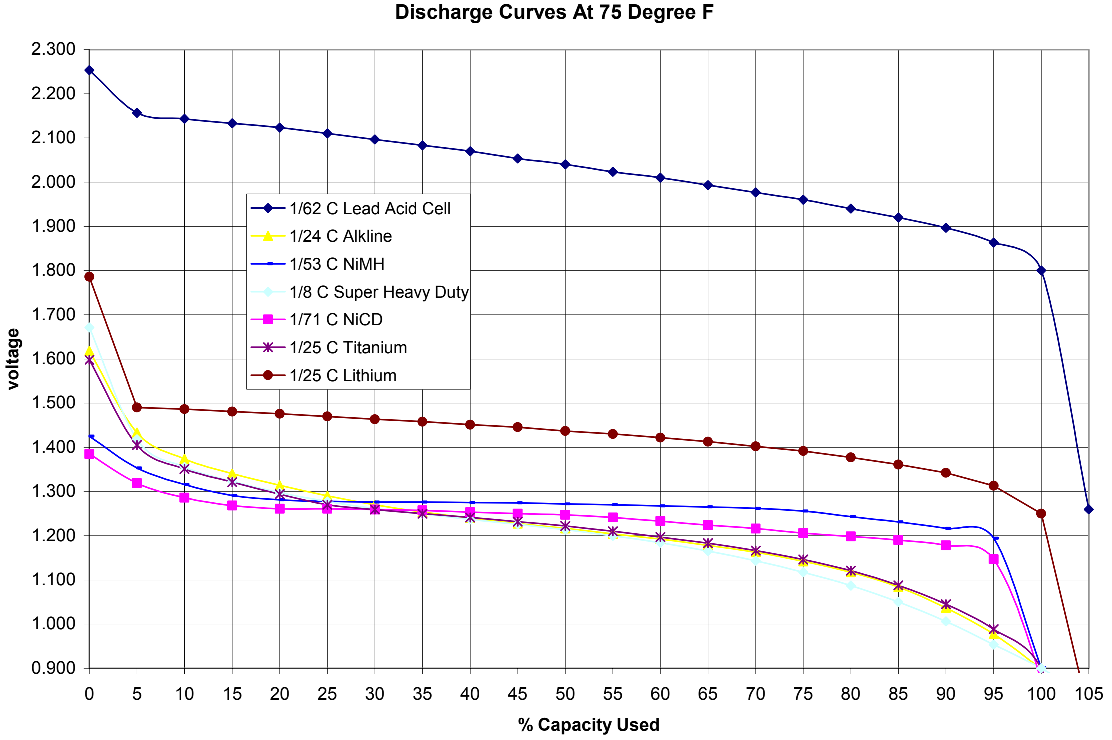
15	85	1.254	1.257	1.291	1.275	1.281	1.258
20	80	1.250	1.252	1.281	1.248	1.259	1.221
25	75	1.247	1.250	1.278	1.231	1.240	1.201
30	70	1.246	1.249	1.276	1.212	1.226	1.183
35	65	1.244	1.248	1.276	1.201	1.213	1.169
40	60	1.243	1.246	1.275	1.187	1.202	1.156
45	55	1.241	1.245	1.274	1.174	1.191	1.145
50	50	1.239	1.243	1.272	1.163	1.181	1.133
55	45	1.236	1.241	1.270	1.148	1.170	1.122
60	40	1.234	1.239	1.267	1.126	1.159	1.110
65	35	1.231	1.236	1.265	1.105	1.148	1.098
70	30	1.227	1.232	1.262	1.081	1.136	1.085
75	25	1.221	1.227	1.256	1.060	1.123	1.070
80	20	1.214	1.221	1.243	1.030	1.105	1.055
85	15	1.205	1.212	1.231	0.995	1.085	1.036
90	10	1.189	1.202	1.217	0.964	1.058	1.014
95	5	1.115	1.188	1.194	0.936	1.015	0.979
100	0	0.894	0.811	0.901	0.900	0.899	0.887

AA Size Rechargeable Cell Discharge Voltages						
	75 deg F	AA-NiCD 700mah	AA-NiCD 700mah	AA-NiMH 2300mah	AA-NiMH-Hybrio-2100mah	AA-NiMH-Eneloop-2000mah
No of Cells		1	1	1	1	1
R ohms/bat =		43	118	12	118	118
Discharge Hrs =		22.8	71.0	16.6	184.9	182.5
mAh =		658	741	1734	1959	1946
ma avg =		29	10	104	11	11
Avg Volts =		1.218	1.226	1.241	1.248	1.254
Watt-hr =		0.80	0.91	2.15	2.44	2.44
Rechargeable times		2000	2000	750	750	750
Energy Cost Factor		0.0107	0.0095	0.0107	0.0094	0.0094
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	1.343	1.385	1.362	1.446	1.461
5	95	1.286	1.319	1.301	1.351	1.364
10	90	1.265	1.286	1.284	1.293	1.316
15	85	1.254	1.268	1.276	1.277	1.299
20	80	1.250	1.261	1.273	1.272	1.286
25	75	1.250	1.261	1.270	1.271	1.275
30	70	1.249	1.259	1.269	1.269	1.269
35	65	1.247	1.257	1.267	1.267	1.267
40	60	1.245	1.253	1.265	1.266	1.266
45	55	1.242	1.250	1.263	1.264	1.264
50	50	1.239	1.247	1.261	1.262	1.263
55	45	1.235	1.241	1.258	1.259	1.261
60	40	1.229	1.233	1.255	1.256	1.258
65	35	1.223	1.224	1.251	1.252	1.255

70	30	1.215	1.216	1.246	1.246	1.250
75	25	1.207	1.206	1.239	1.238	1.243
80	20	1.199	1.198	1.231	1.229	1.235
85	15	1.192	1.190	1.220	1.216	1.223
90	10	1.183	1.178	1.205	1.199	1.208
95	5	1.167	1.147	1.181	1.166	1.180
100	0	0.854	0.871	0.878	0.899	0.898

AA Size Non-Rechargeable Cell Discharge Voltages					
	75 deg F	AA-Super Heavy Duty	AA-Alkaline	AA-Titanium Energizer	AA-Lithium Energizer
No of Cells		1	1	1	1
R ohms/bat =		12	12	12	12
Discharge Hrs =		7.9	23.5	25.4	24.8
mAh =		776	2354	2535	2944
ma avg =		99	100	100	119
Avg Volts =		1.206	1.218	1.214	1.436
Watt-hr =		0.94	2.87	3.08	4.23
Rechargeable times		1	6	6	1
Energy Cost Factor		18.3667	1.0000	0.9319	4.0705
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	1.671	1.618	1.598	1.786
5	95	1.418	1.433	1.405	1.490
10	90	1.356	1.374	1.351	1.486
15	85	1.323	1.340	1.321	1.481
20	80	1.298	1.314	1.294	1.476
25	75	1.277	1.290	1.270	1.470
30	70	1.261	1.270	1.259	1.464
35	65	1.249	1.253	1.250	1.458
40	60	1.237	1.240	1.241	1.451
45	55	1.225	1.228	1.232	1.446
50	50	1.214	1.216	1.222	1.437
55	45	1.200	1.204	1.210	1.430
60	40	1.184	1.192	1.197	1.422
65	35	1.165	1.178	1.183	1.413
70	30	1.143	1.162	1.166	1.402
75	25	1.117	1.142	1.146	1.392
80	20	1.087	1.117	1.121	1.377
85	15	1.050	1.084	1.088	1.361
90	10	1.006	1.037	1.045	1.342
95	5	0.953	0.977	0.988	1.313
100	0	0.900	0.899	0.899	1.250





As an example on if one measured the voltage of the half charge point on a typical cell that you have and found it to be .05 volts lower than the chosen table below then one might subtract this .05 from my reading for all values and use it as your table. The curve is basic the same it just needs moving up or down for the most part to fit your cells. The half charge point is the most flat part of the curve and is hardest to nail down.

The half charged point can be found by using the clock-cell-capacity checker as describe above and pull the battery out of the socket at half the time tested for full charge. Then after letting it sit for a few hours to stabilize test the voltage under a 12 ohm load and compare to the tables above.

The "Energy Cost Factor" is a way of comparing cost of two or more cells based on the energy it would store over it's life time of use. To compare costs multiply the value for "Energy Cost Factor" times the actual purchase price of each cell being compared. The one that ends up with the lowest number will be the lowest cost storage cell and is the one to purchase the most of for emergency use.

Note there are other values of load resistor R1 that were occasionally measured in case one you want to use them.

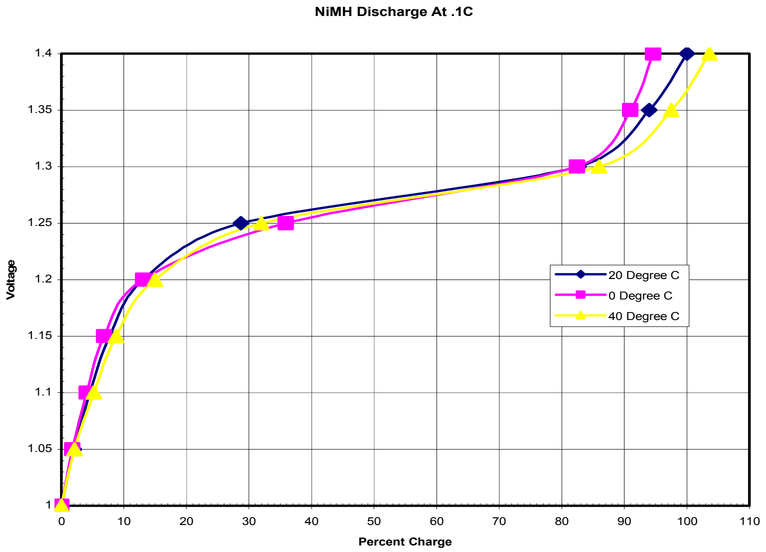
The Eneloop and Hybrio cells were the new very low self-discharge NiMH cells that look very attractive for emergency primitive environment use.

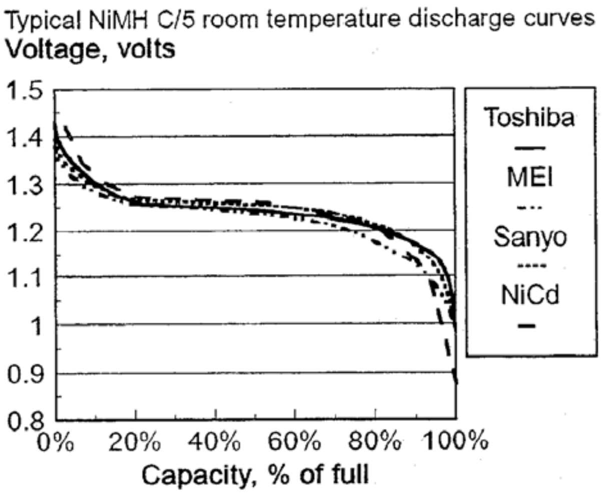
Inaccuracies of Estimating Remaining Cell Capacity with Voltage Measurements are discussed at http://pdfserv.maxim-ic.com/en/an/AN121.pdf

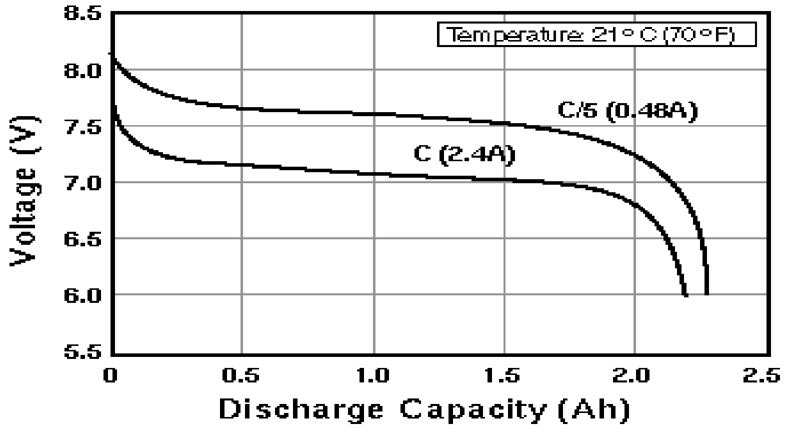
From the data presented in the above link the following table can be made for NiMH at 20 degrees C.

NiMH discharging at .1 of max capacity					
% Charged	% Dis-charged	Voltage (Volts)	% Charged	% Dis-charged	Voltage (Volts)
100	0	1.400	33	67	1.255
99	1	1.390	28	72	1.250
98	2	1.380	23	77	1.240
97	3	1.370	20	80	1.230
95	5	1.360	17	83	1.220
94	6	1.350	15	85	1.210
92	8	1.340	13	87	1.200
91	9	1.330	11	89	1.190
89	11	1.320	10	90	1.180
87	13	1.310	9	91	1.170
83	17	1.300	8	92	1.150
79	22	1.295	7	93	1.140
74	26	1.290	6	94	1.130
69	32	1.285	5	95	1.110
63	37	1.280	4	96	1.090
57	44	1.275	3	97	1.070
50	50	1.270	2	98	1.050
44	56	1.265	1	99	1.030

38	62	1.260	0	100	1.000

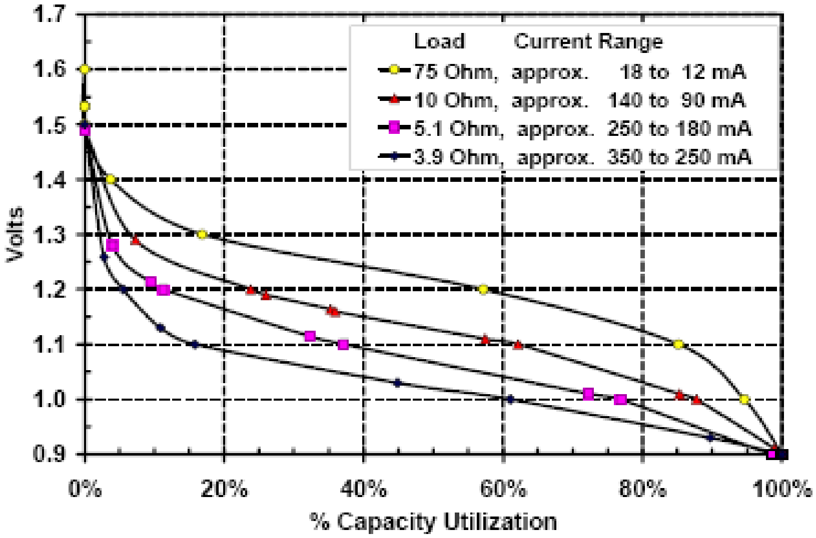






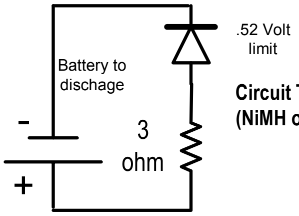
Voltage and capacity of DURACELL DR30 Ni-MH batteries at various discharge temperatures and rates.
[Conditions: Charge: 1C to -ΔV = 60mV @ 21°C (70°F)]

The following are Normalized Discharge Voltage Curves for AA RECHARGEABLE ALKALINE Cells to Estimate Available Capacity at Various Drain Rates.



Removing Memory of Partial past Discharges

The following circuit shows one way of making a discharger that will take the NiMH battery below .6 volts before charging to remove memory. This can be used on troublesome cell to sometimes fix the apparent low capacity. The diode is a simple common diode rectifier that has a forward drop of about .52 volts. Almost any diode that will carry the current will work. No diode is used for NiCD. In this case the cell needs to be taken to zero volts over several days. The choice of the discharge resistor is based on how much time one wants to wait and the wattage of resistors available.



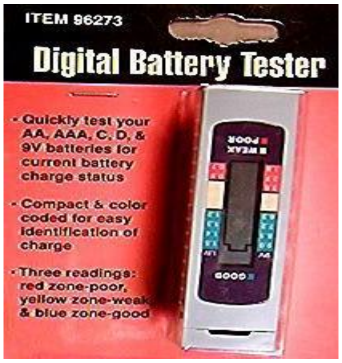
Circuit To Discharge a Rechargeable (NiMH or NiCD) Cell to below .9 Volts

Off the shelf battery Testers:

One can purchase a Maha Energy WizardOne MH-C9000 NiMH battery charger for about $59. It has the capability of measuring the capacity mAh of 4 batteries at a time. It can charge, break them in, and cycle them. This unit is more useful before the pole shift to determine capacity of different brands batteries than after. It does run off 12 volts so can be adapted to car or marine battery use.
http://www.betterlifegoods.com/ProductDetails.asp?ProductCode=BLG-CAT21446

“Watt’s Up” WU100 Watt meter and Power Analyzer made by RC Electronics Inc. can be used to measure capacity in Ah. It costs about $59.
See http://www.rc-cars-planes.com/rc-watt-meter_n.html
My tests with the unit show that as the current goes down the error rate of measuring cumulative amp-hr goes up. If one measures a .1 amp current for a long time the Ah reading will be low by a factor of .94 at .03 amps this factor is .66 at .01 amp this factor is .25. In practice using this unit to measure a AA or AAA cell capacity is very accurate down to at least 400 mAh of capacity. The reason for this is most of the cells discharge current during the discharge cycle is above the .1 amps. One can measure one cell at a time or a battery pack of a series of cells to determine discharging capacity. Will work for efficiency testing.

A portable tester that is light and backpack-able can be purchased from harbor freight tools Item number 96273 for 3.99 to 5.00. I personally like the digital meter item number 90899 that harbor freight sells for $2.99 on sale. It is a little more heaver but gives more accurate voltage readings.



5-Making Soldered Battery Packs

(11/2/2008)

In a survival situation one can accumulate used cells that show corrosion on one or more terminals and use them to make a permanent battery pack. These individual cells would not work well in normal spring-loaded battery holders (they would make poor contact and over time corrodes the battery holder spring-loaded terminals) but would work if soldered.   This is especially important in wet environments where hard wired becomes more reliable.

Separate your batteries by how fast they self discharge by measuring voltage at different days or weeks after a full charge and match decay rate and brand and capacity (mAh) for each battery pack made from individual cells.

The need for Capacity Cell Matching

When cells are connected in series to make a battery pack, it is important that they are all matched with nearly the same amp-hour capacity. The discharge curve of the assembled pack should then resemble that of an individual cell just with a larger voltage scale. But if some cells have a lower capacity than others, they will drop to zero volts while the rest of the pack still has ample power remaining. This one cell then experiences a reverse voltage as current continues to be forced through it even though it is drained. The cell will heat up and suffer internal degradation and possibly vent gas, especially if the current is large.

Battery packs that have been sitting in storage for some time will often wind up with some cells more charged than others. This happens because the internal leakage currents are not necessarily the same from one cell to the next. The longer you use a battery pack the less you want it to fully discharge it or it will reverse a cell.

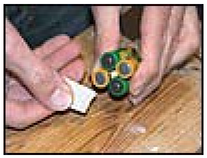
Technique of Making battery NiMH or NiCD soldered packs
Less Heat = More Reliability

Since consumer cells do not have the spot welded copper tag at each end, it's important to apply as little heat as possible for as short a time as possible when soldering. Paradoxically, the secret is to use a hefty 25 Watt soldering iron, so the heat from the iron will transfer quickly to the pads. Conventional wisdom says that soldering paste ('flux') should also be used, but I've found that polishing the terminals with fine wet/dry sand paper alone is OK in conjunction with resin cored lead-based solder.

These photos explain the Construction Sequence:



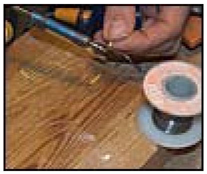


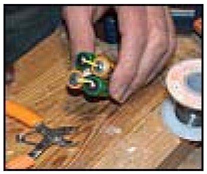


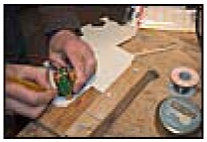
5-Making Soldered Battery Packs

(11/2/2008)









How Cells are Damaged

Sustained high-current overcharge and cell polarity reversal (during discharge) are the main killers of Ni-CD and Ni-MH batteries: If a high charge rate is used, it is essential to terminate charge when the cell is full. If this is not done, the temperature and pressure within the cell will rise quickly as the charging current is dissipated as heat.

Both Ni-Cd and Ni-MH cells have internal vents which will open to allow gas to escape and prevent explosion of the cell. In the case of Ni-Cd, the gas released is oxygen, while a Ni-MH cell will vent hydrogen. The gas that is lost can never be replaced, which means that the lost cell capacity which results from a severe overcharge is not recoverable. It is never wise to rely on the cell's vent as a failsafe, because they often corrode over.

Avoiding abusive high-current overcharge can only be ensured with a well-designed charging system that responds to the signal the battery gives when fully charged.

Cell polarity reversal is a potential problem with any series-connected string of cells: as the battery made of many cells is discharged, the cell that goes down to zero volts first will continue to have current forced through it by the other cells. When this occurs, the voltage across the fully-discharged cell is reversed. A cell that has current forced through it with a reverse voltage across it will heat up very quickly and vent gas in a similar mode to that described for the sustained overcharge, with the same resultant damage.

6-Types of Batteries with notes when to use them

(11/2/2008)

New Low-Self Discharge (LSD) NiMH

A new type of nickel-metal hydride battery was introduced in 2005 that reduces self-discharge and, therefore, lengthens shelf life. By using a new separator, manufacturers claim the batteries retain 70 to 85% of their capacity after one year when stored at 20 degrees Celsius (68F). These cells are marketed as "ready-to-use" or "pre-charged" rechargeables. Besides the longer shelf life, they are otherwise similar to normal NiMH batteries of equivalent capacity and can be charged in typical NiMH chargers.

Low self discharge batteries currently have a little lower capacity than standard NiMH batteries.. However, after only a few weeks of storage, the retained capacity of low self discharge batteries will exceed that of traditional NiMH batteries of higher capacity.

Best Batteries to Purchase and store for emergency use

Purchase the new Low Self Discharge (LSD) Nickel-Metal Hydride batteries of the highest or nearly the highest capacity (mAh) that you can find.

The only exception would be for electronic devices that you use so intensively that you recharge the batteries more than every three weeks or so when you use them. In this case use regular NiMH or NiCD.

For primitive survival situations LSD batteries have a definite live cycle cost advantages over the older fast discharge type. In the mean time some stock of 9 Volt alkaline or NiCd for digital volt meters may be needed. NiCD have a slightly lower self discharge rate than NiMH. LSD batteries are currently not yet available in this size.

Migrate away from devices that use C and D size. Standardize on AA rechargeables or hook the device to 12 volt batteries. Given a bit of time all sizes of low Self-Discharge will be available.

One-use Non-rechargeables (primary cell)

In the past, heavy duty battery was used to refer to Zinc-Chloride batteries which have about 1.5 times the capacity of traditional carbon-zinc (oldest type). Carbon-zinc are not very common now.

Alkaline batteries have about 3 times that capacity of Zinc-Chloride or about 4.5 times the capacity of carbon-zinc. None of these in large quantities are recommended to be stocked up on for survival use. They will last about 10 to 20 years shelf life if kept cool and dry.

Alkaline batteries stored at room temperature self discharge at less than two percent per year. At 85 degrees F they lose about 5% per year and at 100 degrees they lose 25% per year. Alkaline batteries may start at 1.5 but actually average about 1.2 volts over it's discharge life (ending at .7 Volts).

Use Alkaline batteries when you have them already and when long shelf life is needed such as for clocks, timers, digital volt meters, and digital weather forecasting aids. Use them when a low current over long time is needed and disposability when discharged is acceptable.

To get optimum output capacity (mAh) over the life of the battery, the typical maximum current usage needs to be less than 200 ma for D-cell, C 100ma, AA 50ma, AAA 10ma, 9V 15ma, and 6v-lantern 300ma. In a low current use the alkaline batteries have about the same or less storage capacity when compared to one charge-discharge cycle of a NiMH battery.

Alkaline batteries can be recharged a few times. In practice they get more and more leaky (self discharge rate increases and potential case leak) each time they are recharged. In the long run a quality rechargeable battery (like the LSDs) provides more power than an Alkaline battery for less than 1/100th the life time cost.

Rechargeable NiMH Cells

New NiMH batteries can lose anywhere from 1-5% of their charge per day. NiMH batteries self-discharge as a rule of thumb in about a month or two, although when they get old or too hot, they might only last a day. NiMH have about 5 times the internal resistance when compared to NICDs.

Rechargeable battery capacity is rated in mAH (milliampere-hours). The total capacity of a battery is defined as "C", that is it can supply C mA for 1 hour, or 2C for 30 minutes etc. Charge rates can vary from trickle charges to keep the battery 'topped up' of typically 3.3% of C to 5% of C, a slow current charge of 10% of C to 20% of C or a fast charge of 50% of C to 100% of C.

In a survival situation rechargeables are much more cost effective than non-rechargeables. That said rechargeables need more attention or maintenance to keep them alive for the long term. There terminals need to be kept clean.

Moisture in the air can be pulled in to the battery by hydroscopic action of the strong base electrolyte. This in time can cause them to build pressure and leak. They leak at the seals near the plus and minus terminals and typically corrode the charging terminals. A damp rag can sometimes be used to remove the crystals that form where it leaks. Sometimes it is necessary to scrape or sandpaper it off (especially for NiMH). Sometimes a mild acid in a Simi-dry rag to remove the base salts.

Long term storage: Clean and inspect once a year. Keep in a sealed cold container or as a minimum zip lock bags with a drying agent (silica jell as an example). Recharging once every few years may help to keep chemical separation-breakdown to a minimum.

In a survival conserve energy situation plan to use a trickle charge of about 0.14% of C (takes one month to fully charge) about 3 to 4 ma for a 2300 mAh NiMH AA battery. For a 900 mAh NiMH AAA battery it would be about 1 to 1.5 ma. For over night charging using a timer we will be using about near 10% of C for 6 hours. This will put about half a full charge into the cell. It is not efferent to attempt a full charge. That last little bit about 80 to 100% goes in very inefficiently.

NiCD Batteries

Available capacities vary widely. Check the mAh rating before you buy. Curently available are up to 350 mAh for AAA and up to 1,000 mAh for AA.

NiCds have lower storage capacity (about half), high demand current, and slow internal discharge rate. The NiCd looses about 10% of its capacity within the first 24 hours, after which the self-discharge settles to about 10% per month. NiCd rechargeable cells do have memory effects. Cadmium is highly toxic - care is needed when disposing of it.

NiCds have the advantage that they will cycle though charge-discharge more than twice as many times as that of NiMH. NiCDs have Lower internal self discharge than the normal NiMH. Can be stored charged up to several months efficiently. NiCds have a high current drain and are used in battery operated tools. More durable than NiMH for multiple charge cycles per day.

Sometimes NiCDs can be picked up at a price that makes them hard to resist for long term survival. They last twice or more times longer than NiMH at the expense of more weight per watt power. However, for long term survival this type of cell makes lots of sense.

Memory effects of being discharged

The NiCd does not like to be pampered by sitting in chargers for days and being used only occasionally for brief periods. In fact, the NiCd is the only battery type that performs best if periodically fully discharged. All other battery chemistries prefer shallow discharges. So important is this periodic full-discharge that, if omitted, the NiCd gradually loses performance due to voltage depression or so called "memory" effect.

Both NiCd and NiMH develop discharge memory, the NiCd just do it more readily. Discharge memory refers to the behavior of batteries whereby if a battery is discharged, for example, only half way every time it is used; eventually the battery can only be discharged half way before it dies.

Memory effect: If no exercise is applied for several months, the crystals engrain themselves, making it more difficult to dissolve. In such a case, exercise is no longer effective in restoring a battery and "recondition" is required. Recondition is a slow, deep

discharge that drains the cell to a voltage threshold below one volt must be discharged to at least 0.6 volts per cell to dissolve the more resistive crystalline build-up.
While it may be OK to discharge individual cells to 0V, it is certainly not recommended to discharge an entire battery made of many cells. The reason is simple. When the battery is discharged below 0.8V per cell, one of the cells is inevitably weaker than the others, and goes to zero first. If the battery is further flattened this cell becomes charged in reverse, which again makes it still weaker or dead (won't take a charge).

Bottom line - run your NiCd battery packs down to no less than .9 to 1 volt per Cell. This will keep from reversing the voltage on week cells. For individual cells from time to time after discharged short them out (across a resistor of about 3.6 to 5 ohms) for a couple of days. Then recharge. This gets rid of memory effects.

In a primitive survival situation don't be too much concerned with memory effects or depressed voltage effects. If one uses rechargeable batteries that have been in storage for a long time, first use for slow drain LED lighting. Discharges them to the max a few times then shift them into radio's or higher current drain applications. With this strategy one should not be concerned with memory effects (depressed voltage or temporary less storage capacity).

It makes no sense in an energy scarce primitive environment to be changing and discharging batteries just to get there maximum charged capacity back. Use the discharging cycle to produce some light. If you want to get rid of any memory effect after the first discharge cycle then put the cell in a single cell holder and discharge the rest of the charge to zero through a resistor (no diode needed) something like 3.6 to 5 ohms. Then recharge and one should have full capacity.

NiCad cells can be drained fully flat, all the way to zero volts, with no consequence. In fact many sources recommend periodically deep discharging to this point in order to 'recondition' the electrodes. NiMH may cause a leak if one goes all the way to zero. Should stop at .5 to .6 volts. This is in sharp contrast to lead acid and lithium batteries which should never be drained flat.

You don't have to flatten your battery before you recharge it, Don't overcharge your battery beyond 100% of C, and NiCd/NiMH don't like to get too hot, or too cold (0 to 40 degrees C is usually best)

NiMH Batteries

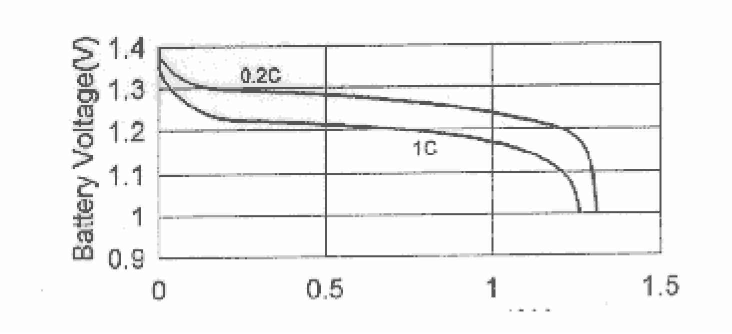
Available capacities at the time of this writing are up to 2700 mAh for AA and up to 1000 mAh for AAA. Check the mAh rating before you buy.

NiMHs have high storage capacity, medium demand current and fast internal self discharge rate. NiMH batteries have low memory effect for most brands. The self-discharge due to internal leakage at room temperature is 5-10% for the first 24 hours after a charge, and stabilizes around 0.5-2% per day at room temperature. After a month expect about 40% loss of charge. At freezer temperatures they loose about 5-10% per month.

The rate of self discharge for any battery depends on the temperature at which it's stored. If they are stored at a higher temperature, they will self discharge at a high rate. Stored at a lower temperature, they self discharge at a low rate.

No toxic chemicals. It takes about 3 charge/usage cycles before they reach rated capacity. Capacity increases up to about 100 cycles (by about 30-50 mAh total) then Capacity loss of about 3% for each added 100 charge cycles with about 500 cycles as max.

This chart indicates the discharge curve of NiMH batteries in various discharge rates. The discharge is measured in the unit of "C", or capacity. 1.0C means 1.0 x capacity of battery (i.e. If the battery is 1,200mAh, then the discharge rate is 1,200mA or 1.2A), and 0.2C means 0.2 x capacity of battery. NiMH batteries will hold full voltage (1.2v/cell) up to 80-90% of usage (varies on discharge rate).



The maximum allowable discharge current of the NIMH is considerably less than that of the NiCd. NiMH are used when low current, high storage capacity and light weight is needed over a short time frame as for two way radios, and task lighting. These are recommended when high mAh storage capacity will be used up over less than a month time frame. Longer than a month use the new low self-discharging NiMH batteries that will become more available with time.

The following measurements on NiMH Cells are from a battery user group list published Feb 2007. This comparison is at a 1.0 amp discharge rate.

Sorted by Brand Name				Sorted by highest measured mAh				Sorted by % off from printed mAh			
Brand Name	Printed on the cell mAh	Measured mAh	% off	Brand Name	Printed on the cell mAh	Measured mAh	% off	Brand Name	Printed on the cell mAh	Measured mAh	% off
AccuPower	2600	2316	10.92	Sanyo	2700	2569	4.85	Ray O Vac IC3	1800	1807	-0.39
AccuPower	2900	2413	16.79	Duracell	2650	2440	7.92	Titanium	2000	2002	-0.10
Ansmann	2300	2188	4.87	AccuPower	2900	2413	16.79	Titanium Power Max	1800	1797	0.17
Brody	2300	2159	6.13	Sanyo	2500	2350	6.00	CBP	1650	1630	1.21

Energizer				Industrial							
CBP	1650	1630	1.21	Titanium	2700	2328	13.78	Radio Shack	1500	1459	2.73
DigitalConcepts	2500	1878	24.88	Powerex	2500	2316	7.36	GP	1800	1747	2.94
Duracell	2300	2000	13.04	Titanium	2600	2313	11.04	Sanyo	2700	2569	4.85
Duracell	2400	2169	9.63	AccuPower	2600	2316	10.92	Ansmann	2300	2188	4.87
Duracell	2650	2440	7.92	Jet Cell	2400	2283	4.88	Jet Cell	2400	2283	4.88
Energizer	2100	1994	5.05	Energizer	2500	2230	10.80	Energizer	2100	1994	5.05
Energizer	2300	1990	13.48	Duracell	2400	2169	9.63	Sanyo Industrial	2500	2350	6.00
Energizer	2500	2230	10.80	Ansmann	2300	2188	4.87	Sanyo	2300	2159	6.13
GP	1800	1747	2.94	Titanium	2400	2125	11.46	Brody Energizer	2300	2159	6.13
Green Sleeve	1400	1289	7.93	Sanyo	2300	2159	6.13	Sanyo Eneloop	2000	1871	6.45
Jet Cell	2400	2283	4.88	SupremePower	2300	2132	7.30	Kodak	1700	1585	6.76
Kodak	1700	1585	6.76	Vapextech	2500	2195	12.20	SupremePower	2300	2132	7.30
La Crosse	2000	1561	21.95	Brody Energizer	2300	2159	6.13	Powerex	2500	2316	7.36
Powerex	2300	1616	29.74	Sony	2300	2068	10.09	Ray O Vac IC3	2000	1842	7.90
Powerex	2500	2316	7.36	Titanium	2000	2002	-0.10	Duracell	2650	2440	7.92
Quest	2300	1566	31.91	X1	2400	2013	16.13	Green Sleeve	1400	1289	7.93
Radio Shack	1500	1459	2.73	Duracell	2300	2000	13.04	Duracell	2400	2169	9.63
Ray O Vac IC3	1800	1807	-0.39	Energizer	2100	1994	5.05	Sony	2300	2068	10.09
Ray O Vac IC3	2000	1842	7.90	Sanyo Eneloop	2000	1871	6.45	Energizer	2500	2230	10.80
Sanyo	2300	2159	6.13	Ray O Vac IC3	2000	1842	7.90	AccuPower	2600	2316	10.92
Sanyo	2700	2569	4.85	Energizer	2300	1990	13.48	Titanium	2600	2313	11.04
Sanyo Eneloop	2000	1871	6.45	Titanium Power Max	1800	1797	0.17	Titanium	2400	2125	11.46
Sanyo Industrial	2500	2350	6.00	Ray O Vac IC3	1800	1807	-0.39	Vapextech	2500	2195	12.20
Sony	2300	2068	10.09	DigitalConcepts	2500	1878	24.88	Duracell	2300	2000	13.04
Sunpack	2300	1271	44.74	GP	1800	1747	2.94	Energizer	2300	1990	13.48
SupremePower	1800	1359	24.50	CBP	1650	1630	1.21	Titanium	2700	2328	13.78
SupremePower	2300	2132	7.30	Powerex	2300	1616	29.74	X1	2400	2013	16.13
Titanium	2000	2002	-0.10	Quest	2300	1566	31.91	AccuPower	2900	2413	16.79
Titanium	2400	2125	11.46	Kodak	1700	1585	6.76	La Crosse	2000	1561	21.95
Titanium	2600	2313	11.04	La Crosse	2000	1561	21.95	SupremePower	1800	1359	24.50
Titanium	2700	2328	13.78	SupremePower	1800	1359	24.50	DigitalConcepts	2500	1878	24.88
Titanium Power Max	1800	1797	0.17	Radio Shack	1500	1459	2.73	Powerex	2300	1616	29.74
Vapextech	2500	2195	12.20	Sunpack	2300	1271	44.74	Quest	2300	1566	31.91
X1	2400	2013	16.13	Green Sleeve	1400	1289	7.93	Sunpack	2300	1271	44.74
average =	2232	1974	11.14	average =	2232	1974	11.14	average =	2232	1974	11.14

The 3 different ways this data is sorted should answer the questions of which companies makes the most capacity and which have the least and most amount of error on there printed labels.

Cycle Life Time

Typically batteries are rated to cycle 500 to 1000 times. What this says is that after this cycle life time the capacity will have declined to 60 percent of the rated capacity and further charging/discharging does not restore battery capacity.

In a survival situation the remaining capacity can still be used. The only time a person would consider stopping the use would be if it doesn't hold a charge for the period of time one needs to use the charge. For example if you are using a portable electric drill and it only holds a charge for 4 days but you need to only use it for 2 hours then it may be that a partial or full charge is indicated.

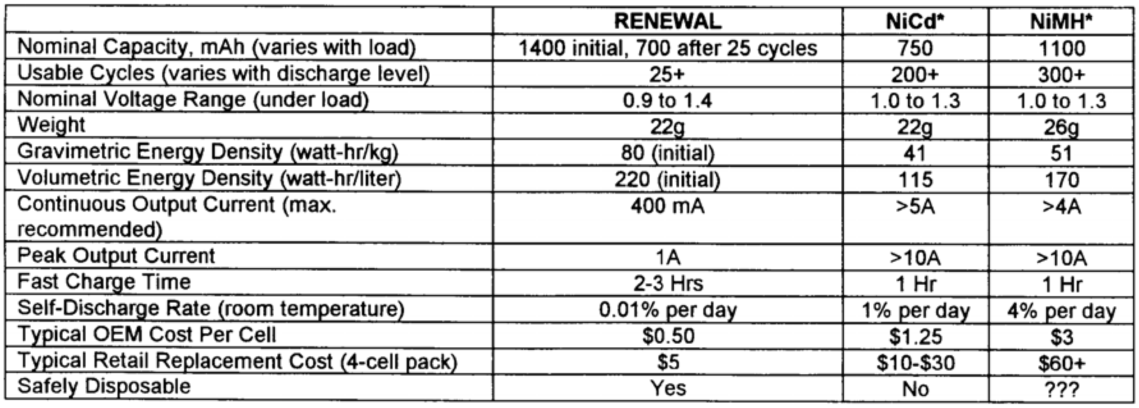
Alkaline Rechargeables:

Rechargeable alkalines can keep their charge for 10 years and have the longest shelf life of any rechargeable battery, something to think about in survival planning. Otherwise they are not as cost effective or as easy to find as NiCads, or NiMH and cannot be recharged as many times.

The Rayovac Corporation successfully introduced the Rechargeable Alkaline Manganese-Zinc (RAM) System for consumer applications in the fall of 1993 in four conventional cell sizes (AA, AAA, C, D). The RAM battery is being consumer marketed as a reusable alkaline battery system under the trademark Renewal.

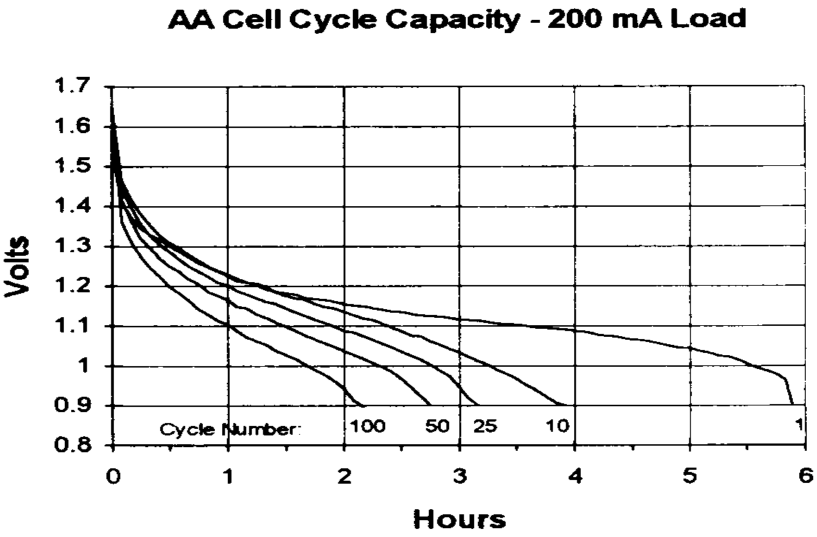
Rechargeable Alkaline batteries are purchased fully charged and have a shelf-life of up to 7 years. They can be produced at lower cost than other chemistries. They do not suffer from memory effect and perform better with shallow discharge prior to recharging.

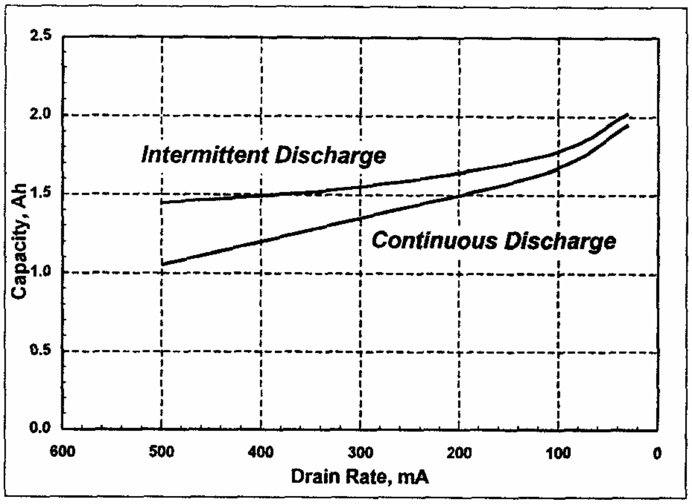
Maximum charging voltage of 1.65 ± 0.05 (for taper charge) 1.75/1.65V (for pulse charge). Maximum charging times range from 2 to 8 hours, depending on cell size and the depth of the preceding discharge.



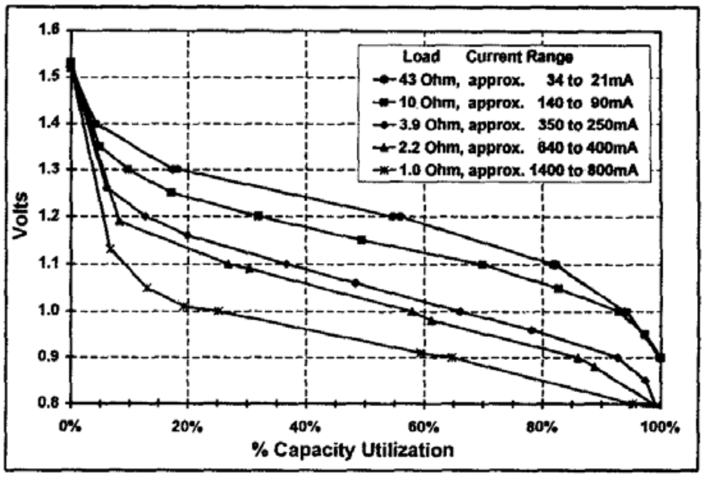
	RENEWAL	NiCd*	NiMH*
Nominal Capacity, mAh (varies with load)	1400 initial, 700 after 25 cycles	750	1100
Usable Cycles (varies with discharge level)	25+	200+	300+
Nominal Voltage Range (under load)	0.9 to 1.4	1.0 to 1.3	1.0 to 1.3
Weight	22g	22g	26g
Gravimetric Energy Density (watt-hr/kg)	80 (initial)	41	51
Volumetric Energy Density (watt-hr/liter)	220 (initial)	115	170
Continuous Output Current (max. recommended)	400 mA	>5A	>4A
Peak Output Current	1A	>10A	>10A
Fast Charge Time	2-3 Hrs	1 Hr	1 Hr
Self-Discharge Rate (room temperature)	0.01% per day	1% per day	4% per day
Typical OEM Cost Per Cell	$0.50	$1.25	$3
Typical Retail Replacement Cost (4-cell pack)	$5	$10-$30	$60+
Safely Disposable	Yes	No	???

RAM = Rechargeable Alkaline Manganese dioxide

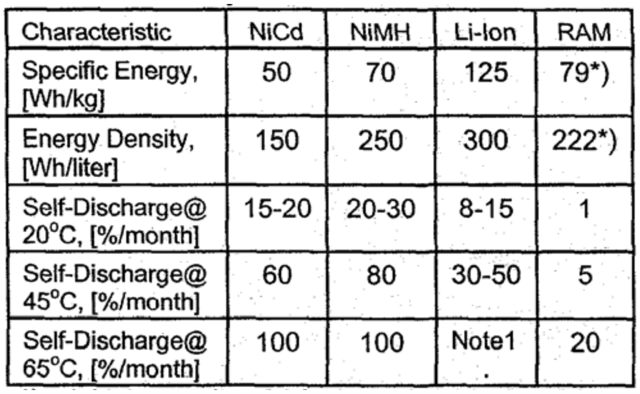




The above shows the Initial Capacity of RAM AA Cells as Function of Discharge Rate.



The above shows Deep Discharge Voltage Profiles for Various Test Loads of RAM Cells at Room Temperature.



Characteristic	NiCd	NiMH	Li-Ion	RAM
Specific Energy, [Wh/kg]	50	70	125	79*)
Energy Density, [Wh/liter]	150	250	300	222*)
Self-Discharge@ 20°C, [%/month]	15-20	20-30	8-15	1
Self-Discharge@ 45°C, [%/month]	60	80	30-50	5
Self-Discharge@ 65°C, [%/month]	100	100	Note1	20

The above shows the Self-Discharge Comparison in percentage of C for Various Battery Chemistries. Note that RAM batteries at room temperature self discharge at about 1/20 th the rate of NiCd and about 1/30 th the rate of NiMH.

See Pure Energy's OEM Designer's Guide and Technical Data for Rechargeable Alkaline Batteries http://www.pureenergybattery.com/press/oemguide2007.pdf

Li-Ion Batteries

The newest category of commercially available rechargeable batteries are the Li-Ion batteries. These batteries have all the advantages of Ni-Cad and NiMH batteries plus they have a longer useful life than either of these two types of rechargeable batteries. The main disadvantage to Li-Ion batteries is that they lose about 10% of their useable capacity each year due to chemical breakdown within the cells. There is nothing that can be done to prevent this condition.

Li-Ion batteries have a typical useful life of between 300-500 discharge cycles or about 4-5 years. You can maximize the useful life of your Li-Ion batteries by keeping them on the charger during use (e.g. laptop computer) or keeping them on the smart charger when not in use. Li-Ion batteries do not suffer from the memory effect.

These batteries also have some important disadvantages, however. They have a volatile chemistry. Each lithium ion pack in your laptop must have its own electronic protection circuit that protects against overcharging, over-discharging, and too-high current. Each cell of the battery pack incorporates a built-in safety vent. All three battery types have a safety vent, but unlike NiCad and NiMH batteries, which can withstand some overcharging, the vent in lithium-ion batteries is designed to disconnect the battery permanently if it ever has to be used. It does not reseal. The potential danger of this type is why Li-ion batteries come as a sealed unit including safety electronics.

6-Types of Batteries with notes when to use them

(11/2/2008)

In a survival situation Li-ion is a potential problem waiting to happen. The average person should stay away for using them unless one plans to still use the charger that was designed to charge it. One should not make or adapt another charger or use 12 volts directly for this purpose – too dangerous. These batteries degrade over time faster than other batteries.

Charging Lithium-Ion and Lithium-Polymer Cells

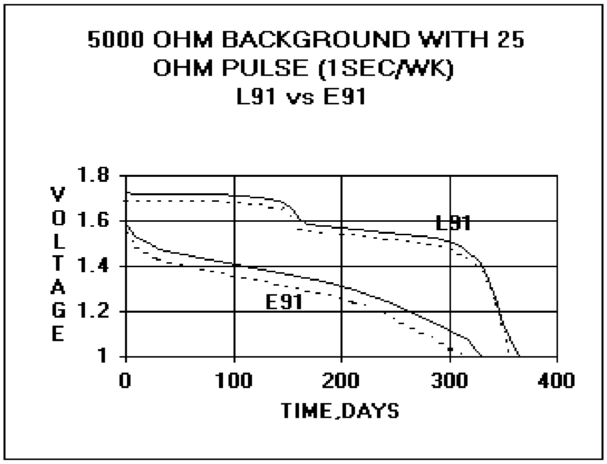
While chargers for nickel-based batteries are current-limiting devices, chargers for Li+ batteries limit both voltage and current. The initial Li+ cells called for a charge-voltage limit of 4.10V/cell. Higher voltage means greater capacity, and cell voltages as high as 4.2V have been achieved by adding chemical additives. Modern Li+ cells are typically charged to 4.20V with a tolerance of ±0.05V/cell. Full charge is attained after the terminal voltage reaches the voltage threshold and the charging current drops below 0.03C, which is approximately 3% of full charge. The time required for most chargers to achieve a full charge is about three hours, although some linear chargers claim to charge a Li+ battery in about one hour. Such chargers usually terminate the charge when the battery's terminal voltage reaches 4.2V. That method of charge determination, however, charges the battery only to 70% of its capacity.

Titanium batteries

Titaniums are batteries with a Titanium core. Titaniums are improved Alkalines and should not be compared with Lithiums. If you want something a bit better than Alkalines, you might buy those. Being new they are more expensive and right now are not worth the extra expense. They bring little to long term survival when compared to more common alkalines. For more information see:
http://www.energizer.com/products/e2.asp
http://www.energizer-e2.com/default.htm

Lithium (Li/MnO2) Non-rechargeable batteries

Lithiums can be used when you are not using rechargeable batteries and need reliable, constant discharge. Lithiums come with high cell voltage, high energy density, are lightweight, operate under a wide temperature range (-40° to 60°C / -40° to 140°F), have excellent storage life at the expense of high cost. For cost effective long term survival these are very low on the list. A few might be good for running a clock a long time.



The above shows a comparison between a Lithium v Alkaline Discharge.

Energy Density

When comparing between battery chemistries, one of the most relevant metrics is the Energy Density in watt-hrs/kg. This figure says how heavy a battery pack will have to be to achieve a certain range. See the table for a full comparison.

Battery specifications	Nickel-metal hydride	NiCD	Lead-Acid	Lithium-ion
Energy/weight	30–80 Wh/kg	40–60 Wh/kg	30-40 Wh/kg	160 Wh/kg
Energy/size	140–300 Wh/L	50–150 Wh/L	60-75 Wh/L	270 Wh/L
Power/weight	250–1000 W/kg	150W/kg	180 W/kg	1800 W/kg
Charge/discharge efficiency	66%	70%–90%	70%-92%	99.90%
Self-discharge rate	30%/month (temperature dependant)	10%/month	3%-20%/month	5%-10%/month
Cycle durability	500–1000	2000 cycles	500-800 cycles	1200 cycles
Nominal Cell Voltage	1.2 V	1.2 V	2.0 V	3.6 / 3.7 V

Battery	**Cost**	**Wh/kg**	**Joules/kg**	**Wh/liter**
Type	**$ per Wh**			
Lead-acid	$0.17	41	146,000	100
Alkaline long-life	$0.19	110	400,000	320

Carbon-zinc	$0.31	36	130,000	92
NiMH	$0.99	95	340,000	300
NiCad	$1.50	39	140,000	140
Lithium-ion	$4.27	128	460,000	230

Comparison of Popular Portable Rechargeable Battery Systems

ALL DATA BASED ON CYLINDRICAL CELLS	**XL RECHARGEABLE ALKALINE**	**Nickel-Cadmium**	**Nickel-Metal Hydride**	**Lithium-Ion**
Initial Typical Capacity - AA (varies with load & endvoltage)	Up to 2000 mAh *	800 mAh	2000 mAh	700 mAh
Initial Typical Capacity - AAA (varies with load & endvoltage)	Up to 800 mAh *	350 mAh	750 mAh	n/a
Typical cell voltage under load	0.8 to 1.4 V	1.0 to 1.3 V	1.0 to 1.3 V	2.75 to 4.10 V
Weight – (AA / AAA)	22 g / 11 g	22 g / 11 g	30 g / 15 g	18 g
Gravimetric Energy Density	88 Wh/kg ** (initial)	42 Wh/kg	80 Wh/kg	136 Wh/kg
Volumetric Energy Density	251 Wh/l ** (initial)	120 Wh/l	300 Wh/l	325 Wh/l
Deep Discharge Cycles (varies with mAh required)	> 50 cycles	> 200 cycles	> 300 cycles	> 500 cycles
Shallow Discharge Cycles (varies with depth of discharge)	> 200 cycles	> 200 cycles	> 300 cycles	> 500 cycles
Maximum Continuous Current recommended	0.5 A	> 5 A	> 4 A	> 1 A
Maximum Pulse Current recommended	1.5 A	> 10 A	> 10 A	> 2A
Charging time with pulse charging (depends on depth of discharge & age of cell)	2 - 6 h	1 – 2 h	1 – 2 h	1 – 3 h
Self-discharge at 20°C (est. from Arrhenius Plot)	<0.25% per month	20% per month	25% per month	10% per month
Self-discharge at 30°C (est. from Arrhenius Plot)	<0.5% per month	30% per month	50% per month	30% per month
Self-discharge at 45°C (est. from Arrhenius Plot)	<1% per month	60% per month	80% per month	70% per month
Self-discharge at 65°C (est. from Arrhenius Plot)	<5% per month	100% per month	100% per month	100% per month

Safety considerations IEC stands for International Electrotech. Commission	Passes IEC safety tests for Primary Batteries	Passes IEC safety tests	Passes IEC safety tests	Passes IEC safety tests, but incidents of fire have been reportedin the past
Usual disposal (depends on local regulations)	Domestic waste	Recycle	Recycle	Domestic Waste
Relative OEM cost per cell	1	Approx. 1.5	Approx. 2.5	Approx. 5
* As described above the deep discharge capacity of RECHARGEABLE ALKALINE cells decreases as cycling continues. ** Average over drain rate range from 30 to 500mA				

Battery Capacity

Type	Capacity (mAh)	Density (Wh/kg)
Alkaline AA	2850	124
Rechargeable	1600	80
NiCd AA	750	41
NiMH AA	1100	51
Lithium ion	1200	100
Lead acid	2000	30

Reference Links For More Information

http://en.wikipedia.org/wiki/Nickel_metal-hydride
http://en.wikipedia.org/wiki/Lithium_ion_battery
http://ebikes.ca/batteries.shtml
http://www.geocities.com/dsaproject/electronics/data_book/battery.html
http://www.alpharubicon.com/altenergy/batteryfred.htm
http://www.angelfire.com/electronic/hayles/charge1.html
http://www.maxim-ic.com/appnotes.cfm/an_pk/3501
http://ibet.asttbc.org/batterys.htm
http://www.rc-soar.com/articles/batterypack/index.htm
http://www.candlepowerforums.com/vb/archive/index.php/t-168903.html
http://reviews.ebay.com/Rechargeable-Battery-Care-and-Maintenance-Guide_W0QQugidZ10000000001229809?ssPageName=BUYGD:CAT:-1:SEARCH:1
http://www.all-battery.com/
http://mistlab.csail.mit.edu/fun/battery.ppt

7-Low Self Discharge NiMh Cells

(11/3/2008)

The **low self-discharge NiMH battery** (**LSD NiMH**) was introduced in November 2005. Self-discharge is reduced thus shelf life is longer compared to normal NiMH batteries. By using a new separator, manufacturers claim the batteries retain 70 to 85% of their capacity after one year when stored at 20 °C (68 °F). These cells are marketed as "ready-to-use" or "pre-charged".

Due to the low self-discharge, they are also suitable for long-term intermittent or low-current uses; they might last up to a year between charges, much better than ordinary NiMH batteries. They can therefore also be used for electrical clocks, remote controls, radios, lanterns, and task lighting.

Aside from their longer shelf life, and moderately higher prices, they are otherwise similar to normal NiMH batteries of equivalent capacity and can be charged with normal NiMH chargers.

It is generally claimed that low self-discharge NiMH batteries retain 90% of their charge after six months, 85% after a year and 70% after two years, when stored at 20 °C (68 °F).

Low self-discharge NiMH batteries are marketed with over twenty different brand names, but only actually manufactured by five companies: Sanyo, Gold Peak, Yuasa, Vapex and Uniross.

Sorted by brand name and product name:

- AccuPower *AccuLoop*
- AgfaPhoto *direct energy*
- Alcava All in One
- Ansmann *maxE*
- Conrad Electronic *Endurance*
- Duracell *ActiveCharge*
- Duracell Pre-charged
- Gold Peak ReCyko
- Hähnel *Synergy*
- Kodak Pre Charged
- Maha Powerex Imedion
- Nexcell *EnergyON*
- Panasonic *INFINIUM*
- Panasonic R2
- Powertech Enekeep
- Radio Shack Precharged
- Rayovac Hybrid
- Sanyo Eneloop
- SBS BiReady
- SKB *ready2use*
- Sony CycleEnergy (manufactured by Sanyo)
- Sunmol *AnyEnow*

- SWISSBATTERIES accubattery
- Titanium *Enduro*
- Uniross *Hybrio*
- VARTA Consumer Batteries *Ready2Use*
- Vapextech Instant

Sanyo's Eneloop batteries are one brand of low self-discharge NiMH battery, rated at capacities of 800 mAh for AAA, 2000 mAh for AA, 3000 mAh for C, and 5700 mAh for D batteries (C and D sizes announced August 2008).

A Sanyo official has stated:

- "The Eneloop batteries are sold charged, but not necessarily 100% fully charged. In Europe about 75%." They are rated to withstand about 1,000 discharge/recharge cycles.
- "Several long term tests have shown that the self-discharge rate decreases over time. This means that Eneloop batteries discharge relatively fast at the beginning and relatively slower the longer you store them."
- "Higher temperatures substantially increase self-discharging. It is best to store Eneloops as cool as possible to keep the charge in the battery. As a rule-of-thumb, every 10 °C increase in storage temperature is equivalent to doubling the discharge rate."
- "The chemical decomposition of the cathode has been reduced substantially by the use of a new super lattice alloy."

For more info see http://en.wikipedia.org/wiki/Low_self-discharge_NiMH_battery

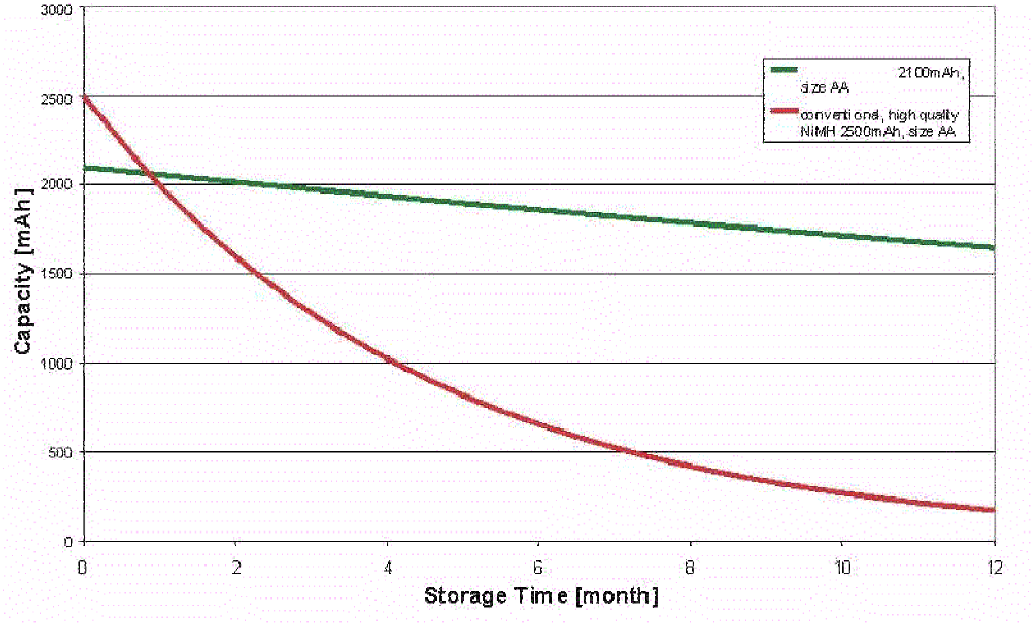
The new low-self discharge NiMH can be used to replace these older types of non-rechargeable. Given a bit of time and all sizes will be available. In the mean time some stock of 9 Volt alkaline for digital volt meters may be needed. Try to get away from devices that use C and D size. For efficiency use AA rechargeables or hook the device to 12 volt primary battery.

The slightly lower storing capacity of the low self-discharge type batteries quickly outpaces the standard NiMH batteries. See the curve below. Capacity remaining after 6 month is 80-85% after one year 70-75%.

If you plan to discharge your NiMH cells within 3 weeks then use standard cells they have slightly more capacity. If you plan to discharge working cells in more than 3 weeks then use the low self-discharge type.

7-Low Self Discharge NiMh Cells

(11/3/2008)



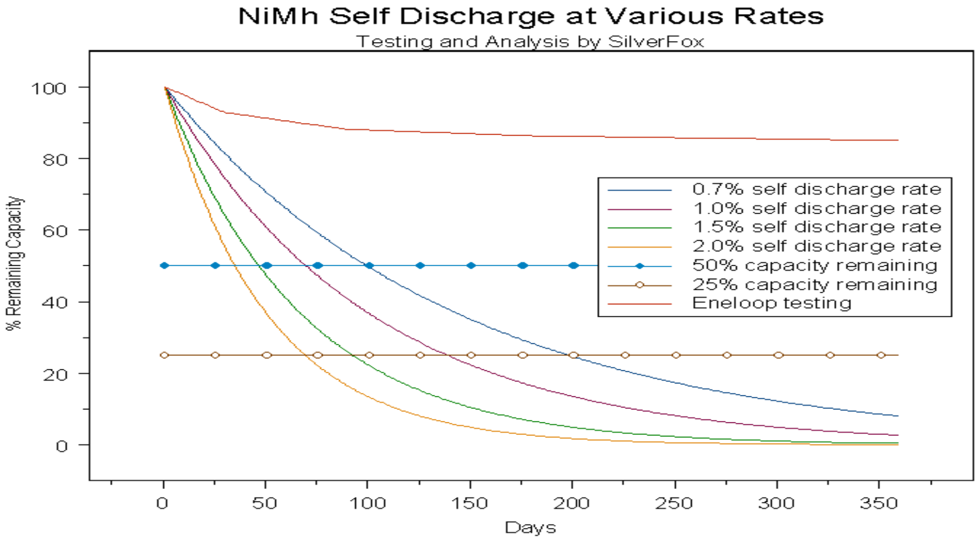
Typically, the highest capacity NiCd batteries hold half or less than half the capacity of best NiMH batteries. However this does not automatically mean that NiCd batteries are not as good. When factoring cost, the type of use, and sometimes temperature, NiCd can be the better choice if the new Low Self Discharge batteries are not available. At the time of this writing, LSD batteries are only available in limited sizes.

A lot of published information has common standard NiMh cells in the 1-2% per day self discharge range. Most good cells are around 0.7% per day with several brands of cells, based on short term tests of around 30 days. The problem type cells will completely self discharge in around 10 days.

Here is a measured graph of NiMh self discharge rates comparing original cell chemistry to the Eneloop cell chemistry.

7-Low Self Discharge NiMh Cells

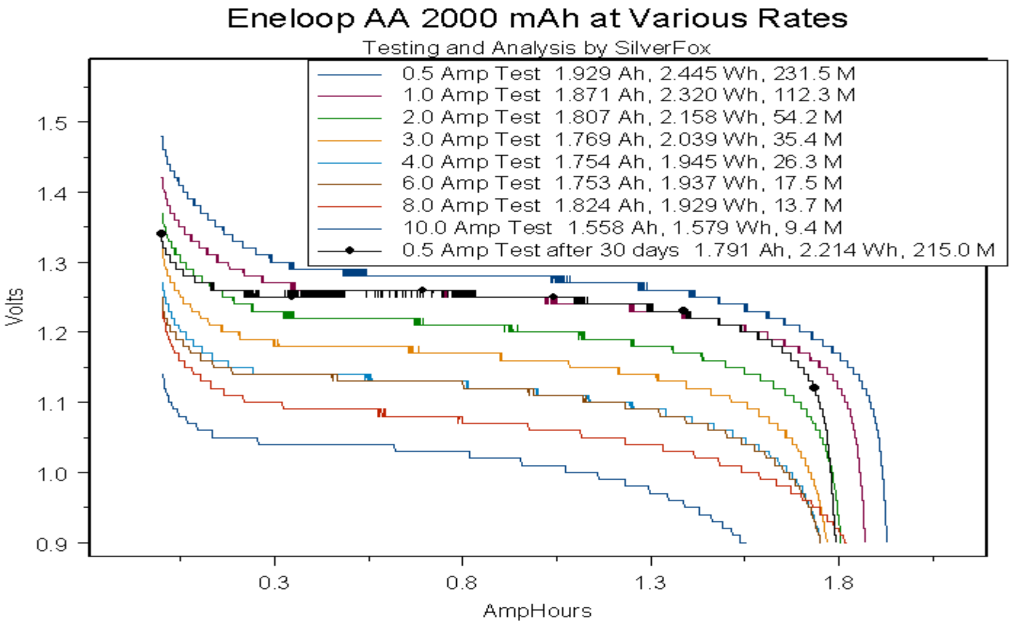
(11/3/2008)



You can see that the biggest drop in state of charge of 50% comes in the first 30 to 100 days. After that one will end up with 25% charge in 70 to 200 days. Eneloop slow self discharge ends up to be about 86% of full charge after 6 months.

In non-emergency times, use of these cells, removes the trying to remember when specific cells were last charged. If you just assume you have around 1.7Ah or so to play with regardless of when they were charged, you'll be in the ball park for your calculated runtimes.

During long term primitive situations these cells become worth there weight many times over when charging any kind of cell becomes a problem.



The above is measured voltage discharge results from a battery user group.

My measurements show that the Eneloop cell will loose only about 3% of the mAh when closely comparing how many mAh it takes to charge and discharge in an ideal situation. I used the WattsUp unit to measure this. I also noticed that the mAh capacity peaked out after 6 cycles and started to decline after that. The maximum was 1853 mAh for a 2000 mAh marked cell. This is 92.6% of the advertised value. A little better than most manufactures will do. The cell started at about 1584 mAh.

8-Battery Sizes, Types, and History

(11/2/2008)

To start with technically, a “cell” is defined as a single vessel containing electrodes and electrolyte for generating current. A “battery” consists of two or more cells. Most people, including battery manufacturers, today treat the two terms as interchangeable.

Batteries come in sizes, voltages and types. There are rechargeable batteries, disposable batteries and disposable batteries that can be recharged. First we'll look at the sizes of the more common batteries. Generally we have

- Button cells of various types
- N cells
- AAAA cells
- AAA cells
- AA cells
- C cells
- D cells
- 9 volt electronic
- 12 volt lighter
- 6 volt lantern
- 12 volt lantern
- 3 volt lithium
- Lithium ion
- Gel cells of various types
- Lead acid batteries of various types

For this article we are not going to discuss the button cells, gel cells or lead acid batteries. You may still be amazed at just how complicated this will get.

All the batteries listed with letter sizes (AA, C, D, etc) come in either 1.5 volts for disposables or 1.2 volts for rechargeables. Generally speaking the two can be used interchangeably. Products intended to run on batteries are designed to function across a range of voltages. What is most important is the ability to deliver current over time and rechargeables have a great advantage.

The most common Battery Sizes

From left to right D...C...AA...AAA...9 volt

8-Battery Sizes, Types, and History

(11/2/2008)

The most commonly used general purpose batteries are identified by a letter designation: N, AAAA, AAA, AA, C and D,

N cells look like a half length AA cell and give 1.5 volts. There is a similar sized 12 volt battery (Duracell calls it an MN21) that is used in alarm remotes and cigarette lighters. It is a stack of 18 tiny coin sized cells and is often mistaken for an N.

AAAA cells are the smallest of the cylindrical batteries. They are as long as an AAA but slimmer. Six of them are ganged together in a 9 volt battery. Some of the smaller consumer personal electronics are starting to use them.

AAA and AA cells are the most commonly used sizes today. Modern consumer electronics demand a combination of smaller size than the larger D and C and higher current than the 9 volt battery can supply. Higher voltage isn't as necessary to drive modern electronics. They are beginning to control more of the flashlight market as extremely bright LED flashlights become more common.

C cells and D cells are slowly falling out of favor. Their primary use is in larger flashlights and portable "boom boxes".

There is also a "sub-C cell" most commonly found ganged together in rechargeable tool batteries and shavers. You won't find these in most retail shops, they are used by manufacturers.

And as mentioned above there are 9 volt rectangular, which are really 6 batteries ganged together in series and 6 and 12 volt lantern batteries which are sub-Cs ganged together in different combinations. They have been around a very long time. The lantern batteries have experienced resurgence due to their use in fluorescent lanterns. The 9 volt batteries are mainly used in digital meter, smoke detectors, some radios, some radio control equipment and assorted other gadgets. They are also great fun to touch to your tongue.

Other batteries such as tool batteries are typically sub-C cells ganged together in series as this illustration shows:

Rechargeable power tool battery

A rechargeable AA is shown next to it for a size comparison.

8-Battery Sizes, Types, and History

(11/2/2008)

You'll notice that all tool batteries are in multiples of 1.2 volts, the voltage for a standard size rechargeable battery. You can fix rechargeable tools when it dies by building your own NIMH or NiCD equivalent battery pack that will fit or not fit the existing case.

Shavers and such often don't have consumer friendly replaceable batteries so when the battery dies for good. Fix it yourself. You won't find sub-Cs and solder tabbed batteries and odd sized at most retail outlets. See write up on “Making Soldered Battery Packs” to make a replacement battery pack.

FRS radios uses 3 rechargeable N cells ganged in series. Here's a AA and an N cell for a size comparison.

3 N cell battery pack

Other types of radio use 4 AAA disposable batteries instead. One could just substitute rechargeables for the disposables with no loss in performance AND longer battery life. Even though the initial voltage is lower, it's the current capacity and overall average working voltage (both are 1.2volts) that counts.

3 volt lithium cells were the first lithium batteries on the consumer market. They are referred to as a CR123 size (a little smaller in size than a C cell) and pack 3 volts. Some cameras and night vision scopes use them.

If you find you need a battery and you don't have the correct size, any other battery of the similar voltage can be used instead. There are a number of folks who make shells to convert AAA into AA and AA into D and C cells. Green Batteries is one.

The most common use is for people who only have an AA sized charger and still want to power their D and C cell devices. They'll work just fine as long as you understand they have less electrical capacity than the original. If all you had were a handful of AAA cells you could indeed power your 7 D cell Maglite using these adaptors. It would only last about 1/10 as long, but it would initially still shine as bright.

In a survival situation one needs to standardize of a minimum number of sizes and make replacement batteries based on these cells. For the most part AA, AAA and 9 volt are good sizes to standardize on.

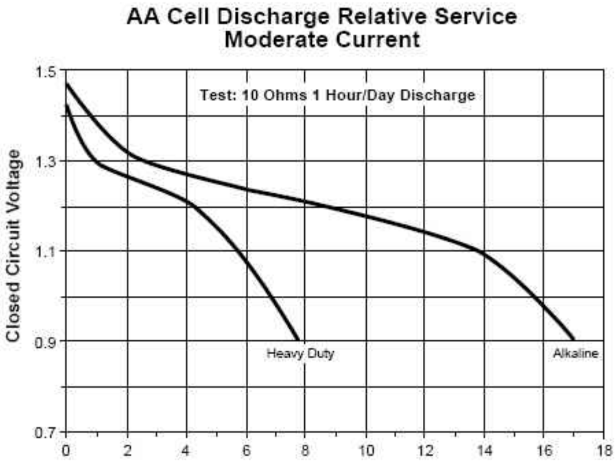
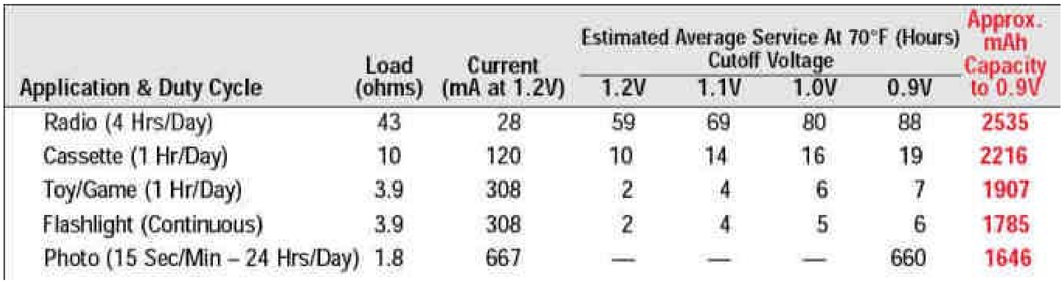


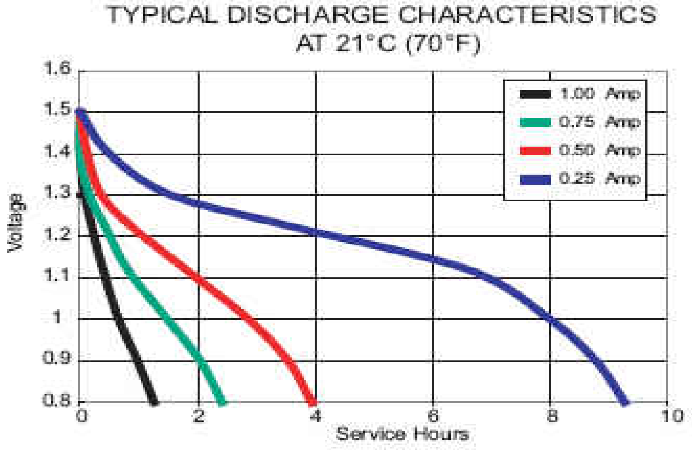
Figure 1
Service Life - Hours

Here's another chart giving typical AA alkaline lifetimes with typical loads. (The flashlight uses a PR-2 bulb.) See how the amount of current capacity varies wildly depending on the load.



Application & Duty Cycle	Load (ohms)	Current (mA at 1.2V)	Estimated Average Service At 70°F (Hours) Cutoff Voltage 1.2V	1.1V	1.0V	0.9V	Approx. mAh Capacity to 0.9V
Radio (4 Hrs/Day)	43	28	59	69	80	88	2535
Cassette (1 Hr/Day)	10	120	10	14	16	19	2216
Toy/Game (1 Hr/Day)	3.9	308	2	4	6	7	1907
Flashlight (Continuous)	3.9	308	2	4	5	6	1785
Photo (15 Sec/Min – 24 Hrs/Day)	1.8	667	—	—	—	660	1646

And here's duty life curve for Duracell CopperTop alkalines. This curve is in terms of load *current* instead of load *resistance* but it you remember **E-IxR** you can figure out what the load resistances must be:



Duracell Coppertop alkaline

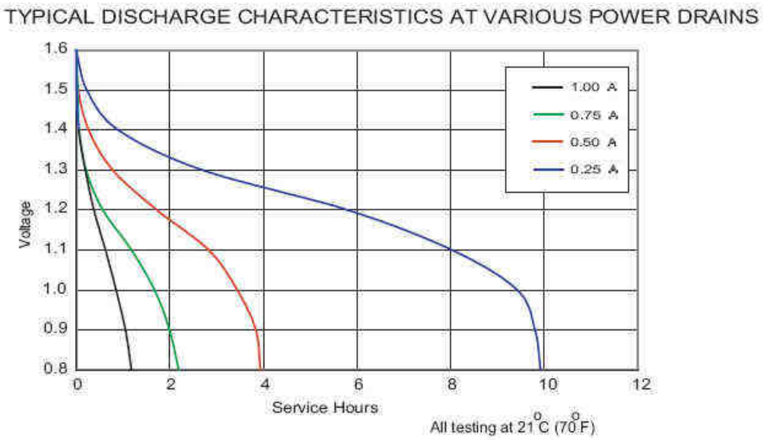
8-Battery Sizes, Types, and History

(11/2/2008)

The "BatteryXtender" works to recharge regular alkaline batteries for a few charges (5 to 10). Self discharge rate increases and some will develop leakage when recharged this way.

There are also alkaline rechargeable (RAM) cells that are designed to be rechargeable in special chargers. They have the advantage of holding a charge for many years but do not have the high current capacity of their non-rechargeable brethren. They work well for long term storage.

"Premium" Alkaline - Manganese Dioxide batteries are much hyped. Examples are Eveready's "e2 Titanium" and Duracell's "Ultra Digital". The manufacturers have added something proprietary (possibly titanium) that reduces the internal resistance slightly allowing for a little more current. These curves are for the Duracell "Ultra" AA alkaline battery:



All testing at 21°C (70°F)

Typical alkaline battery sizes and capacities (at lowest discharge rates)

Size	Capacity (mAh)	Voltage	ANSI/NEDA	IEC	Diam. (mm)	Mass (g)	Height (mm)	Length (mm)	Width (mm)
AAAA	625	1.5	25A	LR8D425	8.3	6.5	42.5	cylindrical	cylindrical
N	1000	1.5	910A	LR1	12	9	30.2	cylindrical	cylindrical
AAA	1250	1.5	24A	LR03	10.5	11.5	44.5	cylindrical	cylindrical
AA	2850	1.5	15A	LR6	14.5	23	50.5	cylindrical	cylindrical
J	625	6	1412A	4LR61	prismatic	30	48.5	35.6	9.18
9V	625	9	1604A	6LR61	prismatic	45.6	48.5	26.5	17.5
C	8350	1.5	14A	LR14	26.2	66.2	50	cylindrical	cylindrical
D	20500	1.5	13A	LR20	34.2	148	61.5	cylindrical	cylindrical
Lantern	26000	6	915A	4R25Y	prismatic	885	112	68.2	68.2
Lantern	26000	6	908A	4LR25X	prismatic	885	115	68.2	68.2
Lantern	52000	6	918A	4LR25-2	prismatic	1900	127	136.5	73

Types of new batteries

Nickel Oxyhydroxide is the newest kid on the block. Examples are Duracell's *PowerPix* and Panasonic's *Oxyride*. Provides significantly more current than alkalines. They were designed for people with digital cameras in mind who didn't want to spend the bucks for lithium.

Lithium - Iron Disulphide - These are the most common consumer lithium batteries. They come in all the standard sizes. They last vastly longer than any current disposable in high current applications but have no advantage over alkaline in low current applications. They also have a big advantage in shelf life - 10 years and hold their charge longer and so are good for devices you tend to forget about like smoke and carbon monoxide detectors.

Lithium ion cells got off to a weak start, as there were many failures in the first batteries shipped. However, the addition of the internal protection circuitry inside the battery (and increased knowledge about the failure modes) has improved this. They are used to power cell phones and laptop computers and always come in custom configurations. They have very high energy density, meaning the most amp-hours packed into a given weight. They also have a tendency to overheat or even catch on fire if they are shocked or used in such a way they cannot get adequate cooling.

Nickel Cadmium (NiCd) are the older style of rechargeable batteries declining in use because the cadmium is considered toxic waste when the battery finally fails. They also typically have half the current capacity of NiMH batteries of the same size. However for a few uses their ability to deliver a LOT of amps VERY quickly is useful. They are more rugged than NiMH, take more recharges and will last longer on the shelf, important for survival planning. Disadvantage is the development of "memory" through the formation of internal crystals which prevents the battery from accepting a full charge if not periodically discharged completely.

Nickel Metal Hydride (NiMH) is the new kid on the block and beating all rechargeable comers in energy density and current capacity, except for lithium ion. NiCd and NiMH cells are rated at 1.2V for design purposes although they normally develop about 1.25V. Under full charge they require about 1.5V to 1.6V. They can supply very large amounts of current and display a remarkably flat discharge characteristic, maintaining a consistent 1.2V throughout discharge. The voltage then drops quite suddenly, and they are almost completely flat at 0.8V. This is called the "knee" characteristic because of the shape of the graph of voltage against time. NiMH do not develop memory problems as NiCds do.

Current Capacity

The current capacity of a battery is measured in milli-Amp-hours or mAh. A thousand mAh battery will supply 1000 mA (or 1 Amp) for one hour before it goes dead - theoretically. In reality different types of batteries have different discharge curves.

Notice that if you drain the power at a 1 Amp rate, you get a little over 1 hour before the thing becomes useless. (Duracell has decided this happens at .8 V but will vary by application.) That's a little over 1 Amp-hr. of capacity. But if you discharge at a 1/4 Amp rate you get almost 10 hours of useful service life. That's almost 2.5 times more capacity.

Important fact: Batteries will produce more total energy running a low demand device for a long time than a high demand device for a short time.

Another related fact: Due to their chemistry, batteries have the ability to self-recharge somewhat after every usage if allowed to rest. (Short spurts of high current usage with breaks in between average out to the same thing as a low current over the same total time.) The fewer rest periods, the less you'll recharge action you'll get. If you run them down to nothing, you lose that self recharge ability almost completely.

Important fact: Batteries of all types are best stored between 32°F to 50°F. Higher and lower storage temperatures will shorten battery life. They should always be allowed to come to room temperature before use as the chemical reactions take place best in that general range. Very high (over 150°F) temps can cause them to explode. If you wish to store batteries over several years you should tightly (not vacuum) seal them. Batteries breath, and exposed to low humidity for long periods of time will dry the contents out. On the other hand extended exposure to high humidity can cause rust and/or leakage.

Important fact: All batteries can leak, especially true for off brands. They are not sealed hermetically, they need to breath and can even dry out in very low humidity. Manufacturing shortcuts, high humidity, high heat, shock and old age are the primary factors. It is important NOT to leave batteries in any unused device over time or the device may be damaged/destroyed if the battery leaks.

Rechargeable Batteries

Rechargeable batteries come in two flavors, Nickel Metal Hydride (NiMH) and Nickel Cadmium (NiCd). NiMH has a higher current capacity per unit volume, accepts more recharge cycles before dying and are classified as toxic waste. The Cadmium in NiCds is poisonous, much more so than lead. The primary uses of NiCds today is in battery packs and often have no informational labels at all. Many have solder tabs. Here is a picture of a NiCd C cell and a sub-C cell:

Rechargeable sub-C with solder tabs

Rechargeable batteries are easier to deal with when they have their capacity printed on the label, as batteries intended for consumers usually do.

You'll notice that we have 2 batteries, both the same type (NiMH) same size (AA) and if you read the label, different capacities, 2500 mAh for the Eveready vrs. 2000 mAh for the Radio Shack. Not all batteries are created equal. There is no standardization in construction as there is with zinc and alkaline batteries. Manufacturers have to put the current capacity on the labels of consumer batteries. Since they are rechargeable, manufacturers count on you're not reading the label AND not noticing the shorter time between recharges. Depending on the manufacturer, AA batteries can range in capacity from 1800 to 2900 mAh. (I find the lower the capacity, the smaller the type face they use.) It gets even worse when dealing with larger sizes.

The range for D cells is from 2500 mAh to **11,000** mAh. How can this be? Most consumer oriented rechargeable batteries larger than AA are just AA or sub-C cells packaged in a larger container. Do they charge the same price? Heavens no! The manufacturers count on you to not doing comparison shopping. They have a rationale for this. Often people never really run down their rechargeable batteries, but rather they self discharge over time. This is the curse of rechargeables, a very limited shelf life between charges. After 28 days they may have lost anywhere from 10 to 70% of their fully charged capacity depending on the quality of manufacture.

A second problem is that some manufacturers have better quality control than others. Consequently some won't deliver the capacity listed. You can try testing yourself or rely on third party testing.

Should you buy the highest capacity battery? You're best economy will come from dividing the cost of a battery by it's current capacity to come up with a cost per amp-hour. An 10,000 mAh battery is not a bargain if it costs 10 times as much as a 2,500 mAh battery.

Charging Rechargeables

When you buy a rechargeable battery, it should be fully charged and discharged a couple of times before being put to “must rely on it” uses. Rechargeables slowly gain efficiency over time and may not reach their peak capacity until have been cycled hundreds of times. Only five cycles are needed to bring one up to written specs.

Do not leave your NiMH or NiCd batteries in the charger. (This runs counter to how they are actually used in the real world. When not in use, most rechargeable devices live on their chargers.) The charger keeps them hot and that is not good for them. It also wastes energy that you will not have in a survival situation. It better now get in the habit of leaving them out and cycle them though the charger just before use.

NiCd chargers can cause NIMH batteries to explode. NiMH chargers are safe for NiCds however. NiCds can be trickle charged while NiMHs like a fast charge. Also keep them out of the sun and hot cars. Do not try and charge Alkaline batteries in a normal charger, they will leak for sure.

Okay So Which Batteries To buy?

- NiMH is better in energy density and will supply current for longer. NiMH chargers will handle either NiMH or NiCd. Rechargeable battery of choice for two way radios, and task lights. The low Self-Discharge Type being the best.
- Rechargeable alkalines can keep their charge for 10 years and have the longest shelf life of any rechargeable battery, something to think about in survival planning. They are also cheap. Otherwise they are not as efficient as regular NiCds, or NiMH and cannot be recharged as many times.
- NiCds are still useful, especially when charging an electronic power tool. They last much longer in long term storage and may be recharged many more times than NiMH. You still see a lot of them around. Beware that NiCd chargers can overcharge and damage NiMH.
- Test various types of batteries in your device to see how long they last. This way you will have experience with which battery lasts the longest and which is most cost effective in YOUR application.

Battery History

1800 Voltaic pile: silver zinc
1836 Daniell cell: copper zinc
1859 Planté: rechargeable lead-acid cell
1868 Leclanché: carbon zinc wet cell
1888 Gassner: carbon zinc dry cell
1898 Commercial flashlight, D cell
1899 Junger: nickel cadmium cell
1946 Neumann: sealed NiCd
1960s Alkaline, rechargeable NiCd
1970s Lithium, sealed lead acid
1990 Nickel metal hydride (NiMH)
1991 Lithium ion
1992 Rechargeable alkaline (RAM)

1999 Lithium ion polymer
2005 Low Self-Discharge (NiMH)

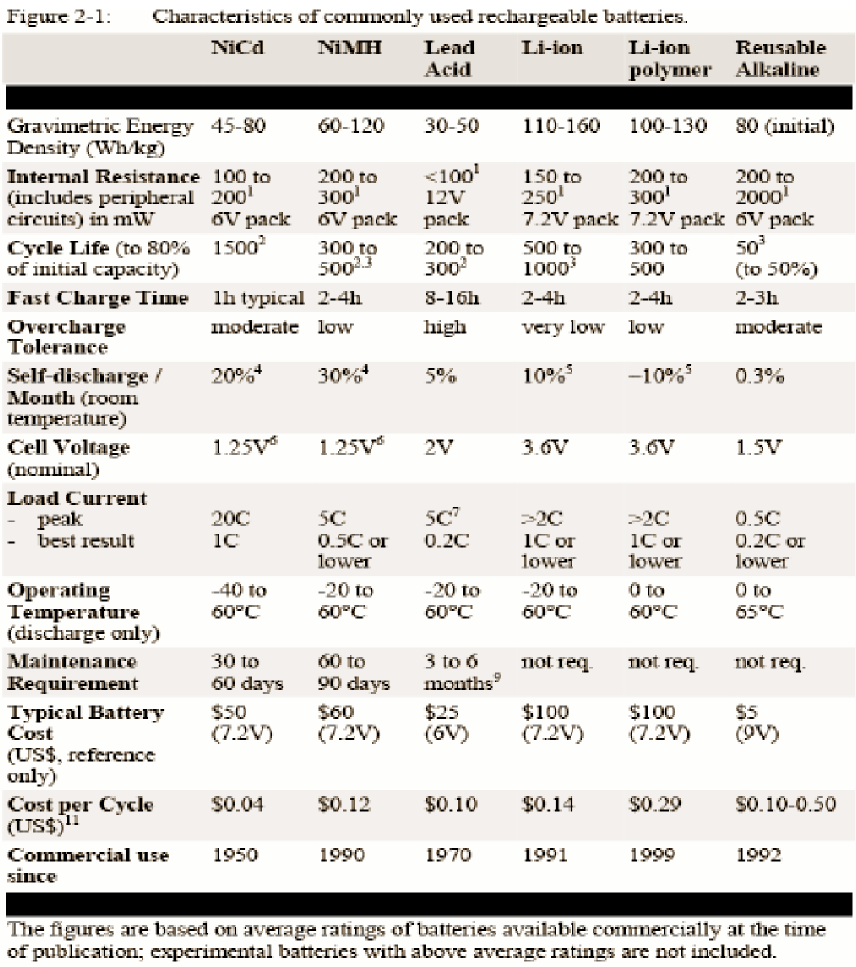
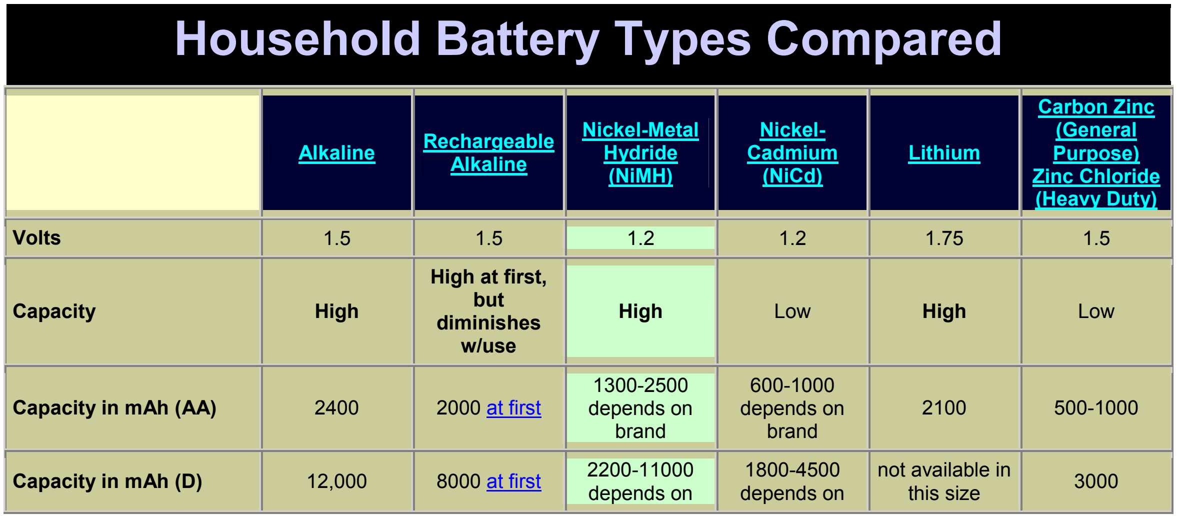


Figure 2-1: Characteristics of commonly used rechargeable batteries.

	NiCd	NiMH	Lead Acid	Li-ion	Li-ion polymer	Reusable Alkaline
Gravimetric Energy Density (Wh/kg)	45-80	60-120	30-50	110-160	100-130	80 (initial)
Internal Resistance (includes peripheral circuits) in mW	100 to 200[1] 6V pack	200 to 300[1] 6V pack	<100[1] 12V pack	150 to 250[1] 7.2V pack	200 to 300[1] 7.2V pack	200 to 2000[1] 6V pack
Cycle Life (to 80% of initial capacity)	1500[2]	300 to 500[2,3]	200 to 300[2]	500 to 1000[3]	300 to 500	50[3] (to 50%)
Fast Charge Time	1h typical	2-4h	8-16h	2-4h	2-4h	2-3h
Overcharge Tolerance	moderate	low	high	very low	low	moderate
Self-discharge / Month (room temperature)	20%[4]	30%[4]	5%	10%[5]	~10%[5]	0.3%
Cell Voltage (nominal)	1.25V[6]	1.25V[6]	2V	3.6V	3.6V	1.5V
Load Current						
- peak	20C	5C	5C[7]	>2C	>2C	0.5C
- best result	1C	0.5C or lower	0.2C	1C or lower	1C or lower	0.2C or lower
Operating Temperature (discharge only)	-40 to 60°C	-20 to 60°C	-20 to 60°C	-20 to 60°C	0 to 60°C	0 to 65°C
Maintenance Requirement	30 to 60 days	60 to 90 days	3 to 6 months[9]	not req.	not req.	not req.
Typical Battery Cost (US$, reference only)	$50 (7.2V)	$60 (7.2V)	$25 (6V)	$100 (7.2V)	$100 (7.2V)	$5 (9V)
Cost per Cycle (US$)[11]	$0.04	$0.12	$0.10	$0.14	$0.29	$0.10-0.50
Commercial use since	1950	1990	1970	1991	1999	1992

The figures are based on average ratings of batteries available commercially at the time of publication; experimental batteries with above average ratings are not included.



Household Battery Types Compared

	Alkaline	Rechargeable Alkaline	Nickel-Metal Hydride (NiMH)	Nickel-Cadmium (NiCd)	Lithium	Carbon Zinc (General Purpose) Zinc Chloride (Heavy Duty)
Volts	1.5	1.5	1.2	1.2	1.75	1.5
Capacity	**High**	**High at first, but diminishes w/use**	**High**	Low	**High**	Low
Capacity in mAh (AA)	2400	2000 at first	1300-2500 depends on brand	600-1000 depends on brand	2100	500-1000
Capacity in mAh (D)	12,000	8000 at first	2200-11000 depends on	1800-4500 depends on	not available in this size	3000

			brand	brand		
Performance in hi-drain devices (e.g., digital cameras)	Standard: Poor Special: Good	Poor	**Good**	**Good**	**Good**	Poor
Rechargeable?	Not really	**Sort of***	**Yes** (but see note about C & D sizes)	**Yes** (but see note about C & D sizes)	No	No
Recharge cycles	??? I'm guessing <10	50-500 Accucell	100's of times	100's to 1000's of times	N/A	??? I'm guessing <10
Special Disposal Needs	**No**	**No**	**No**	Yes	Yes	**No**
Self-discharge rate	**Slow / up to 5 yrs. shelf**	**Slow**	Fast (30%/mo.)	Fast (10% in 1st 24hrs, then 10%/mo.)	**Very slow**	**Slow**
Memory effect	No	No	Sometimes	Sometimes	N/A	No

Here are some links dealing with batteries;

- Battery University
- AA ALKALINE BATTERY LIFE IN VICTORIA RADIO CONTROL APPLICATIONS
- PowerStream Battery Chemistry FAQ
- Rechargeable Battery Review
- Consumer Reports - AA batteries
- Wikipedia on Batteries
- Eveready e^2 batteries
- http://www.alpharubicon.com/altenergy/batteryfred.htm

9-Battery Basic Formulas and Chemistry

(11/2/2008)

Basic Battery Formulas and Terms

When looking at batteries there are a few terms you need to know. All units are derived from the names of famous electrical scientists of the past.

- Load - this is what the electricity is being forced through. The resistance of the load is in Ohms. The power dissipated by the load is in Watts. The amount of work done in powering the load (or energy expended) is in watt-hours.
- Ohm - a unit of electrical resistance. Think in term of plumbing, where a wider pipe offers lower resistance to flow (fewer Ohms).
- Coulomb - a whole lot (624,150,962,915,265,000) of electrons. In plumbing you could think of it as a gallon of water
- Amp (A)- (Technically it is an "Ampere", but the guys name gets shortened in American usage) A unit of electrical current. Think of it as how much water is flowing in gallons per second, only instead it's electrons in Coulombs per second
- Amp-hour (Ah) - Current flowing by at the rate of one Amp for one hour. (3600 Coulombs) A 2500 mAh battery theoretically could push 2500 mA for 1 hour before dying.
- milli (m) - A prefix that means 1/1000. A milli-amp is a thousandth of an amp.
- Volt - A unit of electromotive force. It's how hard the electrons get pushed/pulled through the circuit by the battery or generator. In plumbing you could think of it as water pressure.
- Watt (W) - A unit of power or the *rate* at which energy is expended. One horsepower is roughly equal to 746 Watts.
- Watt-hour (W-h) The actual amount of work that is done or energy expended. The amount of power in Watts multiplied the time is has been applied in hours. This is what the spinning dial on your power meter is measuring. The *rate* at which the dial turns is the amount of power being used while the *number of times it has spun* is how much energy you've used.

Assuming all batteries are identical for simplicity, when batteries are line up nose to tail - positive terminal to negative terminal - and the voltage is taken from the top positive terminal and rear negative terminal they are said to be in series. In this case the final voltage is the sum of all the voltages of the individual batteries but the current capacity is only equal to one battery. If they are beside each other and all the positive ends are joined together and negative ends are joined together they are said to be in parallel. In this case the current capacities are added together while the voltage is equal to that of one battery.

A Brief Study of Ohm's Law

Where P is the power dissipated in Watts, E is the applied voltage in Volts, I is the current produced in Amps and R is the load resistance in Ohms:

- P=IxE - Power equals the current in Amps times the voltage in Volts
- E=IxR - the Voltage is equal to the current produced in Amps times the resistance of the load in Ohms. also witten I=E/R and R=E/I
- P=IxIxR - Substitute the V in the first equation with IxR gives you the power as a function of current and resistance.

Let's say that the voltage is 1.5 Volts and the circuit is 10 Ohms. The equation E=IxR can be rearranged to show I=E/R. How much current is flowing? I=1.5/10, so I is .15 amp in this case. How much power is it dissipating? P=IxIxR so P=.15x.15x10 = .225 Watt.

Types of Batteries

Zinc Carbon is "old school". They are cheap if you can still find them and have been around since the dawn of the 20th century. They still work perfectly well in low current items, they just won't last as long as the newer batteries. Some times the carbon post can be taken out and used for other things, like carbon arc lighting.

Zinc Chloride is an updated Zinc Carbon. This are called "super heavy" duty batteries using slightly different chemistry and purer ingredients.

Alkaline - Manganese Dioxide is the most common battery in use today. It is much longer lasting in every application than either of the first two mentioned. Still at higher loads, they will die very quickly.

All alkalines have a sloping discharge rate meaning that you see a gradual loss of power over time until the battery drops below a useful level. (Duracell says this is about .8 Volt.) Alkalines last more than twice as long as heavy duty.

The great blessing of NiMH batteries isn't as much the total amperage available but rather the peak current in Amps possible. A common alkaline battery of the same size may well have more total amp-hours available, but will die very quickly under a high current demand. Batteries have internal resistance which adds to the resistance of the load.

$$I=E/R \text{ becomes } I=E/(R_{battery}+R_{load})$$

As long as $R_{battery}$ is small compared to R_{load} it is usually ignored. Typical internal resistances are .15 Ohm for NiCad, .32 Ohm for Lithium Ion (that's why they are preferred for many electronic applications) .75 Ohm for NiMH. When you put a very low resistance load across your battery the internal resistance will prevent the current from going beyond a certain level. NiCad batteries have very, very low internal resistance and are still preferred by many for electronic applications where short bursts of very high current are needed.

For more info see http://www.alpharubicon.com/altenergy/batteryfred.htm

Battery Chemistry

These cells/batteries can be broken down according to the type of chemistry used to produce the electricity.

- Zinc-carbon
- Zinc chloride
- Alkaline - Manganese Dioxide
- "Premium" Alkaline - Manganese Dioxide
- Nickel Oxyhydroxide
- Lithium - Iron Disulphide
- Lithium-Thionyl Chloride
- Lithium Manganese

Typical Cylindrical Alkaline Batteries:

- **Cathode** is a mixture of high purity electrolytic manganese dioxide and carbon conductor.
- **Anode** is a gelled mixture of zinc powder and electrolyte.
- **Separators** of specially selected materials prevent migration of any solid particles in the battery.
- **Steel can** confines active materials and serves as the cathode collector.
- **Brass collector** serves as the anode collector.
- **Positive and negative covers** provide contact surfaces of nickel-plated steel.
- **Non-conductive plastic film label** electrically insulates the battery.
- **Molded nylon seal** provides a safety venting mechanism.

Electrochemistry:

An alkaline battery produces electricity when the manganese dioxide cathode is reduced and the zinc anode becomes oxidized. The equation for a simple alkaline cell reaction is as follows: $Zn + 2MnO2 + H2O \rightarrow ZnO + 2MnOOH$ During this reaction, water (H2O) is consumed and hydroxyl ion (OH-) are produced by MnO2 cathode under following reaction: $2\ MnO_2 + 2\ H_2O + 2\ e \rightarrow 2MnOOH + 2OH^-$. At the same time, the anode is consuming hydroxyl ions and producing water: $Zn + 2\ OH^- \rightarrow ZnO + H_2O + 2\ e$. The electrons (e) generated during the reaction are used to power devices. The rate of the reaction is dependent on the quality of the raw materials and availability of water and hydroxyl ions during reaction to proceed.

A battery is designed to keep the cathode and anode separated to prevent the reaction from occurring. The stored electrons will only flow when the circuit is closed. This occurs when the battery is placed in a device and the device is turned. This principle is the same as turning on and off a light switch in a house.

When the circuit is closed, the stronger attraction for the electrons by the manganese dioxide will pull the electrons from the zinc anode electrode through the wire in the circuit to the cathode electrode. This flow of electrons through the wire is electricity and can be used to power applications. Alkaline batteries typically have a sloping discharge curve.

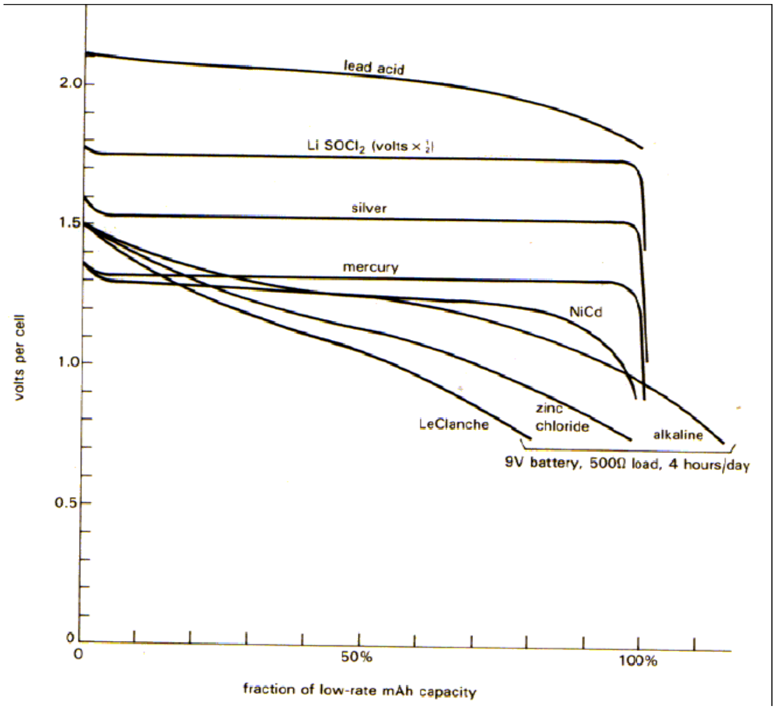
Most devices are designed to operate within a voltage range (for example from 1.6 volts to 0.9 volts per cell) to accommodate this sloping discharge characteristic. The sloping discharge in alkaline batteries is primarily due to the increase in battery internal resistance due to reaction byproducts forming on the electrode surfaces and decrease availability of the fuels (i.e.,water).

Hydrogen gas is a byproduct of the chemical reaction in all alkaline batteries. Under normal usage, this gas production is very low. However, in abusive conditions, (i.e. charging or electrically shorting) high levels of hydrogen can be produced with larger battery sizes having a greater capacity to generate hydrogen gas.

In devices that use a tightly sealed battery case (i.e. diving lights), the hydrogen gas can mix with air to create an explosive atmosphere. For devices with tightly sealed or water proof battery compartments, hydrogen gas generation under normal or abusive conditions needs to be addressed as a potential safety issue to prevent the accumulation of dangerous levels of hydrogen gas within the device.

See http://data.energizer.com/PDFs/alkaline_appman.pdf

The following curves show the voltage for different chemistries.



The Electrochemical Series

Most want to reduce
(gain electrons)

- Gold
- Mercury
- Silver
- Copper
- Lead
- Nickel
- Cadmium

- Iron
- Zinc
- Aluminum
- Magnesium
- Sodium
- Potassium
- ***Lithium***

Some want to oxidize
(lose electrons)

The above gives an idea how the negative (left side) and positive (right side) terminals are chosen when building a battery. In a primitive environment one can use two of these dissimilar metals and salt water, acid or a basic solution and produce electricity to some extent. It can be use for teaching the younger generation about electricity. Not much power can be produced this way. Proper use of existing batteries (or if Lead-acid, possibly rebuilding) is a more productive way to provide storage of electrical power.

10-Home Made Batteries

(11/2/2008)

I have found Homemade batteries some times called earth batteries have the following characteristics:

- Lots of surface area is needed per milliamp current flow.
- Oxidizing surfaces limit capacity and life time.
- Usually not rechargeable.
- Electrolyte can be air, water, salt, acid or base.
- Difference between Electrochemical negativity between electrodes gives the voltage expected.
- Series connected cells in the earth are usually not practical due to difficulty in electrically isolating the cells. Try grater than 10 times distance between cells as per distance between plates in a cell.
- Cells embed in earth are dependent on rain and soil moisture.
- Cells built in a bucket are usually more reliable.
- Good for demonstration of electronegativity of elements but not good for producing power over extended time.
- Potato and lemon cells depend on a source for these.

What a HOT battery!

Jalapeno's make for a good battery. In this example I used a copper wire and a regular steel nail. You can get voltage just by probing the pepper with a sensitive meter {from 0 to about 2 volts.} Although we get about a half a volt, the current is only about 2 to 4 milliamps.

What a Lemon!

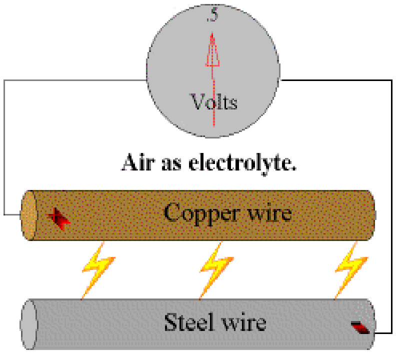
This is the best smelling battery I have tested. This is a good metal cleaner also. {see below} Once again using the same copper and steel as bi-metals. As with the jalapeno, you can get voltage without bi-metals but they are better for these tests. The voltage is better than the current with the lemon. The acid in lemon juice, vinegar, Jalapeno's all make good electrolyte for batteries.

What a metal cleaner!

These metals were oxidized before the lemon test. You can see the metal shine where it was inserted into the lemon. This might come in handy when cleaning coins etc. when you can not use abrasives.

You call this a battery?

This was a test using the length of the bi-metal exposure to determine voltage and current. Solutions such as salt water, vinegar, jalapeno's were tested. The current of this battery is about 10 MA. As you can see ALL of these test use household items. Carbon, Zinc and Copper are used in many batteries. I'll bet you didn't know you could charge a potato! Some say the eyes look better after a charge.



Voltage between Metals.

The best battery I made used Galavonized pipe, and a copper pipe using jalapenos for the electrolyte. The voltage per cell is 1.2 volts and a current of 800 milliamps. Store bought batteries are better, smaller and have more current for the size, if they are available. Bringing two dissimilar metals close together without touching will produce a small voltage and about 200 Microamp..

See: http://www.geocities.com/capecanaveral/lab/1287/hb.html

Homemade Lead Acid Battery

Lead acid batteries were invented in 1912 and in essence haven't changed much since. Two plates of lead immersed in 30% sulphuric acid produce about **2V** of electric potential after being charged at **2.15V** or more. The greater the surface area, the greater the maximum current that can be taking in during charging, and given out by the battery cell. A lead acid cell is typically about **70% efficient** - to get 100 AmpHours out you need to put 143 AmpHours in. At room temperature, charging a cell below **2.25V** is 'safe' in that it will not cause gassing - at higher voltages water is split into hyrdogen and oxygen gasses. Deep cycle batteries are ideally charged at about **2.5V** per cell. Forming the plates is the process of using crystal formation to roughen the surface of the plates, greatly increasing the surface area exposed to the electrolyte.

Thin plates very close together give the best maximum current, but are subject to distortion under heavy current, and corrode away more easily. Thick plates give a long life

I am not sure what effect the distance between the plates has - I suppose it introduces resistance, and so ideally is kept to the minimum without danger of the plates touching or being bridged by sediment.

So the only way to know is to try! I cut out about 80cm2 of 1mm thick lead sheet, plus a tab to connect the wire to. A large jam jar with a plastic lid, melt two slits in the lid, and presto a battery cell.

I covered the plates with battery acid (33% H_2SO_4), so had 160cm2 area per plate. There was about 130mV generated by this for some reason!

I then used a small DC power supply to push 3 volts into it, and it drew 0.25A. I cranked up the supply voltage to "4.5V", which increased the current to about 0.64A and the voltage actually stayed at about 3 to 3.5V. The plates bubble away merrily, with the positive going rust coloured (lots of small bubbles) and the other looking the same silver/grey (larger bubbles).I think what is happening is the positive plate is getting lead peroxide, and the negative plate is just reuniting electrons with H^+ ions.

Be warned the bubbles are hydrogen, and explosive when mixed with air. Keep well ventilated, and no flames or sparks!

The analogue ammeter is connected via a 1K Ohm 1% resistor, to make a simple voltmeter (showing 3 "volts", or 30mA). The digital meter is showing amps.

The DC power supply is marked as rated for 500mA. It seems to survive 650mA! Another one I tried to run above its puny 9W rating worked for a while, and then made a horribling fizzling noise. May it rest in peace. It seems the cell is happy to absorb more current, but the DC power supply is not able to. With too much current, at some point the heating and rapid bubbling may cause the peroxide to flake off the positive plate as it forms.

Once that has charged, I will draw a current to discharge the cell. This should result in $PbSO_4$ forming on both plates. Then charging it again should convert the $PbSO_4$ to spongy lead on the negative plate, and PbO_2 on the positive.

Will the peroxide ($PbS04$) powder and fall off the plate? If so some sort of retaining mat will be needed. Or what about having the positive plate horizontal at the bottom of the jar?

More tests are needed...

27 July 2006

For the next attempt, I wanted to get 6V and more surface area, so I cut out six strips of lead sheeting, 70mm x 400mm, which when rolled up fitted neatly into a medium sized jam jar. To keep the plates from touching, two sheets of woven glass fibre mat were put in between the sheets of lead. So each cell has two sheets of lead and four sheets of glass mat.

This time I left it to soak in the acid overnight, as I wanted lead sulphate ($PbSO_4$) to form on the plates. Once a thin layer of $PbSO_4$ forms, it covers the remaining lead and stops the reaction. So in the morning I put it on charge using a small DC power pack. I set it to 3V, which actually develops 7.1V open circuit. I kept track of the current flowing into the cells.

This time there was no bubbling.. perhaps the bubbling was a symptom of over charging the first model?

I noticed a salt like sediment forming in the bottom of the jars. Perhaps these are the sulphation crystals that are mentioned in warnings about overcharging batteries. To get rid of them I put the jars in a 1-2cm bath of boiling water, and stirred the jars once they had heated. This seems to get the sediment back into solution.

So back to charging.... I am not getting very much charging current... the positive should go rust coloured from PbO_2 formation. Perhaps this is due to the lack of spongy lead which will hopefully form after repeated charge/discharge cycles (thereby hugely increasing the surface area).

It seems that a way of monitoring the sulphation and discharge process is needed. Or perhaps I should push more current into the cells on charge? And should discharging be done by just shorting out the cells (individually or all together?) or by controlling the discharge current?

Is there anyone out there with more knowledge of the chemistry involved who can suggest anything? Please email me, and I will post it here.

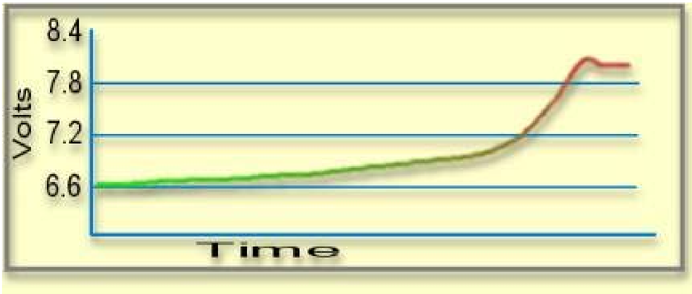
Currently (ha ha), the cells are drawing about 5 - 10mA on charge at 6.9V. A new test is an electric motor which spun for 7 seconds from the batteries - I will now alternate charge and discharge and monitor this to see if it increases or decreases. More to follow soon...

29 - 30 July 2006

10-Home Made Batteries

(11/2/2008)

So here is a graph of what should happen during charging. It makes it clear I was using too low a voltage, so I increased the charge voltage to a nominal 6V, which delivers 7.9-8.2V during charging. After charging at this voltage, this time the motor ran for 35 seconds. Thereafter (with the load removed) the voltage climbs slowly back to around 5.4V after a few minutes. It then went back on charge, which started out drawing 78mA, dropping to 33mA after 20mins.



So following a sort-of pattern of allowing the charge voltage to rise to over 8V, and then running the motor, then charging again gave the following results. Sometimes I shorted the battery out after the motor stopped. In all cases, the positive plate stays much darker than the negative, meaning PbO2 remains on the positive plate. To get maximum surface area, should all the PbO2 be converted to PbSO4 after discharge? Any ideas or suggestions?

Time charged	Final charge voltage	Seconds motor ran	
2.5hrs	7.17	7	Charged at "4.5V" setting
14hrs	8.55V	35	Switched to "6V" setting
1.5hrs	8.29	40	
75min	8.10	52	
12min	8.05	55	Then short out for a few minutes
15min	8.01	69	Then slow discharge via LED
18min	8.02	80	
8min	8.1	99	Switched to 6V battery charger
2min	8.56	96	
8min	8.58	103	

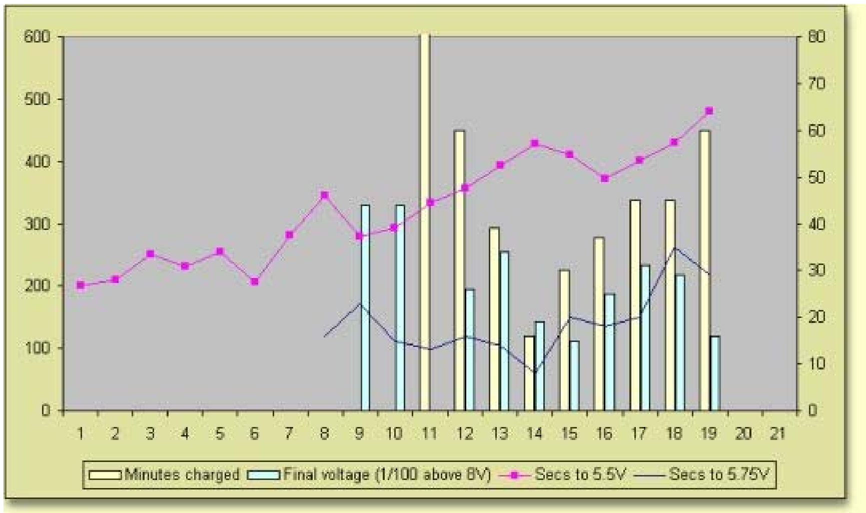
	Here I reversed charged, but the PbO2 started to flake off alarmingly		
25min	8.60	141	Back to normal charge polarity
	Here I filtered the electrolyte using a coffee filter paper (after heating a bit)		
?+12+11min	8.32	147	
11min	8.44	174	
2min	8.1	140	
10min	8.35	203	
10min	8.44	209	
24min	8.31	220	
4+9+2+24+16	8.38	203	Tried a bit of reverse charging again
34+10	8.44	221	
30	8.44	290 5V:239 5.5V:200	Now measuring secs to 5V & 5.5V
5	8.46	270 5V 5V:243 5.5V:210	
21+3		330 5V:276 5.5V:232	
7	8.38	341 5V:298 5.5V:254	

I think the motor draws 750mA at first, and working with this, the battery is about 0.062 Amp hours! Not so great - to get 10 Amp hours would need plates half a square meter each! (plates are currently 70x400mm each, two per cell)

If left for 15min after charging, the battery settles at about 5.91V, 1.97V per cell. This is too low! Will repeated charging improve this? Suggestions and ideas welcome!

I will now continue the charge/discharge cycling (down to 5.5V), and record and graph the time the motor runs. Results to follow...

2 August 2006



One of the cells started to behave strangely - it didn't bubble when charged, and didn't maintain its voltage under load. So I drained it, rinsed, unrolled it, and cut new glass fibre mat to size, and rolled it up again. The electrolyte was filtered (coffee filter paper again), and topped up with a bit of water and acid. Part of the rerolling process was banging it flat, which would have destroyed the high surface area pitting, so this cell is likely to take a while to catch up to the others. The glass fibre mat had changed consistency - it was stuck to the lead in places, and was very weak. It 'came apart in me hands' as I pulled it off. Perhaps its not the best material to use as a separator; perhaps some sort of rubber mesh would be better. Any ideas? If so please let me know.

I cut a sliver of lead off the negative plate and looked at it under a microscope - the surface was very rough, and I could see it had been pressed smoother even from the light pressure of handling. Unfortunately I can't take photographs through the microscope.

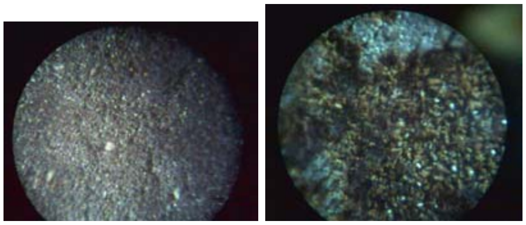
So now the charge/discharge cycle continues, and here is the graph of the motor time test so far. I keep trying things, like varying the charge time, putting the cells in a hot bath, shorting out after discharge (or not), etc., so the variation is to expected.

After this (point 19 on the graph), the new cell took a few charges/discharges to start catching up to the other two more mature cells. A feature of a lagging cells is the battery voltage drops rapidly to around 5V where it is maintained for quite a while.

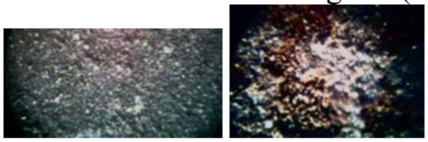
August 2006

Hmm, the same cell cell shorted itself out again (voltage drops to zero almost immediately charging voltage is removed). I unwrapped it again, and it seems the glass fibre mat is not a good separator. It had already gone mushy, and came apart in places under finger pressure while unrolling the lead. So next attempt is some curtain liner, which looks like nylon, which has a thickish and dense weave. Its much more pleasant to work with than glass fibre!Two layers were put in between the plates, and they were rolled up again, and back into the electrolyte (filtered through coffee filter paper again).

I took the opportunity to cut a corner off each plate, and looked at them under the microscope. The spongy texture is clearly visible on both the negative and positive. There were also long clear crystals on the surface of the negative plate. Perhaps sulphur, or sulphate? Amazingly, I could capture an image by holding my phonecam to the eyepiece of the microscope - see below for the negative and positive plates respectively, at about 12 000 X magnification.



And the same under a brighter (but more yellow) light:



And here are the long "crystals" - on second thoughts I think they are actually glass fibres

After the first charge, the voltage stayed above 5.5V for 314s - looking much better! One interesting thing was that in the two cells that had been left in a charged state for a day or so, a deep red clear pigment came off the positive plate for the first few minutes of charging.

5 August 2006

The nylon(?) separator seems to be working really well - the re-made cell is catching up. When discharged,the two plates are very similar colours - dark grey. When charged, the positive plate goes rust coloured, and the negative gets a silvery sheen. In one cell (cell 1), the small exposed part of the negative plate does not go dark grey (although some patches of it do). The silvery sheen on this plate is probably crystals of sulphur or sulphate.

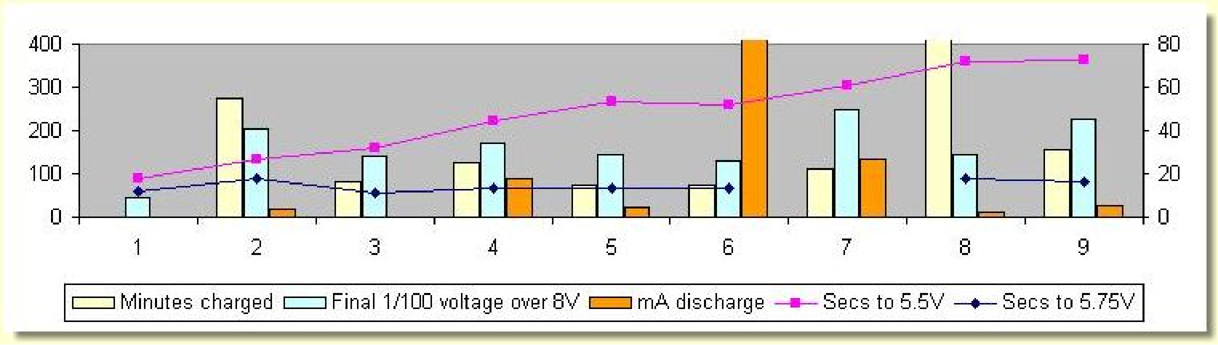
A hot water bath during discharge doubles the shorted out current (eg. from 40 to 80mA) within a minute or so.

6 August 2006

One of the other cells started to misbehave (voltage changed when moved around) , so I unwrapped and rerolled the remaining two cells using the nylon(?) separator. The 'leg' of the positive plate of cell 2 was weak, so I replaced the plate with a fresh sheet of lead. While busy, I couldn't resist jabbing holes in both sides of the plates with a clean compass point, and also scratching crossed diagonal lines into both sides. Hopefully this will increase the initial surface area, and allow the sponge-forming to penetrate more deeply.

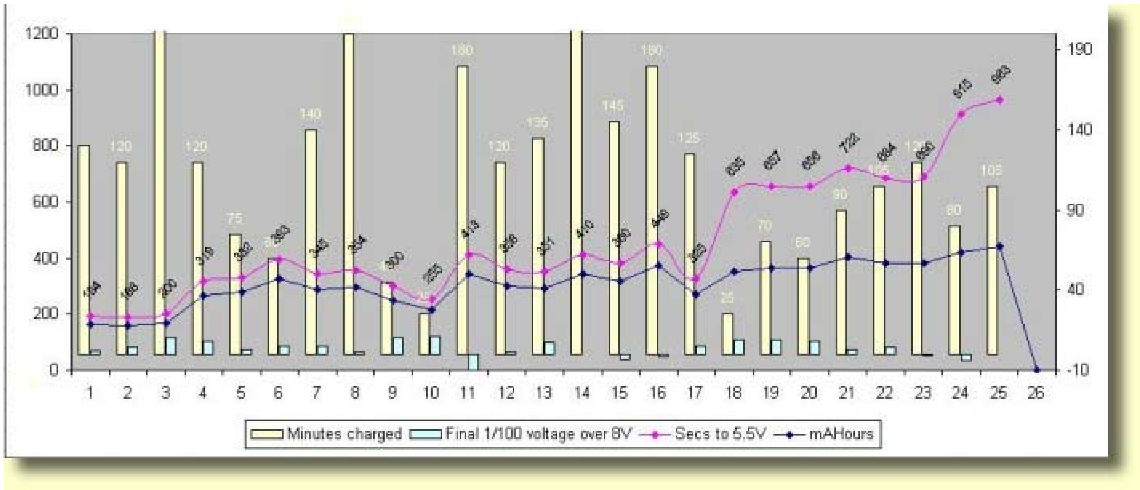
The new positive plate is quite a different colour to the other positive plates - here are photos (left) of it fully discharged (after the first charge/discharge cycle), and then when it is charged (right).

And here is a graph of the latest test results - now getting just over six minutes of motor running time.



13 August 2006

So by now have got up to 10 minutes (600s) running time on the motor. At an estimated 750mA, this is **0.13 AmpHours**. Ten minutes is too long to watch a motor spinning, so I switched to a 50W 12V light bulb, which ran for at most 120s drawing about **2.85A** (before the voltage dropped below 5.5V), which makes **0.10 AmpHours**. This suggests better ratings at lower current, and to be fair, 2.8A is probably a bit much to ask from



these small test cells. It would be ideal to set up a test at 100mA, which would need a current limiting circuit and electronic timer. Any collaborators welcome!

The test times have hit a plateau, so in desperation I am trying to reverse charge cells 2 and 3. This will hopefully change to shapes of the surface of the plates, exposing more surface area. Using the battery charger to reverse charge all three cells results in the ex-positive plate being blasted from inside (flakes of PbO2 start to fall off), so I used a lower power DC supply set on a nominal 4.5V to charge just the two cells. Cell #1 is streets ahead - it can run a batch of LEDs overnight on its own and still deliver **1.8V**+ in the morning.

The performance of the cells at high current is highly temperature dependant eg. 17 seconds cold, 112 seconds in a hot water bath.

28 August 2006

There doesn't seem to be much change with repeated charging now - I get just over 3mins at about 2.85A (50W bulb), making about 0.15 AmpHours.

The charge level seems to have levelled off. Note the big jump after the third entry of the graph. This happended after I removed some electrolyte from cell #2 (about 50ml or so) and replaced it with fresh battery acid (30% H_2SO_4). I did this after discharging the cell completely, which means the plates were sulphated, i.e. the acid would be at its weakest. I picked cell #2 because I measured the cell voltages during discharge, just after the total voltage dropped to below 5.5V. Consistently, I found cell #2 would be at 1.8V, whereas cell #1 was at 1.86V. As the discharge continued, cell #2 would drop rapidly down to zero volts (and then go negative due the effect of the other cells), while cell #1 was still up around 1.8V. I recorded the voltage of each cell as above during discharge, as well as after full charge (but before disconnecting the charger). This gives a very good indication of relative cell performance (and generated huge volumes of data, which I have not recorded here).

Since drawing 3A from these dinky cells may be giving skewed performance, I also used

2 50W bulbs in series to draw less current. This was to test if the AmpHours rating increased (as measured by time taken for the voltage to drop to below 5.5V). This drew about 2A - see the 18th reading on the graph, where the time jumps up, and the mAHours also increases, but not as markedly.

BTW the 16th point (449 seconds) was measured after the batteries had stood discharged for a few weeks - it seemed to do them good!

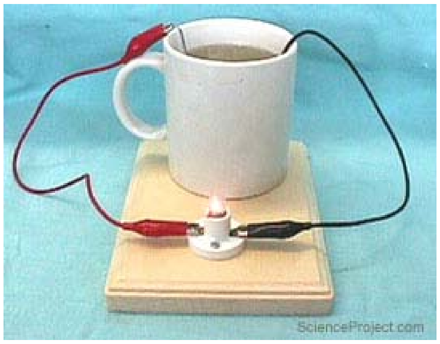
So now some estimates can be done to see what surface are of plates would be needed to produce a battery of say 10 AmpHours. Bearing in mind, of course, that this is using plain sheets of smooth lead. Based on the approx. 3A load for 449 secs (the highest reading obtained), it would need about 26x the surface area per plate, or 0.72m2, or 85cm by 85cm. Based on the 2A load and 400secs, we get 0.7m2, about the same. The 1.65A loading gives 0.63m2, or 80cm by 80cm.

Cell #1 still seems to perform streets ahead of the others - when #2 and #3 are flat, it it still putting out 1.8V. I really need to test the electrolyte somehow. See: http://windpower.org.za/batteries/batteries.html

Make Electricity From Saltwater

If you are asked to do a science project and you are looking for a good science project idea, this might be what you have been looking for. Making electricity from salt water is ranked among the 10 best science project ideas by a group of project advisors at ScienceProject.com.

Life application:



We all know that the world is now facing an energy crisis and everyone is trying to do something about that. Some people try to use solar energy and wind energy; some others try to invade and occupy oil producing countries; and now you can show them that electrical energy or electricity can be made from air and saltwater. After all, both the air and the saltwater are freely available everywhere. These are the two things that we have plenty of them available in most areas.

This may seem impossible.

I could not believe it myself the first time that I heard about it. It almost sounds like a magic trick. Finally, I decided to test it anyway.

I tried different concentrations of salt water, different temperatures, and different electrodes and had no success. It took me a few months thinking about it until I solved the problem in my mind and decided to repeat my experiments again. This time everything worked fine and I was able to make enough electricity to light up a small light bulb.

The concept is easy. The same way that you burn wood and make heat energy, you should be able to burn metals and get electricity. The difference is that you are not really burning any thing; instead, you are producing a condition for oxidization which by itself is the same as slow burning. So what you really do is oxidizing iron in saltwater using the oxygen from the air or any other source. (At least, that's my theory at this time)

I don't know if this system of producing electricity is economical and cost effective. What I know is that it is worth to try. If with one cup of salt water and some metals I was able to light up a small light bulb, maybe you can light up the entire building by a tank of salt water and a few hundred pounds of scrap metal.

No mater what is the results, you can be proud that you can make an emergency battery for yourself if you need it.

It took me a long time to make the first working battery using the salt water; however, you don't have to waste that much time. I have combined the results of all my experiments and made a recipe for success. Just follow the instructions below and you will get results in the first try.

Verified and approved by ScienceProject.com

This project idea is verified and approved by a group of project advisors at ScienceProject.com. It is ranked as a multi-level project that can be tried by students as young as 12 years old, up to the 4th year chemistry college students. At higher grades student may also study the movement of ions and the chemical reactions that cause the production of electricity in saltwater battery.

What is the cost of material?

Some people may already have all the materials at home or be able to get them free; however, if you choose to buy all materials, you may end up spending about $20 or more.

A good Project title

Need an exciting and attractive title for your science fair project? You have many interesting choices with this project. Following are just a few samples:

1. Electricity from air
2. Electrical energy from chemical reactions
3. Electricity from saltwater
4. Air battery

5. Saltwater battery

Introduction:

Batteries have been made with many different chemical compounds. Scientists often try to make batteries that provide more energy and last longer. Many of such high quality batteries are commercially available today. They are used in flashlights and electronic devices such as radios, watches, computers and calculators.

Making a battery is always an exciting science project. Your home made batteries can be used as chemistry, physics or electricity project. This project can be performed and conducted as a display project, engineering project or experimental project. In this project you will make a saltwater battery.

How the battery is made?

A battery is made of two different electrodes inserted in a chemical compound. A chemical reaction between the electrodes and the chemical compound produces electricity. For example if you insert a copper rod and an iron rod in a cup of orange juice, that will be a battery. In this example copper rod and iron rod are the electrodes and the orange juice is the chemical compound or electrolyte. The problem is that the electricity produced by such a battery is too little and has no practical use and you cannot use it to light up a light bulb. The saltwater battery described in this project guide can light up a light bulb for a few seconds or a few minutes. When the light goes off, you can simply recharge it by providing fresh salt water or providing additional air or oxygen. Simply empty the used salt water and add fresh salt water to get light again.

Does it really work?

Although a saltwater battery is not as strong as a commercial battery, it can produce visible light on a low voltage light bulb. It is also safer than batteries that use many harmful chemicals.

What chemicals do I need?

The only chemical that you need is Sodium Chloride (NaCl) also known as table salt. This is the salt that you usually have it at home and use for cooking. If not, you can buy it from grocery stores. Good quality, pure and inexpensive packages of salt are often marked as kosher salt. You also need water (H2O).

What electrodes I can use?

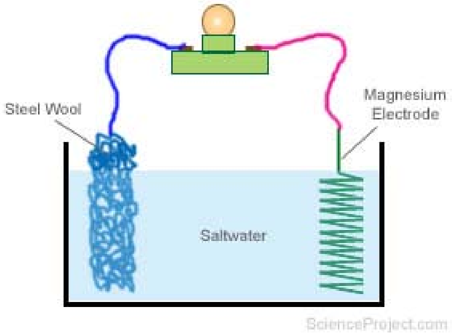
Some articles suggest using Aluminum and Copper metals as electrodes; however, I have not been able to verify that. I suggest using iron and magnesium electrodes. Of course you can test any combinations of metals that you like. Iron is widely available in the form of wires, nails, metal strips, steel wool and many more; however, I used steel wool because it has a larger surface in compare with others. If you want to use iron wires or strips, you may make a coil out of them to fit a larger surface in a smaller space.

Magnesium metal is mostly used in construction of airplanes and some automobile parts. Some magnesium alloys contain large amounts of aluminum. For this project you need pure magnesium or a magnesium alloy with more than 65% magnesium. Any broken piece of a magnesium part may be used as electrode. Pure magnesium electrode is not sold in stores; however, you can order them online from MiniScience.com.

Electrodes must be clean; so if you are trying to use a machine part as your electrode, you may need to wash them with warm water and dishwashing detergent prior to use. Any oil on the surface of electrodes can interrupt or prevent the chemical reactions and the electrical current.

Suggested List of material:

1. Salt and water
2. Iron electrode (Steel wool is good)
3. Magnesium electrode (Flat or coil)
4. Wire lids with alligator clips
5. Miniature 1.2-volt light bulb (Low voltage)
6. Miniature base
7. Hydrogen peroxide



Procedure:

1. Make a strong solution of salt (about 200 grams of salt per liter) in a deep plastic container (topper ware).
2. Screw the light bulb in the base and connect one wire to each of the contacts on the base.
3. Connect the open end of one of the wires to the iron electrode (Steel wool).
4. Connect the open end of the second wire to the magnesium electrode.
5. Insert both electrodes at the same time in two opposite ends of the plastic container. Make sure the electrodes are completely or mostly in the saltwater. At this time you should get a light in the light bulb.
6. If you remove the light bulb and connect a DC voltmeter to the electrodes, you must see a voltage of about 1 (one) volt.
7. To get more light, add some hydrogen peroxide (an oxidizer) to the saltwater solution.

Trouble shooting:

If you are not getting any light, following are possible problems that can be verified.

1. The light bulb is defective, improperly installed or requires much higher voltage. Test your light bulb with a AA battery and it should work.
2. Check all the connections. Placing a AA battery between the electrodes must light up the light bulb; otherwise, at least one of the connections has problem. If you are using regular wire, make sure you have removed the insulation in all contact points.
3. The electrodes are very small or just a small portion of them is inserted in the saltwater.

Safety precautions:

After a few minutes of light production, the salt solution becomes alkaline. Alkaline solutions can irritate eyes and cause dryness of skin. Avoid contact with the used saltwater solution. Used saltwater can be disposed in the sink or sewer system along with other household liquid waste. If you add hydrogen peroxide to the solution, you must dispose dilute it with plenty of water before disposing it. Hydrogen peroxide is an oxidizer can can cause rust in metal pipes if it is not diluted.

Why is it called air battery?

Batteries are usually known by their electrolyte or their electrodes. Although we call it saltwater battery (because it is using saltwater as the electrolyte); it also needs air or oxygen. Oxygen is needed in order to oxidize the iron and this battery will not work where no oxygen is available. Because of the important role of oxygen in this battery, some people call it air battery.

Where can I buy materials?

The Magnesium Electrode is available at MiniScience.com, all other materials may be purchased locally. A kit for this experiment is available at klk.com or KidsLoveKits.com.

Photo and diagram are from ScienceProject.com website, printed with permission. This article is also available online at http://www.MiniScience.com/link

http://www.miniscience.com/link/Airbattery.htm

Homemade Battery Basics

Summary
Simple homemade batteries are described that can be made from items found in the home or school lab.

The simplest cell (a battery is simply a group of cells) is made by putting two different metal electrodes into an electrolyte (usually a solution of a salt or acid in water). Each metal receives an electrical charge and one becomes more positive (+) than the other (-). Because opposites attract, there is an energy of attraction (called the voltage) between the charges, which is the origin of the battery's power (see below for a more full explanation of voltage, current, energy and power) of the battery.

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(11/2/2008)

A simple battery can be made by pushing a zinc-coated screw and a piece of copper into a lemon. This wonderfully simple cell can even produce enough power to run a LCD clock / watch and its worth experimenting with the cheap 'toy' watchs that are easy to find in markets. A carbon-rod electrode instead of the copper will also work. Three potatoes each having a carbon rod and a zinc-coated screw electrode system can be wired in series (like a daisy chain) to power an LED (Light Emitting Diode) light. Here we describe carbon rod and screw batteries using sea (salt) water as an electrolyte, which are made from household ice cube trays!

How they batteries work - electrolysis

The voltage created in a battery is due to ionic chemistry. When a metal electrode is immersed in an electrolyte a rather complex dynamic process occurs. Let us assume that the metal electrode is initially uncharged (the atoms from which the electrode is made are neutral - they have equal numbers of electrons and protons). When the metal is immersed in the electrolyte, positive metal ions are formed on the surface of the electrode. These ions pass into solution, making the electrode progressively more negative, as the positive ions move away. There will come a time, however, when the negatively charged electrode will start to attract back the oppositely charged ions. So a dynamic equilibrium is thus formed between those ions leaving and those returning to the metal surface. How far the equilibrium goes one way or the other is dependant on the reactivity of the metal.

A battery must have two electrodes, so meanwhile on the other electrode, a similar process must be taking place. If this second electrode is of the same metal as the first, then each electrode will charge to the same extent (voltage), and there will be no resulting difference between them. There will thus be no attractive force (electromotive force EMF) between them, and so no current will flow.

However, if the electrodes are of different metals, then their reactivity's will be different, and so different equilibria will be set up. One electrode will become charged to a greater extent than the other and because of the difference in reactivities will have a different voltage. In other words, there will now be a voltage difference between the electrodes. Because of this difference, electrons will want to move from one electrode to the other. This attractive potential is the voltage that we measure between the electrodes, and the origin of the batteries electrical power.

The Electrochemical Series

If we imagine a series of batteries, each made up of one metal electrode but each also having a 'standard electrode' (the standard that is used is an electrode composed of a platinum wire in a hydrogen gas envelope but we don't need to know much of the details here). We can draw up a table, called the Electrochemical Series, of the voltages arising from these different batteries. Such a table will be useful for comparing different electrode systems. We can actually use it to predict the voltage of a cell made up from two different metals (i.e. without the reference electrode). It is simply the difference between the two values of the standard electrode potentials (Note: it is important to keep in mind the sign + / - of these standard potentials when doing the calculation).

Voltage, current and power

As opposites attract, once the electrical circuit is completed, there will be a tendency for the negative electrons to be attracted to the more positively charged electrode. If a wire is connected between the two electrodes, this is precisely what happens. This potential energy (work that can be done) to move electrons when a circuit is connected is called the voltage of the battery:

V = Volts = energy per charge (joules / coulomb).

The amount of charge passing per unit time is known as the current:

A = Amp = rate of charge passing (coulombs / sec).

If we multiply the voltage between the electrodes by the particular current that is passing, we get the power of the cell:

P = Power = V x A = (joules / coulomb) x (coulombs / sec) = joules / sec
Which is the work done per time.

Battery efficiency

The voltage is dependant on the difference between the individual electrode potentials. However, in practice, this is only true in the ideal case where we can measure the voltage without drawing any appreciable current. This is the case when using a very high resistance voltmeter, but not the case when we use the battery to drive a radio, for example. In practice, what we find is that, as we start to draw current from the cell the voltage drops away.

This limitation of a real life battery is due to at least two factors; the nature of the electrolyte and the electrical resistance of the electrodes. The dependency of the battery voltage on the electrode potentials explains why similar results can be obtained using different electrolytes (eg.for example: Salt water, vinegar, sulphuric sulfuric acid, and even urine!). But of course the battery must also be dependant on the concentration and type of ions in the electrolyte. The limiting case being when there are no ions present at all (e.g. in a non ionic liquid or a battery that has dried out etc.).

Assuming that the electrolyte is above a threshold concentration the surface resistance of the electrodes then has to be considered. This is the electrical resistance made between the solid electrode and the solution due to the flow of electrons and ions. If the electrode resistances are low, the cell voltage will drop of slowly with rising current. If the resistance is high, the voltage will appear to drop as current is drawn from the battery. The internal resistance of cells is a major limiting factor in the application and usefulness of a real battery.

An experimental sea sea-water battery

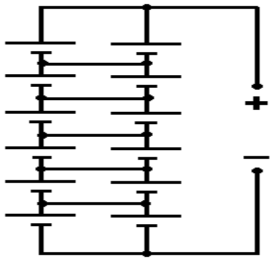
We have seen how a pair of electrodes can produce a voltage when immersed in an electrolyte. In the following experiments we use of galvanised (zinc- plated) screws and carbon rods as the electrodes and salt water as the electrolyte. While carbon is a good conductor of electricity, the chemistry that takes place at the carbon electrode is more complicated than would be the case when simply using metals. However, larger potentials are produced with carbon and zinc than with copper and zinc, so it is worth the complication. Carbon is a good conductor of electricity. In these cells the metal (zinc) electrode is negative (-) while the carbon becomes positive (+).

To get round the limited voltage and current of such a simple cell, we can join up cells to make a battery of cells - thereby increasing the power. An effective arrangement is shown in the diagram Figure 1. Household ice- cube trays are used to hold the electrolyte, and wood supports the multiple pairs of electrodes, a set for each ice cube tray.

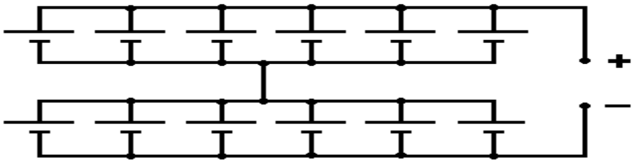
Making the battery
Each of the ice cube trays is 3/4 filled with a salt solution (sea water or a solution of table salt in water). Galvanised screws can be purchased from any hardware store. Pencil leads can be used for the carbon rods or, better still, they can be salvaged from carefully dismantled old ('flat') batteries. Then the electrode pairs are lowered into their respective ice cube tray solutions to create the 12 cells. They are then wired-up on the top side of the wooden support to form the battery.

Wiring the cells up in series or parallel?
So what is the best way to wire up the 12 cells to get useful power from the battery? Consider a single cell; it can produce a voltage of V volts and a maximum current of say I amps. Wiring a number (n) of these cells in series (one after the other in a sort of daisy chain) will multiply the voltage giving n x V volts. However, the maximum current produced by this arrangement will be the same as that of a single cell - I. On the other hand wiring all the cells in parallel will increase the current n-fold but maintain the voltage equivalent to that of a single cell (i.e. V). Combinations of series and parallel cells with produce combination of possible total V and I.

The ice cube tray used in these experiments had 12 compartments (ice cubes) and so to get useful power from the battery two combinations of wiring were chosen (see Figure 2): The first a) consists of two sets of six cells wired in series and these two sets then wired in parallel - giving a total of 6 x V and 2 x I. b) consisted of two sets of six parallel cells which were wired in series - giving a total of 2 x V and 6 x I.



6 x 2 cells
6 x single cell voltage
2 x single cell current



2 x 6 cells
2 x single cell voltage
6 x single cell current

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(11/2/2008)

Figure 1. two of the many possible circuit arrangements for making a battery from 12 sea water cells

Parts list:
Table 1) Salt (NaCl)
2) Ice- cube trays
3) Wood for electrode support
4) galvanized screws (ca. 5 cm long) for each battery
5) 12 pencil leads (2B or softer), or better still, school lab carbon rods or ones salvaged from old worn out batteries
6) Tinned copper wire

Figure 2. The multiple pairs of electrodes are shown attached to the wooden support. This is the 'high' voltage, 'low' current version. The ice cube trays hold the electrolyte for each cell. The cells are wired up above the board.

A sea water power plant (!)
The first battery circuit provides a relatively higher voltage than the second and so it can therefore be used to power devises devices that need 'higher voltages' but low currents. A pocket LCD calculator, an LED (and series resistor), and possibly a pocket radio, will work well using this arrangement. In the demonstrations we use a simple flashing LED circuit to dramatically show the battery working. This circuit requires about 3V, but only about 1 or 2 mA to work.

Please Note: remember to check that the device you are powering is correctly wired to the – and + connection of the battery (metal (zinc) = -, carbon = +).

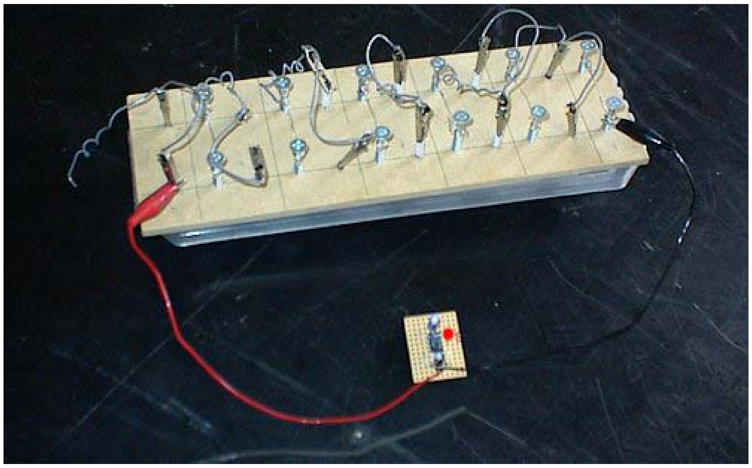

Figure 3. The complete 'high' voltage, 'low' current sea water battery connected to an LED flasher circuit

The second battery circuit will work well on for devices that need a greater current but not a particularly high voltage. A good example of this would be a low voltage motor. Some motors will run on only about 1 volt but need 10 mA or so in order to turn (see notes section below for details of suitable motors).

Ideas for further experiments

The basic battery described above is capable of driving low power devices. As the battery is a device that converts chemical potential into electrical potential eventually the battery will fail (run down) as the chemistry develops at the electrodes and in the electrolyte. The zinc on the screws is dissolving and their may also be zinc hydroxide (and / or zinc chloride) forming on the electrodes which will increase the resistance. The electrodes will therefore need to be cleaned before each use of the battery to reduce the resistance and the chemical build up that inevitably occurs.

The obvious places for further experimentation are to try different electrode materials (what is the effect of the surface area of the electrodes for example) and try using different electrolytes (for example try orange juice, vinegar, sulfuric acid, or even urine!). Does the current produced from the battery simply depend on electrolyte concentration or does it fail at some threshold value? What is the effect of the temperature of the electrolyte in the cells and if so why does it have an effect? Does this help to explain why you can rejuvenate used batteries by putting them on a warm radiator?

If you want the battery to start to work (to be activated) when immersed in sea water then try putting small pieces of sponge between the electrodes. When the empty battery is immersed, the sponges soak up sea water so that electrolyte remains between the electrodes when the battery is taken out. (If you leave the contraption in the sea many of the cells would be shorted out by the sea water - hence you need to take the battery out of the sea after the water gets in). This was the way we made the emergency life jacket lights in the fifth series of Rough Science set in Zanzibar (BBC2 Feb. 2005). When the life jacket went into the sea it activated the battery, powering the emergency lights.

The Baghdad Battery

In 1800 Count Alessandro Volta made what was thought to be the first device that we can consider as a modern day battery. He found from experiments that different metals in contact with each other via salt solution soaked strips created electricity. He made a device composed of an alternating pile of metal coins sandwiched between electrolyte (salt water) moistened felt strips. Connection to the two end of the pile allowed access to the voltage. This device became known as a 'voltaic pile' (historically this is where the terms volt and voltages got there names). In their modern form batteries are a recent invention although of course voltages have been present since the elements were formed and electrolytes could form and also in creatures such as electric eels etc. But was Volta's pile the first battery? There is however a rather controversial theory that batteries might have been around for more than 2000 years!

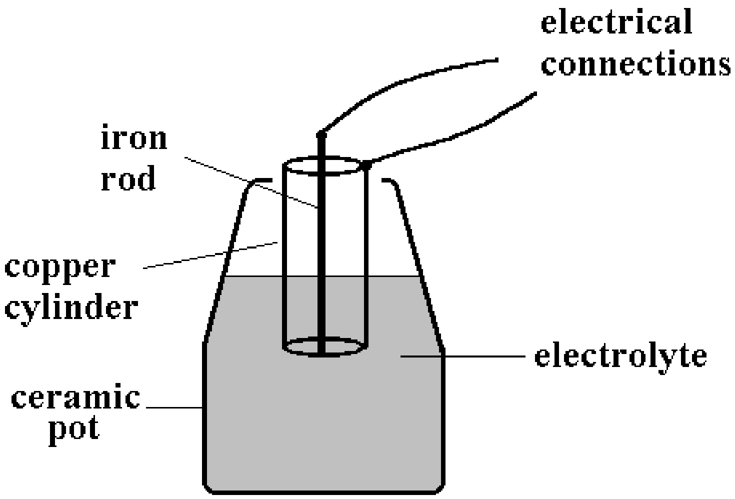

Figure 4. Schematic of the 200 BC Baghdad Battery composed of a ceramic pot, a copper cylinder, iron rod and vinegar electrolyte

In 1938 an archaeologist Von Wilhelm Konig working at the Baghdad Iraq Museum, claimed to have discovered a very old battery. He thought the Mesopotamians had invented the battery in 200 BC! ! His so-called 'Baghdad Battery', shown in the picture, consisted of a ceramic pot about 20cm high, in which was placed a cylinder of copper metal and an iron rod. It appears that the iron rod was surrounded by an oil/pitch based insulator, and evidence for organic material was found in the pot.

Recently we have made copies of these devices using vinegar (which of course would have been an available electrolyte at the time). A single device produces about 1V at 10mA. Of course from what we have learnt in this article such a system would indeed work as a battery, but was this the intention over 2000 years ago - did the Mesopotamians really mean to invent the battery, or did the device have some other, quite unconnected purpose?

It seems very un-likely that they purposely made a battery, especially as no wires were found with the device. However, assuming that they were using them as batteries, there are several theories that have been put forward for their purpose? One suggestion was that the Mesopotamians may have wired up many of the batteries so that they could electrify holy statues to give them 'magical' powers. This is a nice theory / idea perhaps, but electric shocks depend on high voltage, and they would have needed hundreds of batteries to produce a shock!

Another theory is that these small voltages could have been used in acupuncture (which had been discovered / invented by this time). Some of the devices batteries were found next to fine needles. It is possible that needles put in the skin and wired to a few volts might have produced therapeutic effects - well, some kind of effect anyway!

Finally in the course of our own recent investigations into Baghdad batteries, we tried to use the voltage from several batteries in series to drive a simple electrolysis reaction. The idea was to produce silver ions from a silver electrode (we used a silver bracelet), and use it to plate another (cheaper) metal electrode. Using silver and copper electrodes in a vinegar electrolyte we found (given enough time) that we could successfully silver (although not very nicely!) plate the copper using our set-up!

So, could the ancient Mesopotamians have used the similar Baghdad batteries to plate cheaper intricately designed copper statues with a silver layer? Unfortunately, no proof for this wonderfully appealing possibility exists in the archaeological records. The origin, use and purpose of the so called Baghdad batteries therefore still remains a mystery.

References

For details of the LED flashers click here

For details of the electrochemical series click here

Notes;
1) We have found that 'carbon rods' are much better than 'graphite rods' of the same purity. Even though both types may be high purity carbon the 'carbon' rods appear to be more porous than the shinny graphite rods. The carbon rods therefore present a much greater surface area to the electrolyte. As a consequence the electrode resistance is much less, creating a better battery.

2) We made our first sea-water battery on in the very first series of Rough Science, and we have been hooked ever since! The batteries described here are regularly used in an electricity workshop we run at the CSC. In the fifth series of Rough Science (Zanzibar, Feb. 2005, BBC2) we used sea water batteries to power emergency lights on a life jacket.

3) It is worth checking the various companies that sell electronic component as most stock 'ultra bright' LED's as well as 'solar-cell' motors that work on very low voltages and currents suitable to be powered by these experimental batteries.

See: http://www.creative-science.org.uk/sea1.html

What was learned about Homemade Batteries

All batteries involve a comparison between two chemical reactions that take place at different places within the battery. The negative end of the battery is connected to a metal that is releasing electrons (in the case of the battery we made, zinc metal is turning into positively charged zinc ions by giving up two electrons for each zinc atom: $Zn \rightarrow Zn^{++} + 2 e^-$). At the positive end, electrons are combining with a different positive ion (for example, two hydrogen ions plus two electrons makes one molecule of hydrogen gas: $2 H^+ + 2 e^- \rightarrow H_2$). It costs energy to remove the electrons at one side (i.e. from the zinc) but we gain more energy at the other. The net release of energy is what makes the current go around the circuit. By having the two reactions separated from each other, they cannot take place except when the current is flowing.

The voltage of the battery is determined by the amount of energy released in the two chemical reactions, and is largely determined by the chemical reactions that are involved. Our battery would work much better if we had a better chemical reaction at the positive end. For example, if there were copper ions in the solution, they could absorb the electrons (producing copper metal). Another possibility is to add hydrogen peroxide to the solution, allowing the reaction

$H_2O_2 + 2 H^+ + 2 e^- \rightarrow 2 H_2O$

-- that is, hydrogen peroxide + hydrogen ions + electrons makes water.

Using magnesium metal instead of zinc metal also makes a better battery, because it costs less energy to remove the electron from magnesium metal (this means it is more chemically reactive). Theoretically, aluminum would be a good choice, but in practice it doesn't work very well, because the aluminum surface is almost completely covered by a thin layer of aluminum oxide, which is an insulator: aluminum is too reactive to use in air.

The current flow is limited by the rate at which the chemical reactions can take place. The reactants in contact with the conducting surface get used up quickly, and then nothing more can happen until more chemical moves into place. This is why the LED starts bright but quickly dims when we connect it to the battery we made. It is also why this battery will not light a light bulb.

We have found no design using common chemicals that will cause a light bulb to glow. The voltage (measured when the battery is not doing anything) is not high enough, and a set of the batteries in series will not work either, because the chemical reactions take place too slowly, which limits the amount of power that the battery can deliver. We are surprised that published descriptions of ways to make a battery frequently invite you to try to light a light bulb with it -- evidently the authors have never tried their own experiment.

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In producing the design described in this section we have tried a number of designs. Here is a brief review

- The best electrolyte we found was hydrogen peroxide + table salt. Hydrogen peroxide is available at drug stores and safe to use, but we suspect the solution has to be made up fresh -- it won't keep.
- We didn't notice much difference between salt solutions or acid solutions for the electrolyte. The main role is to provide a medium that is a good conductor, and which allows the reactions to take place. Lemons and potatoes could be used instead of wetted paper: they will hold the metal parts in place, but otherwise seem to be a waste of a perfectly good vegetable.
- We tried using prepared mustard diluted with a little vinegar as the electrolyte. Here are the instructions. This material has the advantage that it will stay in place a little better than the salty vinegar, and it is easier to tell that the electrolyte is where it should be and only where it should be. It also makes battery-making a little less mysterious. The "mustard sandwich" cells (brass/mustard/zinc) stick together, making handling simpler. But it makes a mess to clean up afterwards.
- Magnesium metal gives a higher voltage than zinc, and is easily obtained (ask any high school chemistry teacher). We decided against this just because it made the battery seem too magical -- you don't really need a special material.
- We tried using aluminum foil instead of zinc several times. This made a really good battery just once, and even then the battery quit working within a few seconds. We suspect that the chemical reactions at the aluminum surface are rapidly covering it with insoluble insulating material.
- Brass or copper work equally well at the positive side. Since we are making hydrogen gas there, it doesn't matter what you use.

Finally, we will mention that there is a traditional copper/zinc battery that has four layers:

copper metal | copper sulfate solution | salt solution | zinc metal

At the copper surface, the copper ions in the copper sulfate solution are turning into copper metal. This is easier than trying to make hydrogen gas, and gives a higher voltage. However, the copper solution must be isolated from the zinc surface, or it would directly react with it, so we need another layer of a solution that does not contain copper (it eventually will become a solution of zinc sulfate). Making this kind of battery requires having two paper layers, one wetted with copper sulfate and one wetted with salt solution. Since copper solutions are rather poisonous, we didn't try to develop this battery. http://www.pa.uky.edu/~sciworks/em/preview/voltz.htm

Testing Capacity of Homemade batteries

I had lots of fun building homebrew batteries. I wanted to build a radio transmitter powered by natural, homebrew power sources. The first thought, was a lemon battery (or few).

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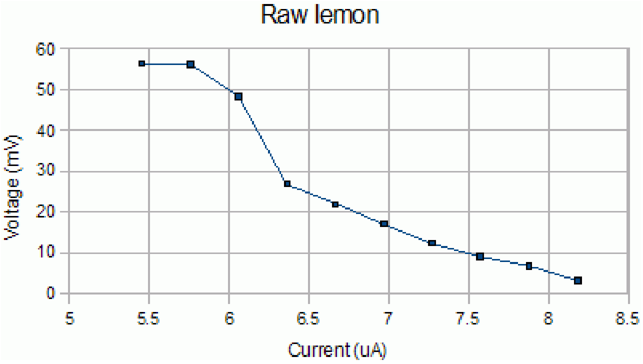
(11/2/2008)

All over the place on the internet, you can read about the classic school science project, sticking two dissimilar metals into a lemon and generating some small amount of power. Sometimes potatoes. You can even buy "kits" to do this in toy stores. What seems to be generally lacking is any measurements on such batteries. How much power can they supply? And for how long? And what factors are involved to determine these parameters? Sure, you can power an LCD clock, until the lemon dries out. But they consume a miniscule current anyway. I found some websites which claimed that a single lemon will produce 0.5V and 1mA of current. They didn't say how long for. Several lemons in series are supposedly enough to light an LED.

On this page, you can click all thumbnail photographs to get bigger versions. But the graphs are already the full-size versions, so you can't click them.

Simple lemon cell

My first attempt at a lemon battery consisted of a standard lemon, fresh from the supermarket, with a copper wire (solid core household cable with the insulation stripped off) poked in one side and a normal steel bolt pushed in the other side. To test this power generation masterpiece, I rigged up a 10k variable resistor in series with a 330-ohm fixed resistor and my two DVM to measure voltages and currents.



Indeed, when unloaded, the lemon produced around 0.5 Volts. But what about under load? The 10K potentiometer allowed me to vary the load between 10.3k and 330 ohms. The graph to the right shows the resulting battery voltage vs load current. As soon as I connected the load, the voltage dropped to 56mV even though the load was more than 10kOhms. The current was only 5.5 microamps! At the other end of the potentiometer, by the time the load was reduced to 330-Ohms, the current increased to 8uA, but the voltage falls to only 2.6mV. This lemon battery produced only 0.3uW of power across a 10k load! To power my 40m QRSS transmitter I'd need about 30,000 lemons.

Next, I cut a strip of baked bean can tin, maybe 50 x 5mm. I inserted that into the lemon, in place of the steel bolt. The open-circuit voltage was 498mV, dropping to approx 300mV through my 10.3kOhm load. That's a current was of 29uA, for a power of 8.7uW. That's a 28-fold increase in power production! But still, nowhere near the claimed 1mA on some websites. If they lit an LED with some of these in series, then Ok, but it must have been a low-current LED. To power my 40m QRSS transmitter, now I'd only need 1,000 lemons. But that's still a lot of lemons.

In the end, I was so disappointed with the ability of a lemon to produce much current, that I even forgot to take a photograph. So all you get is the graph.

Lemon juice cell

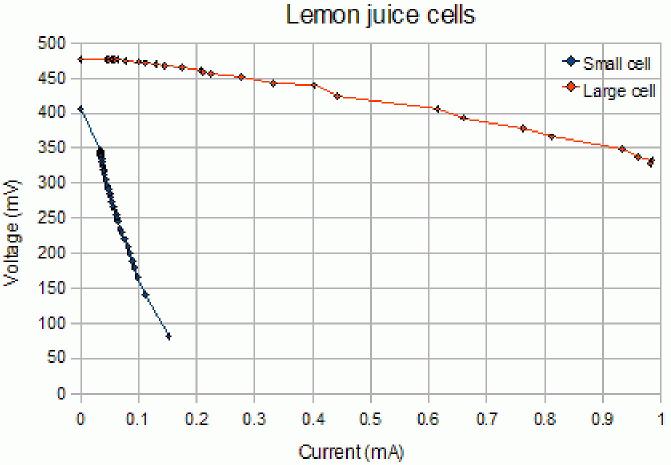
Not quite ready to give up on lemons altogether, however. My next battery cell was made from baked bean tin, soldered into a small cup. The dimensions of the cup are 35 x 23 x 4mm. A small 25 x 25mm square soldered on the bottom keeps it upright. The tin cup is the negative terminal of the battery. To construct the other electrode, I used about 25cm of copper wire, wound into a flat spiral. The copper wire is household lighting cable, with the insulation stripped off. To keep the electrodes apart, I wrapped the copper spiral in a piece of kitchen tissue. Then poured in lemon juice squeezed directly from a lemon. The idea here, is to increase the surface area of the electrodes and decrease the distances involved, to reduce the internal resistance of the battery.

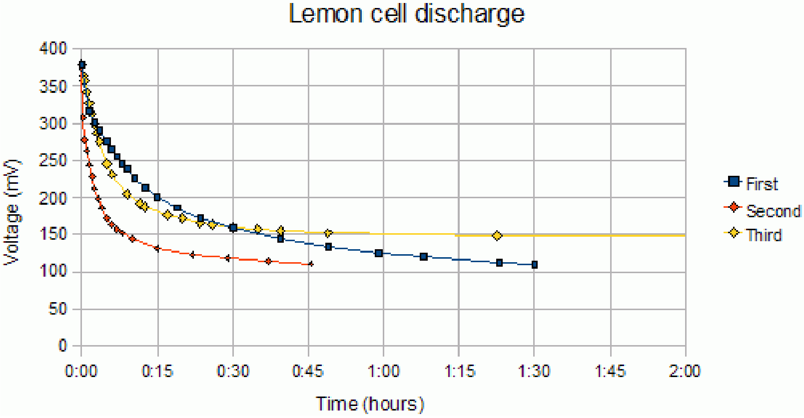
The results of this experiment were a little bit more encouraging. The current at 10.3k load was 34uA, which was only a little bit more than the raw lemon alone. But it coped better with lower resistance loads, and at about 500 ohms load could support a current of 150uA and the voltage dropped to 81mV. Peak power production occured at a little lower current than this, and was 17uW. This cell is therefore about twice as good as my raw lemon (with tin strip electrode).

Improved lemon juice cell

I was encouraged by this result and decided to build a bigger version of the same cell, incorporating larger electrodes and keeping the electrode separation as small as possible. For this larger cell, I used a whole 400g baked bean can. I cut the wall of the can into two pieces, folded together such that I produced a cell having three compartments. A piece of tin strip from the offcuts completed this small tank. All soldered together (baked bean can tin solderes very nicely). The size of this cell was about 70 x 50 x 20mm. The flat spiral coil is in this case still made from copper wire, but a longer length of it. Three such spirals are used in this battery. Each one was wrapped in a piece of kitchen tissue to stop it touching the tin electrode. Finally, lemon juice was poured into the cell. One lemon produces enough juice to fill the cell. The three compartments weren't sealed from each other; the only reason for the three compartments was to keep as much tin and copper as close together as possible.

Well, the results from this cell were much better than previous attempts, as might be expected:





The first graph (above left) shows the voltage vs current of both the small lemon juice cell (see above) and my larger cell (this section). The large cell shows a massive improvement. It can cope with a 1mA current draw, and the voltage drops only to 324mV. This is a power production of 322uW, which is 19 times better than the small lemon juice cell!

In my second graph (above right), I discharged the battery through a fixed resistance of 330 ohms, which initially takes more than 1mA of current. Note that the discharge isn't a constant current one. As the voltage declines, so does the current so the power consumption is decreasing as the experiment runs. I repeated the discharge experiment three times. The first, started at 22:38 in the evening and I left it running for 90 minutes. The following morning, I tried again at 10:30am. I found that the voltage decay was faster, and to a lower value, than the first discharge, which is not a surprising result. What

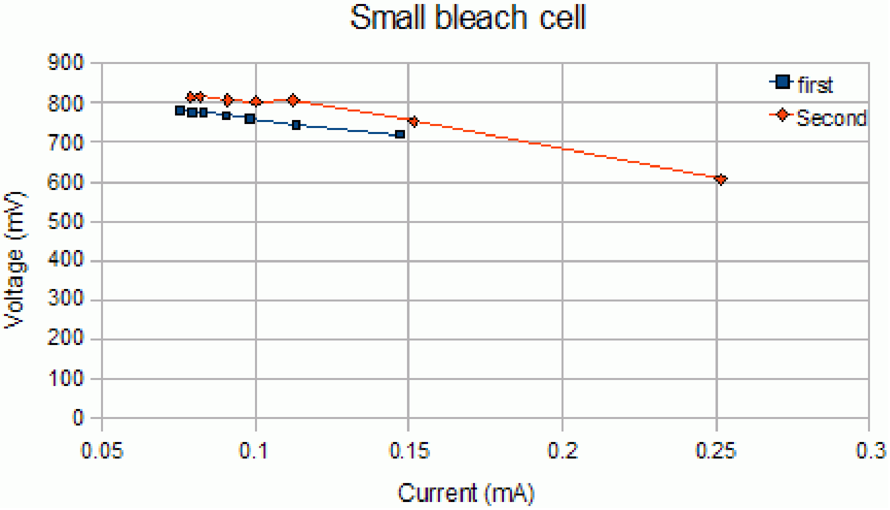
WAS more surprising however, was when I tried a third discharge run at 13:30. In this case the battery seemed to substantially recover, such that the decay was less rapid and to a higher voltage. In fact even 18 hours into this 3'rd discharge run, the voltage was practically unchanged at 155mV. At that point, the power production is 73uW.

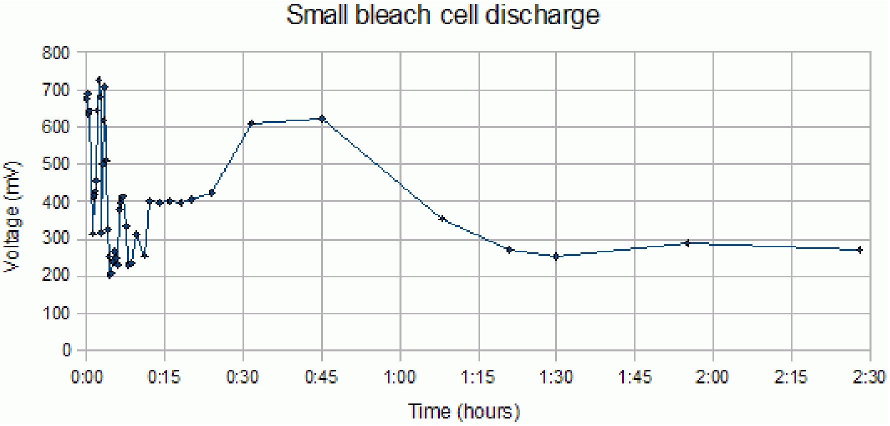
Whilst certainly a big improvement, the long term power production of 73uW means that if I wanted to produce say 10mW of power in order to produce a few mW of RF from a transmitter, I would require approximately 140 of these cells connected together. That's 140 baked bean cans, 140 lemons, a lot of soldering, and a whole LOT of mess. Somehow, I don't think I'll be giving Duracell much competition any time soon.

Bleach cell

A little bit more internet research. I read somewhere of a fellow who put bleach into an ice cube tray, with electrodes separated by kithen tissue and connecting "cells" made from each ice cube's hole, in series. So I decided to have a go with bleach. I cleaned the original "small" lemon juice cell to get rid of all the lemon juice, used a new piece of kitchen tissue to separate the electrodes, and filled it up with undiluted bleach.

Now here's a REALLY much more impressive result! Forget about lemons. Keep them for your cooking. Try bleach instead! It's cheaper than lemons, and it works MUCH better. In fact, it even SMELLS better, and less strong! You'd think not, but it's true. Too much lemon juice and the room will really start to smell. Bleach smells strong when it's been spread over a large area, but not so bad when the exposed surface area is small.





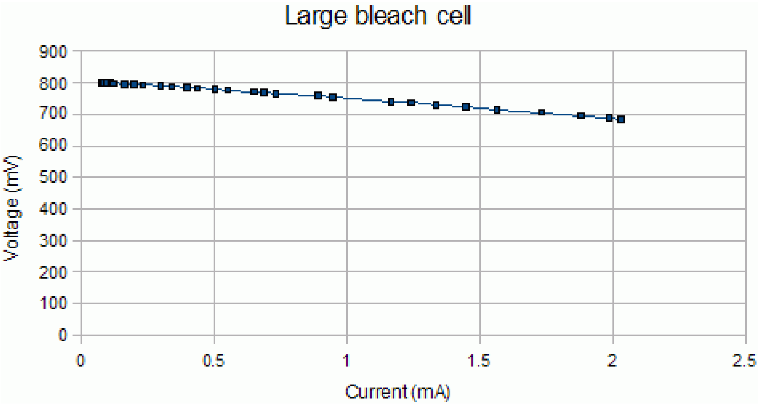
The first graph shows the voltage vs current characteristic. The first thing to notice is that the unloaded voltage of the bleach cell is 0.8V, which is substantially more than the 0.5V produced by a lemon juice electrolyte. Even this small cell can supply 0.25mA of current whilst only dropping the voltage to 606mV. I did two separate runs. In noticed that the bleach cell seems to take a while to "warm up". The performance improves, after a little use. I noticed this several times in subsequent experiments. The power production of this cell was 152uW into 330 ohms load. At smaller loads, it would be even more (but the voltage would suffer). What this means is that roughly speaking, the identical same cell is **TEN TIMES** better when filled with bleach, compared to lemon juice!

The second graph shows the discharge characteristic through a fixed 330 ohm resistor. This small bleach cell sustained a current of around 1mA for over 2 hours! You will note the wild fluctuation in voltage during this time, which would make it rather unsuitable for powering many applications. This was I suspect due to bubbles in the bleach, of which there were many. Furthermore, it was noted that the bleach partially disolved the kitchen tissue, leaving a translucent gunge in its place.

Because of the disolved kitchen tissue, I decided NOT to try bleach in my larger improved lemon juice cell (see above). It was very difficult already to get those larger spiral coils of wire neat and flat, wrapped in tissue, and somehow squeezed into the three narrow compartments of the cell. To do that again with bleach rather than lemon juice, and the attendant problems of disolving kitchen tissue, not to mention the damage to clothing... basically it really did not appeal.

LARGE bleach cell

Right. Enough of the research, now I want a practical cell that I can use to power my 40m QRSS transmitter. The kitchen tissue dissolving problem meant it isn't suitable as a means to keep the two electrodes apart. Bleach is fierce stuff and it is difficult to think of suitable separating materials which would let the bleach through, but not be rapidly degraded. On the other hand, I wanted to get as much copper and tin as close together as possible. I thought long and hard about this and the solution I came up with is effective yet very simple to make.

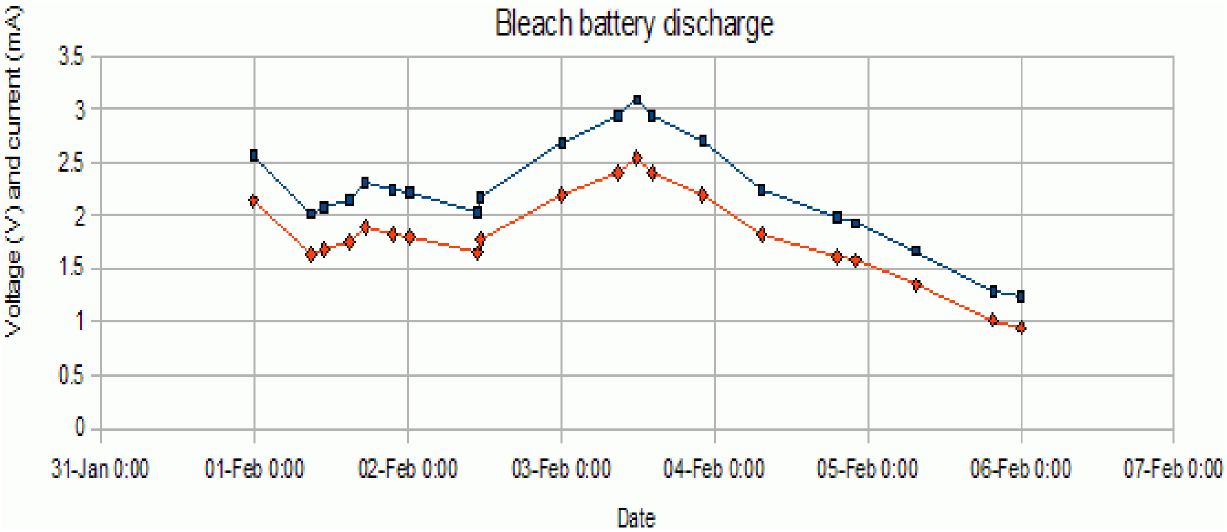

Large bleach cell

Above, the construction process. One cell uses one baked bean can. I liked baked beans, and anyway I have a collection of baked bean cans because they are great as shielding material, or as circuit substrate for "ugly" construction. Next comes the "other" electrode, for which I used copper wire again. The copper wire is from a bit of old house lighting cable, left over on a reel. I have grey and white coloured ones (on the bottom and top respectively, in the picture). I used the white wire because the copper was thicker - over 1mm diameter of copper. Stripping off the red and black insulation was a big task and I got blisters on my hands.

Each cell uses two 7-foot lenths of copper wire joined end-to-end. The join is brought OUT of the cell and soldered outside, so as to avoid corrosion breaking the contact if the wires were just twisted together. The wire is wound on a 250ml Johnson's orange juice bottle. I drink one of these at lunchtime so collected them over the course of a week. I filled the orange juice bottle with water, so that 1) it was less compressible than it would have been if it was air-filled and 2) so that it was heavy enough to rest firmly on the bottom of the can when the bleach was poured in, rather than trying to float. The third-from-left photo above shows three cells in various stages of construction. I like the orange juice bottle idea. The separation between the copper wire and tin walls is about 7mm, but no material is required between the two to keep them apart, as long as the cell is placed carefully on a horizontal surface. Furthermore, the orange juice core means that much less bleach is required, limiting it to about 150ml per cell.

The far right photo above, shows the test setup where I am characterising one bleach cell.

The results for this battery cell are at last good enough for it to be seriously considered for powering my 40m QRSS transmitter. Across my usual 330 ohm load, it produces 2mA current, dropping the cell voltage to nearly 700mV and producing 1.4mW of power.



Bleach battery

I built FOUR of these baked bean can cells, and connected them in series. One 750ml bottle of ASDA thick bleach costs 60 or 70 pence and is more than enough to fill all four cells and clean the toilet too. The voltage of the four cells is more than 3V. I connected the homebrew battery up to my 40m QRSS transmitter - it's the circuit in the bottom right corner of the photo, 3'rd from left. That circuit is built on a baked bean can tin substrate too!

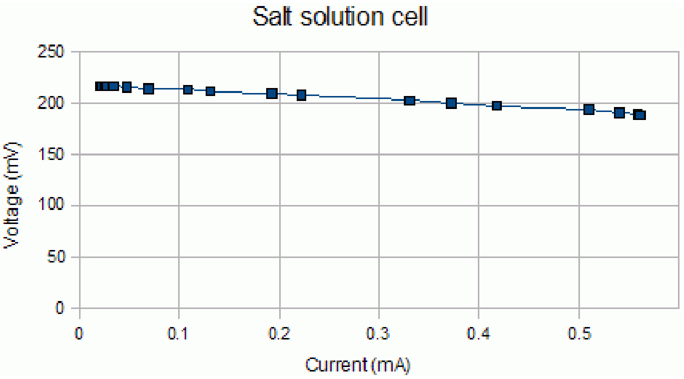
SUCCESS! With this battery powering the TX, it produced an output of about 3mW (into 50 ohm load) on frequency 7,000,850. On the first day of operation, the beacon received reception reports from G3VYZ, ON5SL, and GM0RZY. The report from ON5SL is shown as the rightermost image above. click that photo or Click here to read more about my 40m QRSS transmitter.

Demise of the bleach battery

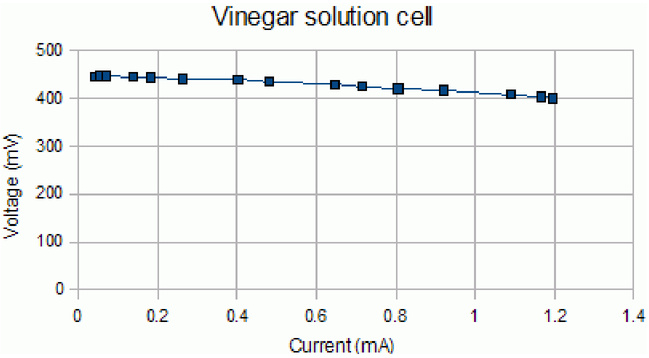
The bleach battery powered my 40m QRSS transmitter for over a week, at a peak RF power output of over 6mW. The last reception report was received on the 5'th day, after which the RF power output dropped to below a milliwatt so reception would have become increasingly difficult from my poor aerial.

The graph to the right shows the discharge of the bleach battery. The upper (blue) curve is voltage (V) and the lower (red) curve is the current (mA). One could estimate an average current of perhaps 2.2mA over this 5 day period, leading to some kind of rough estimate for the capacity of this battery of approximately 250mAh. The voltage variation during the discharge is quite harsh, and not at all even. Around day 3 the battery peaked in performance. It is interesting that the battery improved during the first few days, rather than simply discharge from its initial value.

The photos below show that some severe corrosion of the baked bean can tin occured during this experiment. After a couple of days, the corrosion started to eat through the tin at the seam between the wall of the tin and its base and I had to stand them on saucers. Two of the tins were much worse affected than the others. When I finally threw away the tins, the base of the tin could easily be broken with gentle pressure. However, the inside of the tin, and the copper wire, were clean and uncorroded. The corrosion all seemed to happen at the interface with the air, or at the join in the tin. (Last three photos are courtesy of Steve G0XAR while visiting).



Salt cell



Considering the acceptable state of the copper electrodes following the bleach battery experiment, and also encouraging reports of salt and vinegar experiments from Anders Sandström, I decided to try a salt cell. I dissolved a large amount of salt into boiling water, until I could dissolve no more. This ensures a saturated salt solution. I used fresh baked bean cans but the same bottle with copper wire wound around.

My measurements on the salt cell are shown in the graph on the right. The same standard set-up was used as for evaluation of previous cells. It seems capable of supplying a good current but the voltage is rather low, which is consistent with what Anders found.

Vinegar cell

Next comes my vinegar cell. Balsamic vinegar, to be exact, since I had no plain vinegar. I covered the bottom of a new baked bean can with a few mm of balsamic vinegar, put in the orange juice bottle with wire wound around, and filled up with water.

My measurements on this vinegar cell are in the graph on the right. It produces about twice the voltage of the salt solution, but half the voltage of the pure bleach. The toxicity of this weak solution of vinegar is considerably less than the bleach. The current provision ability is good, like the salt. I decided to connect four of these vinegar cells in series and try them on the 40m QRSS transmitter.

Finally - click here for the spreadsheet containing raw data (Open Office format)

Ideas and comments from Anders Sandström

Anders writes: After I read the page about homemade batteries on your website I decided to try to make some batteries myself.

I had some good results with using a steel can and copper wire, with vineager essence and caustic soda between. I could only get 600 mV and 3 mA of short circut current with only the vineager essence, but after i pored in some caustic soda I got over one volt from a single cell and over 60 milliamperes of short circut current! I tried to make another one, but the second one I only got 700 mV from, but still the same high current. There was also some salt in the first one from another experiment, but I found that poring salt into the soloution actually decreases the voltage, but increses the maxium current. I had also good results with using copper and zink, but my only source of zink were nails with zink on the outside (I don't know what they are called in English). However, I have no idea for how long the battery cells can last.

I have now made 2 new cells, using copper pipe and sheet metal. I used water and drain opener as electrolyte. First i took a piece of copper tube, about 6-7 cm long and wrapped it in paper as insulation. I cut some sheet metal and wrapped it around it to form another tube. I put it in a small glass jar and poured in water (about 0,75 dl) and a spoon (15 ml) of caustic soda. The voltage was almost 1,2 volts for a new cell, but i decreases fast to about 1 volt and then stays there. I measured the current of a cell when it was places in a short circut and it was over 100 mA.

I tried to recharge the cells when they were almost empty, and it worked. I used a car battery charger set to 6 V and the current was about 300 mA, probably to much because bubbles started to form and after one hour the caustic soda solution was bubbling over the jar. But it worked and cell voltage was increased to 1,1 V and I could power a mp3 player for almost 3 minutes with 2 cells in series.

I have attached 2 photos of the cells in this email. The cells were about 1 day old when they where taken.

Ideas and comments from John Beech G8SEQ

John writes: I had a look at your batteries and I'm not sure I agree with your calculations (though they might be true for your batteries). Way back in the early 1970's (which was probably before you were born) we had what was called the "Three Day Week" where everyone (except me!) worked a three day week because the power workers went on strike and we had electricity cuts left, right and centre.

People were making oil lamps that run on smoky, smelly cooking oil and animal fat, but I thought I could do better and made a battery out of houseold materials (People had panic-bought all the dry cells and most of them had gone flat by then). I used an aluminium 35 mm film can, some copper wire and household bleach.(I tried cooking salt first) This gave enough energy to light a 1.5 v torch bulb to full brightness for about 2 hrs. I then progressed to aluminium foil and jam jars, but these used up too much bleach, so I filled the jam jars with marbles (later quarz pebbles) as inert displacers. Later I used aluminium drinks cans. I have made loads since as demos to school kids and at Amateur Radio Rallies. The design was published in RadComm TT many years ago. At one rally I actually used one cell to re-charge some Nicads and then had a QSO on 2m using a 2W handheld. I did a test using a Coca Cola Can and a jumbo LED (about 40 mA) - it lit it for a fornight continuously. Then the experiment was stopped because it was end of term and the lab techs wanted to clear up!

These cells work better if you use a carbon rod as the positive electrode. The off load terminal voltage is about 2 v. Salt will produce this sort of voltage, but the cell quickly polarizes, reducing the current. By using chlorate bleach, the hydrogen produced is oxidized to water and current is maintained. Chorate bleaches also contain sodium hydroxide which attacks aluminium whether you are drawing current or not, but this soon gets used up. However, it has the effect of etching the aluminium surface increasing its area and increases the current generating capability. Several of these cells would definitely work a QRP TX directly in an emergency.

Incidentally, I wrote to Guiness in the 70's to ask them to change the design of their cans. I tried theirs and was dissapointed with the results until I found that their cans were steel with aluminium tops. I explained that this was the worst possible combination of metals from the re-cycling point of view. They did change the design and they are now all aluminium. Whether or not I had any influence on it I don't know, but I would like to think so. Conerting aluminium metal back to electricity is NOT the most efficient way of recycling aluminium, Re-melting and re-processing is the most energy efficient and therefore money efficient way.

I have been toying with the idea of making a cell which uses seawater as the electrolyte. This would be flushed with fresh seawater every time a wave came up the beach. I reckon there might be enough oxygen in the sea water to depolarize the cell. Just the job if you are stuck on a desert island with only a pile of coke cans or bits of aircraft!.
http://www.hanssummers.com/radio/homebrew/battery/index.htm

Rough science and homemade batteries

Rough science is the Open University's popular science programme on BBC2 in which five scientists are set scientific challenges, which they have to complete using natural resources. Inspired by this series, investigations involving simple batteries made from items found in the home or school laboratory can help KS3 pupils understand the origin of current, voltage and power, and the chemistry that drives batteries.

A simple battery can be made by pushing a screw (best if it is zinc-coated/galvanised) and a piece of copper into a lemon and connecting these two electrodes using wires to the device you want to power. This cell can produce enough power to run an LCD clock/watch. Using a carbon-rod electrode instead of the copper also works, and you can use potatoes as well as lemons. Three potatoes, each having a carbon rod and a galvanised screw electrode system can be wired up and will supply enough power to light a light emitting diode (LED). How a pair of electrodes produces a voltage when immersed in an electrolyte is revisited in the Box.

Sea-water batteries

In the first series of *Rough science*, broadcast in 2000, set on a remote island off the coast of Tuscany, we had to make a sea-water battery. We used galvanised (zinc-plated) screws and carbon rods as the electrodes, and saltwater as the electrolyte. While carbon is a good conductor of electricity, the chemistry that takes place at the carbon electrode is slightly different than would be the case when simply using metals. However, slightly larger potentials are produced using carbon and zinc than with copper and zinc. In such cells the metal (zinc) electrode is negative and the carbon electrode is positive.

10-Home Made Batteries

(11/2/2008)

Fig 1 *The sea-water battery*

To get round the fact that the voltage and current of such a simple cell is limited, we wired up several cells in such a way as to combine the output. One effective arrangement is shown in *Fig 1*. We used a 12-compartment ice-cube tray to hold the saltwater electrolyte, and a wooden frame support for the 12 pairs of (zinc and carbon) electrodes. We found that 'carbon rods' are much better than 'graphite rods' of the same high purity (even though they are both made of carbon). Carbon rods appear to be more porous than the shiny graphite rods. They therefore present a much greater surface area to the electrolyte. As a consequence, the electrode resistance is much lower, creating a better battery. To make a similar battery in the lab you will need:

- tap water;
- table salt (NaCl);
- 12-compartment (or similar) plastic ice-cube tray;
- piece of wood or thick card to support the electrodes; tinned copper wire (*ie* with no insulation);
- 12 galvanised screws (*ca* 5cm long), one for each cell, obtainable from any hardware store;
- 12 pencil leads (2B or softer), one for each cell, or you could use school laboratory 'carbon' rods, or salvage them by carefully dismantling old batteries.

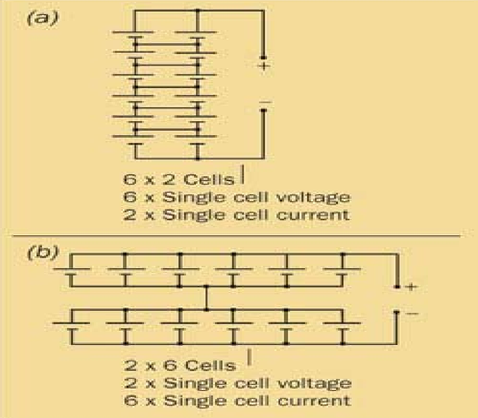
Experimental

Make up a dilute solution for the electrolyte by dissolving a teaspoon of salt in a mug of water (or if possible you could use sea water instead). Fill each of the ice-cube tray compartments three-quarters full with the salt solution. Lower the electrode pairs (one of zinc and one of carbon) into their corresponding ice-cube tray compartments to create the 12 cells. To complete the battery the electrodes will need to be wired up on the top side of the wooden support.

There are several ways of wiring up the cells. Combinations of series and parallel-wired cells will produce a range of voltages and currents. The arrangement in *Fig 2*(*a*) consists of two sets of six cells wired in series, with these two sets then wired in parallel. Such a combination would produce a total of 6 × V volts and 2 × I amps (where V and I are the voltage and current, respectively, produced by a single cell). The arrangement in *Fig 2*(*b*) consists of two sets of six parallel-wired cells, each set wired in series. Such an arrangement generates a total of 2 × V volts and 6 × I amps. The battery circuit in *Fig*

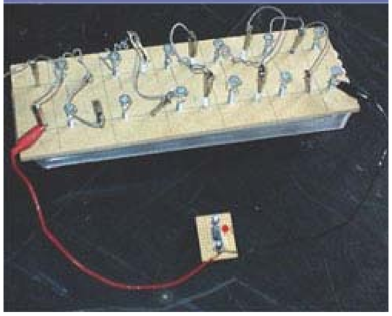
2(*a*) provides a relatively higher voltage than the circuit in *Fig 2*(*b*), and it can therefore be used to power devices that need 'high' voltages but 'low' currents - a pocket LCD calculator, an LED (and series resistor), or possibly even a pocket radio, will work well using this arrangement. (Note: in circuit *Fig 2*(*a*) you don't need the central horizontal connections between the pairs of cells for the battery to work but it does make the overall battery less prone to any bad connections there may be between the cells.)

Fig 2 Two circuits for a 12-cell battery: (a) 'high' voltage, 'low' current; (b) 'high' current, 'low' voltage



The battery circuit in *Fig 2*(*b*) will work well for devices that need a 'high' current but not a particularly large voltage. A good example would be a low-voltage 'solar cell' motor that will run on about 1 V, but needs >10 mA to turn. *Figure 3* shows a flashing LED circuit wired to the battery. This circuit requires about 3 V, at only 1 or 2 mA, to work.

Fig 3 A sea-water solution



The basic sea-water battery can drive a number of low-power devices. However, since the battery is converting chemical potential energy into electrical energy the battery will eventually fail (run down) as the chemistry at the electrode surfaces and in the electrolyte develops. The zinc on the galvanised screws dissolves over time, and zinc hydroxide may also form on the electrodes, thereby increasing the resistance. The electrodes therefore need to be cleaned each time you use the battery, so as to reduce the chemical build-up that inevitably occurs.

Further activities

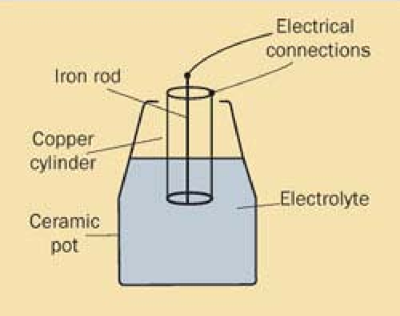
Students could use different electrode materials to assess the range of voltages and currents that can be obtained. They could also see what effect changing the surface area of the electrodes has, and what happens when they use different electrolytes (try lemon juice or vinegar, for example). Other experiments would be to find out if the current produced by the battery depends on electrolyte concentration, and does the battery fail if you over-dilute or over-strengthen the concentration? Would an increase or decrease in electrolyte temperature affect the voltage and/or current produced, and if so, why? Does this help to explain why you can temporarily rejuvenate used batteries by putting them on a warm radiator?

In a recent series of *Rough science*, filmed in Zanzibar (shown on BBC2 in March 2005), we were challenged to make an emergency life jacket incorporating LEDs that would be activated and light on contact with sea water. We simply modified the ice-cube tray sea-water battery by placing small pieces of sponge between the electrodes in each of the tray compartments. When the life jacket went into the sea, the individual sponges soaked up sea water, thereby completing an electrical circuit and cell chemistry in each cell. The current that was produced was then used to power several LEDs.

The Baghdad battery

In 1800, Count Alessandro Volta made what was thought to be the first device that approximated to a modern battery. He found from experiments that different metals in contact with each other via paper strips soaked in saltwater generated electricity. He built a stack of alternating discs of zinc and silver, separated by pieces of blotting paper soaked in saltwater. When he attached a wire to the top and bottom discs he found he could measure a voltage and a current. This device became known as a 'voltaic pile'. But was Volta's pile the first battery? Some people believe that batteries have been around for more than 2000 years. Their 'evidence' comes from Baghdad.

Fig 4 *The Baghdad battery*



In 1938, Von Wilhelm Konig, an archaeologist working at the Baghdad Iraq Museum, claimed to have discovered a much older battery than Volta's. Konig claimed that it was made by the Mesopotamians as long ago as 200BC. His 'Baghdad battery', shown in *Fig 4*, consisted of a ceramic pot about 14 cm high, in which was placed a cylinder of copper encasing an iron rod. The iron rod was surrounded by an oil/pitch-based insulator to separate the two. In the pot, Konig found mysterious evidence of organic material.

We recently made a copy of a Baghdad battery. Our device used the same electrodes as the original, with vinegar (which would have been available at the time) as the electrolyte. Our Baghdad battery produced about 1V at 10mA. Such a system did indeed work as a battery, but was this the Mesopotamians' intention over 2000 years ago - or did the original device have some other, quite unconnected purpose?

It seems unlikely to us that the Mesopotamians intended to make a battery; an observation supported by the fact that no wires were found with the device (though these could easily have rusted away over time). On the other hand, if they were using them as batteries, what might their purpose have been? One suggestion is that the Mesopotamians may have wired up many such batteries so that they could electrify holy statues - to give them seemingly supernatural powers. This is a nice idea, but electric shocks depend on high voltages, and hundreds of batteries would have been needed to produce anything approaching an impressive shock.

Another theory is that the devices were used to produce small voltages that could have been used in acupuncture (a therapy in use at the time). Indeed, some of the batteries were actually found next to fine needles. It is possible that needles applied to the skin and wired so as to generate a few volts might have produced a therapeutic effect.

In the course of our own recent investigations, we have used the voltage from several Baghdad batteries wired up in series to drive a simple electrolysis reaction. The idea was to electroplate some copper metal using a cell containing vinegar, silver and copper electrodes. Powered by the Baghdad batteries, silver ions are produced at the silver electrode (we used a silver bracelet), which then travel through solution to form a thin layer of silver metal on the (cheaper) copper electrode. Given enough time, we found we could successfully silver-plate the copper.

Could the ancient Mesopotamians have used a similar process to plate intricately designed copper statues with a layer of silver? Unfortunately, no proof for this wonderfully appealing possibility has yet been found in the archaeological records. The origin, use and purpose of Baghdad batteries remains a mystery.

(*Note*: many companies that sell electronic components stock 'ultra bright' LEDs as well as 'solar-cell' motors that work on very low voltages and currents. These would be suitable for use with the experimental batteries described in this article.)

Batteries revisited

When a metal is immersed in an electrolyte, positive metal ions are formed at the surface of the electrode. These ions pass into solution, making the electrode more negative as the positive ions move away. There will come a time, however, when the resulting, negatively charged electrode will start to attract back the oppositely charged metal ions.

A dynamic equilibrium is eventually set up between those ions leaving and those returning to the metal surface. How far the equilibrium goes one way or the other depends on the reactivity of the metal involved.

A cell has two electrodes, and a similar process takes place at the second electrode. If this metal is the same as the first, then each electrode will charge to the same extent, and there will be no resulting charge difference between the two. There will be no attractive force between them and no potential difference or voltage will be developed.

However, if the electrodes are made of different metals, different equilibria will be set up on each, with one electrode becoming charged to a greater extent than the other. Because of this charge difference, electrons will move towards the more positive electrode when a circuit is formed. This attractive potential is the voltage that we measure between the electrodes and the origin of the cell's power.

If a wire is connected between the two electrodes to form an electrical circuit potential energy (work that can be done), which the moving electrons will have once a circuit is established, is the voltage of the battery.

V = Volts = energy per charge/electron
(joules/coulomb)

The amount of charge passing per unit time is the current:

A = Amp = rate of charge passing
(coulombs/s)

Since the charge on the electron is tiny (1.6×10^{-19} C), even a current of 1/1000 Amp (1 mA, just enough to light an LED) represents a massive number of electrons moving, *ca* 1×10^{15}/s. If we multiply the voltage between the electrodes by the current that is passing, we get the power of the cell:

$P = V \times A$

= (joules/coulomb) × (coulomb/ second)
= joules/second

The power is the amount of work done per second.

Battery limits

The voltage of the cell is determined by the difference between the individual standard electrode potentials of the two electrodes involved. However, in practice, this is only true in the ideal case in which the voltage is measured without drawing any appreciable current. This is the case when using a very high resistance voltmeter, but not the case when we use a battery to drive a light or a radio for example. In practice as we draw current from the cell we see that the voltage drops away.

This limitation of a real life battery can be attributed to at least two factors: the nature of the electrolyte and the electrical resistance of the electrodes. The dependency of cell voltage on the electrode potentials explains why very similar results can be obtained by using different electrolytes (for example, sea water, vinegar, sulphuric acid, and even urine). The cell voltage is also dependent on the concentration and type of ions in the electrolyte, the limiting case being when there are no ions present at all (*eg* in a non-ionic liquid or a battery that has dried out).

Assuming that the electrolyte is above a threshold concentration, the surface resistance of the electrodes also has to be considered. This is the electrical resistance made between the solid electrode and the solution (by the passage of the electrons and ions). If the electrode resistance is low, the cell will produce a nearly constant voltage as more and more current flows. If the resistance is high, the voltage will appear to drop significantly as current is drawn from the battery. The internal resistance of cells is a major limiting factor in the application and usefulness of real batteries.

http://www.rsc.org/Education/EiC/issues/2006Jan/Rough.asp

Building the electrochemical series

Arranging redox equilibria in order of their E° values

The electrochemical series is built up by arranging various redox equilibria in order of their standard electrode potentials (redox potentials). The most negative E° values are placed at the top of the electrochemical series, and the most positive at the bottom.

For this introductory look at the electrochemical series we are going to list the sort of metal / metal ion equilibria that we looked at on the previous page (plus the hydrogen equilibrium) in order of their E° values. This will be extended to other systems on the next page.

The electrochemical series

equilibrium	E° (volts)
$Li^+_{(aq)} + e^- \rightleftharpoons Li_{(s)}$	-3.03
$K^+_{(aq)} + e^- \rightleftharpoons K_{(s)}$	-2.92
$Ca^{2+}_{(aq)} + 2e^- \rightleftharpoons Ca_{(s)}$	-2.87
$Na^+_{(aq)} + e^- \rightleftharpoons Na_{(s)}$	-2.71

$Mg^{2+}_{(aq)} + 2e^- \rightleftharpoons Mg_{(s)}$	-2.37
$Al^{3+}_{(aq)} + 3e^- \rightleftharpoons Al_{(s)}$	-1.66
$Zn^{2+}_{(aq)} + 2e^- \rightleftharpoons Zn_{(s)}$	-0.76
$Fe^{2+}_{(aq)} + 2e^- \rightleftharpoons Fe_{(s)}$	-0.44
$Pb^{2+}_{(aq)} + 2e^- \rightleftharpoons Pb_{(s)}$	-0.13
$2H^{+}_{(aq)} + 2e^- \rightleftharpoons H_{2(g)}$	0
$Cu^{2+}_{(aq)} + 2e^- \rightleftharpoons Cu_{(s)}$	+0.34
$Ag^{+}_{(aq)} + e^- \rightleftharpoons Ag_{(s)}$	+0.80
$Au^{3+}_{(aq)} + 3e^- \rightleftharpoons Au_{(s)}$	+1.50

A note on the hydrogen value

Remember that each E° value shows whether the position of the equilibrium lies to the left or right of the hydrogen equilibrium.

That difference in the positions of equilibrium causes the number of electrons which build up on the metal electrode and the platinum of the hydrogen electrode to be different. That produces a potential difference which is measured as a voltage.

Obviously if you connect one standard hydrogen electrode to another one, there will be no difference whatsoever between the positions of the two equilibria. The number of electrons built up on each electrode will be identical and so there will be a potential difference of zero between them.

Oxidation / reduction and the electrochemical series

Reminders about oxidation and reduction

Oxidation and reduction in terms of electron transfer

Remember that in terms of electrons:

OIL RIG

oxidation is loss reduction is gain

Now apply this to one of the redox equilibria:

$$Mg^{2+}_{(aq)} + 2e^- \rightleftharpoons Mg_{(s)}$$

When solid magnesium forms its ions, it loses electrons. The magnesium is being oxidised.

Taking another example . . .

$$Cu^{2+}_{(aq)} + 2e^- \rightleftharpoons Cu_{(s)}$$

When the copper(II) ions gain electrons to form copper, they are being reduced.

Reducing agents and oxidising agents

A ***reducing agent*** reduces something else. That must mean that it gives electrons to it.

Magnesium is good at giving away electrons to form its ions. Magnesium must be a good reducing agent.

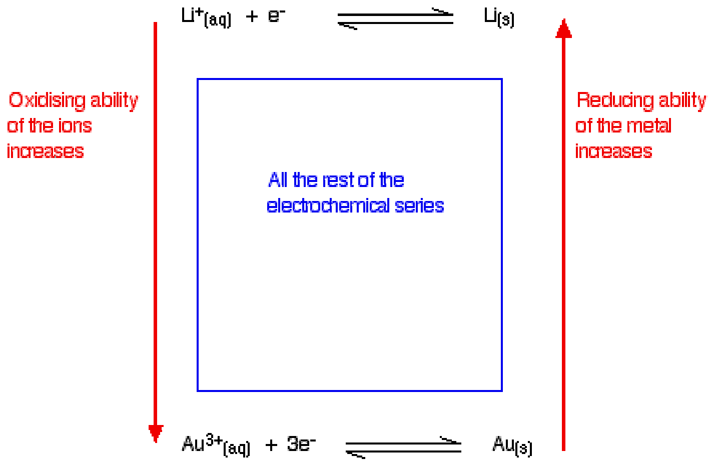
An ***oxidising agent*** oxidises something else. That must mean that it takes electrons from it.

Copper doesn't form its ions very readily, and its ions easily pick up electrons from somewhere to revert to metallic copper. Copper(II) ions must be good oxidising agents.

Summarizing this on the electrochemical series

Metals at the top of the series are good at giving away electrons. They are good reducing agents. The reducing ability of the metal increases as you go up the series.

Metal ions at the bottom of the series are good at picking up electrons. They are good oxidising agents. The oxidising ability of the metal ions increases as you go down the series.



Judging the oxidising or reducing ability from E° values

The more negative the E° value, the more the position of equilibrium lies to the left - the more readily the metal loses electrons. The more negative the value, the stronger reducing agent the metal is.

The more positive the E° value, the more the position of equilibrium lies to the right - the less readily the metal loses electrons, and the more readily its ions pick them up again. The more positive the value, the stronger oxidising agent the metal ion is.

REDOX POTENTIALS FOR NON-METAL AND OTHER SYSTEMS

This page explains how non-metals like chlorine can be included in the electrochemical series, and how other oxidising and reducing agents can have their standard electrode potentials (redox potentials) measured and fitted into the series

Measuring redox potentials for more complicated systems

Systems involving gases

The obvious example here is chlorine. Chlorine is well known as an oxidising agent. Since the electrochemical series is about ranking substances according to their oxidising or reducing ability, it makes sense to include things like chlorine.

This time we are measuring the position of this equilibium relative to the hydrogen equilibrium.

$$Cl_{2(g)} + 2e^- \rightleftharpoons 2Cl^-_{(aq)}$$

Notice that the equilibrium is still written with the electrons on the left-hand side of the equation. That's why the chlorine gas has to appear on the left-hand side rather than on the right (which is where the metals and hydrogen appeared).

How can this equilibrium be connected into a circuit? The half-cell is built just the same as a hydrogen electrode. Chlorine gas is bubbled over a platinum electrode, which is immersed in a solution containing chloride ions with a concentration of 1 mol dm^{-3}.

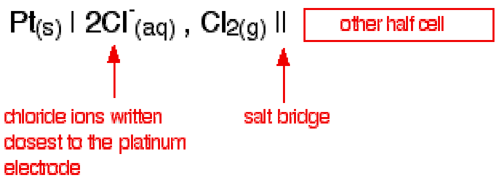
The conventional way of writing the whole cell looks like this.

$$Pt_{(s)}\ [H_{2(g)}]\ |\ 2H^+_{(aq)}\ ||\ Cl_{2(g)}\ ,\ 2Cl^-_{(aq)}\ |\ Pt_{(s)}$$

$$E^o = +1.36\text{ v}$$

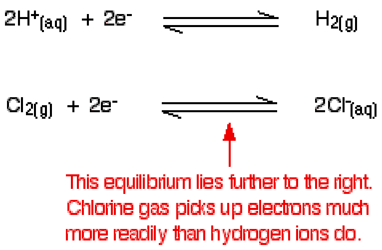
Notice the way that the chlorine half cell is written. The convention is that the substance losing electrons is written closest to the electrode. In this case, the chloride ions are losing electrons.

If you had the chlorine half cell on the left-hand side in a different situation, then the convention still has to hold. The half cell would then be written:



What does the E° value show in the Cl_2 / Cl^- case?

The value is positive and moderately high as E° values go. That means that the position of the Cl_2 / Cl^- equilibrium lies more to the right than the hydrogen equilibrium. Chlorine is much more likely to pick up electrons than hydrogen ions are.



Chlorine is therefore quite good a removing electrons from other things. It is a good oxidising agent.

Measuring redox potentials for other systems

The Fe^{2+} / Fe^{3+} system

Iron(II) ions are easily oxidised to iron(III) ions, and iron(III) ions are fairly easily reduced to iron(II) ions. The equilibrium we are interested in this time is:

$$Fe^{3+}_{(aq)} + e^- \rightleftharpoons Fe^{2+}_{(aq)}$$

To measure the redox potential of this, you would simply insert a platinum electrode into a beaker containing a solution containing both iron(II) and iron(III) ions (1 mol dm^{-3} with respect to both), and couple this to a hydrogen electrode.

The cell diagram would look like this:

$$Pt_{(s)}\ [H_{2(g)}]\ |\ 2H^{+}_{(aq)}\ ||\ Fe^{3+}_{(aq)}\ ,\ Fe^{2+}_{(aq)}\ |\ Pt_{(s)}$$

$$E^{o} = +0.77\ v$$

Notice that the E° value isn't as positive as the chlorine one. The position of the iron(III) / iron(II) equilibrium isn't as far to the right as the chlorine equilibrium. That means that Fe^{3+} ions don't pick up electrons as easily as chlorine does. Chlorine is a stronger oxidising agent than Fe^{3+} ions.

Potassium dichromate(VI) as an oxidising agent

A commonly used oxidising agent, especially in organic chemistry, is potassium dichromate(VI) solution acidified with dilute sulphuric acid. The potassium ions are just spectator ions and aren't involved in the equilibrium in any way.

The equilibrium is more complicated this time because it contains more things:

$$Cr_2O_7^{2-}{}_{(aq)} + 14H^{+}_{(aq)} + 6e^{-} \rightleftharpoons 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$$

The half cell would have a piece of platinum dipping into a solution containing all the ions (dichromate(VI) ions, hydrogen ions and chromium(III) ions) all at 1 mol dm^{-3}.

There is yet another convention when it comes to writing these more complicated cell diagrams. Where there is more than one thing on either side of the equilibrium, square brackets are written around them to keep them tidy. The substances losing electrons are written next to the electrode, just as before.

$$\text{hydrogen electrode}\ ||\ [Cr_2O_7^{2-}{}_{(aq)} + 14H^{+}_{(aq)}]\ ,\ [2Cr^{3+}_{(aq)} + 7H_2O_{(l)}]\ |\ Pt_{(s)}$$

$$E^{o} = +1.33\ v$$

Including these new redox potentials in the electrochemical series

These values can be slotted seamlessly into the electrochemical series that so far has only included metals and hydrogen.

An updated electrochemical series

equilibrium	E° (volts)
$Li^{+}_{(aq)} + e^{-} \rightleftharpoons Li_{(s)}$	-3.03

$K^+_{(aq)} + e^- \rightleftharpoons K_{(s)}$	-2.92
$Ca^{2+}_{(aq)} + 2e^- \rightleftharpoons Ca_{(s)}$	-2.87
$Na^+_{(aq)} + e^- \rightleftharpoons Na_{(s)}$	-2.71
$Mg^{2+}_{(aq)} + 2e^- \rightleftharpoons Mg_{(s)}$	-2.37
$Al^{3+}_{(aq)} + 3e^- \rightleftharpoons Al_{(s)}$	-1.66
$Zn^{2+}_{(aq)} + 2e^- \rightleftharpoons Zn_{(s)}$	-0.76
$Fe^{2+}_{(aq)} + 2e^- \rightleftharpoons Fe_{(s)}$	-0.44
$Pb^{2+}_{(aq)} + 2e^- \rightleftharpoons Pb_{(s)}$	-0.13
$2H^+_{(aq)} + 2e^- \rightleftharpoons H_{2(g)}$	0
$Cu^{2+}_{(aq)} + 2e^- \rightleftharpoons Cu_{(s)}$	+0.34
$Fe^{3+}_{(aq)} + e^- \rightleftharpoons Fe^{2+}_{(aq)}$	+0.77
$Ag^+_{(aq)} + e^- \rightleftharpoons Ag_{(s)}$	+0.80
$Cr_2O_7^{2-}{}_{(aq)} + 14H^+_{(aq)} + 6e^- \rightleftharpoons 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$	+1.33
$Cl_{2(g)} + 2e^- \rightleftharpoons 2Cl^-_{(aq)}$	+1.36
$Au^{3+}_{(aq)} + 3e^- \rightleftharpoons Au_{(s)}$	+1.50

By coincidence, all the new equilibria we've looked at have positive E° values. It so happens that most of the equilibria with *negative* E° values that you meet at this level are ones involving simple metal / metal ion combinations.

An update on oxidising agents

Remember:

- The more positive the E° value, the further the position of equilibrium lies to the right.
- That means that the more positive the E° value, the more likely the substances on the left-hand side of the equations are to pick up electrons.
- A substance which picks up electrons from something else is an oxidising agent.
- The more positive the E° value, the stronger the substances on the left-hand side of the equation are as oxidising agents.

Of the new ones we've added to the electrochemical series:

- Chlorine gas is the strongest oxidising agent (E° = +1.36 v).
- A solution containing dichromate(VI) ions in acid is almost as strong an oxidising agent (E° = +1.33 v).
- Iron(III) ions are the weakest of the three new ones (E° = +0.77 v).
- None of these three are as strong an oxidising agent as Au^{3+} ions (E° = +1.50 v).

There will be more to say about this later in this series of pages.

See http://www.chemguide.co.uk/physical/redoxeqia/nonmetal.html#top

Riddle of 'Baghdad's batteries'

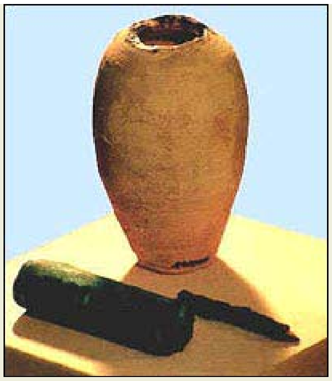
Arran Frood investigates what could have been the very first batteries and how these important archaeological and technological artifacts are now at risk from the impending war in Iraq.

War can destroy more than a people, an army or a leader. Culture, tradition and history also lie in the firing line.

Iraq has a rich national heritage. The Garden of Eden and the Tower of Babel are said to have been sited in this ancient land.

In any war, there is a chance that priceless treasures will be lost forever, articles such as the "ancient battery" that resides defenceless in the museum of Baghdad.

For this object suggests that the region, whose civilizations gave us writing and the wheel, may also have invented electric cells - two thousand years before such devices were well known.



"I don't think anyone can say for sure what they were used for, but they may have been batteries because they do work"

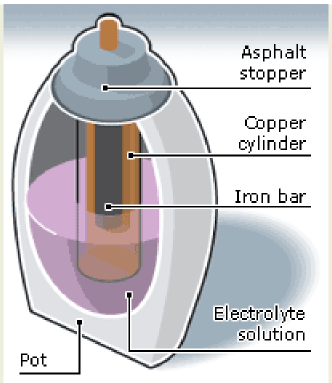
Dr Marjorie Senechal

Biblical clues

THE KEY COMPONENTS

It was in 1938, while working in Khujut Rabu, just outside Baghdad in modern day Iraq, that German archaeologist Wilhelm Konig unearthed a five-inch-long (13 cm) clay jar containing a copper cylinder that encased an iron rod.

The vessel showed signs of corrosion, and early tests revealed that an acidic agent, such as vinegar or wine had been present.



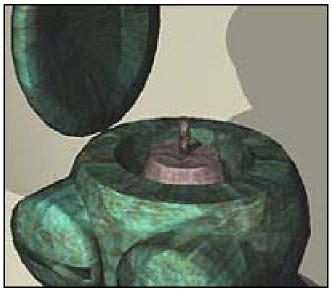
Batteries dated to around 200 BC
Could have been used in gilding

[Click here for more on what the batteries might have been used for](#)

Enough zap

It is certain the Baghdad batteries could conduct an electric current because many replicas have been made, including by students of ancient history under the direction of Dr Marjorie Senechal, professor of the history of science and technology, Smith College, US.

"I don't think anyone can say for sure what they were used for, but they may have been batteries because they do work," she says. Replicas can produce voltages from 0.8 to nearly two volts.



Could the batteries have been placed inside idols?
(*Image by Stephanie Yong*)

Making an electric current requires two metals with different electro potentials and an ion carrying solution, known as an electrolyte, to ferry the electrons between them.

Connected in series, a set of batteries could theoretically produce a much higher voltage, though no wires have ever been found that would prove this had been the case.

But he is sure the objects are batteries and that there could be more of them to discover. "Other examples may exist that lie in museums elsewhere unrecognised".

He says this is especially possible if any items are missing, as the objects only look like batteries when all the pieces are in place.

Possible uses

Some have suggested the batteries may have been used medicinally.

The ancient Greeks wrote of the pain killing effect of electric fish when applied to the soles of the feet.

The Chinese had developed acupuncture by this time, and still use acupuncture combined with an electric current. This may explain the presence of needle-like objects found with some of the batteries.

But this tiny voltage would surely have been ineffective against real pain, considering the well-recorded use of other painkillers in the ancient world like cannabis, opium and wine.

Other scientists believe the batteries were used for electroplating - transferring a thin layer of metal on to another metal surface - a technique still used today and a common classroom experiment.

This idea is appealing because at its core lies the mother of many inventions: money.

In the making of jewellery, for example, a layer of gold or silver is often applied to enhance its beauty in a process called gilding.

http://news.bbc.co.uk/1/hi/sci/tech/2804257.stm

Homemade batteries are commonly made of common items found around the house. Almost any fluid or moist object containing sufficient ions (charged particles) can serve as the electrolyte for a cell. It is possible to generate small units of electricity from a lemon, potato or glass of soft drink by placing two electrodes into them. A clock by name "'two-potato clock" is commonly available in hobby and toy shops. It contains a pair of cells (each with a potato or lemon with two electrodes) wired in series to form a battery with adequate current to operate a digital clock.

When acids are present in water, they produce ions that are the same as the charged particles in electric current. For example, lemon juice contains citric acid. The lemon battery is formed by inserting two metal electrodes (zinc as anode and copper as cathode) into the lemon juice without them touching each other. A potato battery works the same way as a lemon battery. Here, the electrolyte is phosphoric acid. Homemade batteries can also be built from other vegetables and fruits.

Homemade cells of these types have no real practical use, as they generate extremely lower current than commercial batteries. Because of the need for frequent substitution of the fruit or vegetable, they are also inconvenient in most situations. However, the cost of homemade batteries is much lower than commercial batteries.

Clorox bleach battery is a powerful type of homemade battery that can be made using Clorox mixture. It lasts only a week or less, since its electrodes rust very quickly. In the "tap water battery" two special metals (usually made of stainless steel) serve as electrodes it that can be used to light LED bulbs for many days or weeks. There is no need of charging this battery,. Just refuel it with tap water every 4 to 7 weeks.

http://ezinearticles.com/?Homemade-Batteries&id=353827

Saltwater Battery

Introduction

But using safe, readily available materials, you can make a simple battery that you can use to power buzzers and clocks.

Material

- Nonmetallic cup (Styrofoam, paper, or plastic work well)
- Salt, water, vinegar, and bleach
- A variety of metal strips or pieces:
  - Aluminum (aluminum foil)
    Copper (household electric wire or water pipe)
    Brass (brads or keys)
    Iron (uncoated nails)
    Silver (silverware)
    Zinc (galvanized nails)
    Graphite (large mechanical pencil filler, artists graphite)
- Alligator clip leads (available at Radio Shack)
- DC Mini Buzzer (available at Radio Shack)
- LCD clock (like the cheap stick-on clocks or cheap child's watch)
- Homemade ammeter or commercial ammeter and voltmeter

To Do and Notice

Fill the cup about 3/4 full of water. Add about a teaspoon of salt, about a teaspoon of vinegar, and a few drops of bleach. Into this solution put strips of two different metals. (Copper and aluminum are a good pair to start with.) Make sure the two metals do not touch each other. You can clip the metals to the top of the cup with the alligator clips, but don't let the clips touch the liquid. You now have a simple low-power battery.

You can test your battery using the homemade ammeter (see below) that you built. Connect a wire from one of the metal strips to one end of the coil of wire in your ammeter and connect another wire from the other metal strip to the other end of the coil. When the magnet twists, that indicates your homemade battery is working. You can also use a commercial ammeter.

You can test the relative strength of different metals for attracting electrons by putting various pairs of metals into the solution and watching the direction that the magnet on your homemade ammeter swings. A metal that is positive in one pairing may be negative in another. Try listing the metals in order from the strongest to the weakest. The order is known as the electromotive series. Measure the voltage produced by your battery using a voltmeter, notice how the voltage depends on both of the metals you use as electrodes.

You can also experiment with different proportions of the ingredients in your liquid solution.

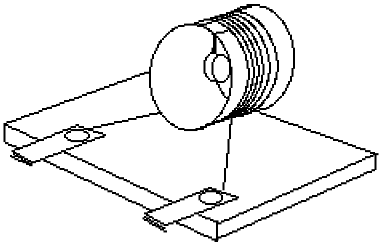
With some of the stronger homemade batteries, you can power a small buzzer or an LCD clock. (Take out the battery in the clock and connect your saltwater battery in its place.) If your battery isn't strong enough to power a clock or buzzer, you may need to wire two homemade batteries together in series, connecting the plus of one battery to the minus of the other.

http://www.exo.net/~pauld/summer_institute/summer_day15current/saltwaterbattery.html

Homemade Ammeter

Introduction

An ammeter is a device that detects an electric current. With some readily available materials, you can build your own ammeter and use it to measure current produced by batteries including homemade batteries and generators.



Ammeter

Material

- Magnet wire, 10 meters or more of 22 gauge or higher, (available from Radio Shack). (The higher the gauge, the finer the wire, and the harder it will be to wind.)
- two small disk magnets (1 cm diameter available from Radio Shack)
- thread or fishing line
- a cardboard tube (e.g. from a toilet paper roll.)
- a Base, a piece of corrugated cardboard about 10 cm x 10 cm (For a more rugged meter use wood.)
- Hot melt glue (or staples)
- Aluminum foil, two 5 cm squares
- Tacks or pushpins
- Two alligator clip leads (available at Radio Shack)
- Sandpaper

- AA battery (almost any battery will work)

Assembly

Cut a 4 cm (1.5 inch) length from the tube.
Wind a coil of at least 100 turns of magnet wire around the section of cardboard tube, leave at least 10 cm of wire free at each end of the coil. Use masking tape or hot melt glue to hold the coil in place on the tube.

Hot melt glue, or staple, the paper tube to the base.

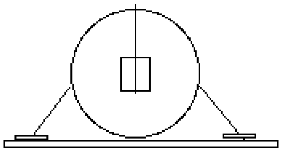
Sandpaper the ends of the magnetic wire to remove the insulating layer of enamel. The ends of the wire should appear as shiny copper.

Take one free end of the wire from the coil make it into a loop and twist the loop several times. Fold the aluminum foil around the looped bare ends of the wire until it makes a rectangle, several layers thick and about 1 cm x 2.5 cm. Use a pushpin or staple the aluminum foil pad to the cardboard. Do the same with the other free end of the wire. Mark a + sign near one end of the wire, it does not matter which end.

Hang the magnet from a string in the center of the coil: ,make a string sandwich, hold the string between the two disk magnets. Make a slit in the center of the top of the tube, run the slit up to the edge of the coil. Make another slit on the other side of the coil. Hang the magnet by slipping its thread through the first slit then slip the thread through the second one. The friction of the thread going through two slits will hold the magnet in place. Adjust the thread so that the magnet hangs in the middle of the coil.

To do and notice

The hanging magnet aligns itself with the earth's magnetic field, just like a compass needle. (see the activity titled, "Where's North?")
To use the ammeter, turn the coil so that the coil is lined up north and south. When you look in the end of the tube you should see the edge of the magnet.



End view of the ammeter with the magnets aligned with the Earth's magnetic field.

Attach the battery to the leads. Attach the + side of the battery to the + lead of the meter. The hanging magnet should turn so that one face is toward the aluminum pads. Attach a piece of tape to that face and print + on the tape.
Reverse the connections to the battery the magnet should rotate the opposite direction.

Your ammeter is very sensitive. The magnets in ours deflect 45 degrees when 10 milliamps flow through them. To measure the sensitivity of your meter connect a calibrated ammeter in series with a battery and a variable resistor. Change the resistance until the ammeter magnet turns 45 degrees read the current on the calibrated ammeter

You can use your ammeter to measure the current produced by your own lemon batteries or home-made generators.

What's Going On?

The electric current running through the coil of wire produces a magnetic field. The coil has a north pole end and a south pole end. The magnetic field of the electromagnet pushes on the the hanging magnet, making it twist. The hanging magnet is held in its no-current position by the earth's magnetic field. The stronger the current in your coil, the stronger the magnetic field produced by the coil and the more the magnet twists.

When the magnetic field of the electromagnet equals the magnetic field of the earth the magnets will hang at a 45 degree angle from a line down the axis of the tube.

Going Further

Measure the current through a lamp from a AA battery, try a 2 volt christmas tree light from a string of 50 lights.

Measure the current through a motor made by a AA battery.

Measure the current from a lemon battery.

Measure the current from a solar cell.

Alternative construction

Build the same as above but use PVC tubes 1 inch in diameter instead of cardboard tubes.

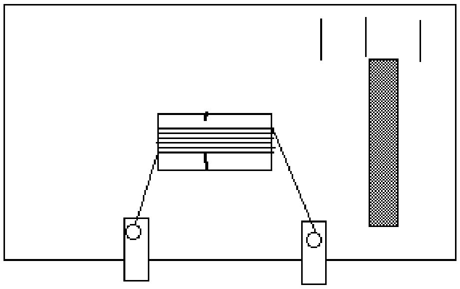
or

with a compass

Wrap a coil of 100 turns of wire around the compass. Wind the coil so that it passes over the north and south end of the compass, and yet still allows you to see the compass needle.

Making the ammeter quantitative

Replace the earth with the largest magnet you can find.



A large magnet can be used to calibrate the ammeter.

Use a calibrated ammeter in series with your ammeter and move the large magnet until the central disk magnets make a 45 degree angle with the axis of the tube. Then make a mark on the base to indicate the position of the large magnet.

http://www.exo.net/~pauld/summer_institute/summer_day15current/ammeter.html

How can I make an electrical battery at home?

The principle of this is actually closer to chemistry than to physics, but with a few easily acquired substances, it is possible to create your own battery. (Actually, to be more precise, a cell, as a battery is a collection of cells).

But first, a bit of theory behind how it works. When a rod made of a transition metal, such as copper, is dipped into a solution of its own ions, such as copper sulfate, an equilibrium is set up between the metal in its solid state and the metal as aqueous ions. (A certain proportion of the metal atoms exist in the rod as solid atoms and a certain proportion exist in the solution as aqueous copper 2+ ions).

When some of the metal on the rod dissolves to become aqueous ions, electrons are given up by the atom (A copper 2+ ion has loses 2 electrons) and build up on the rod giving a negative electrical charge. This is called a half cell.

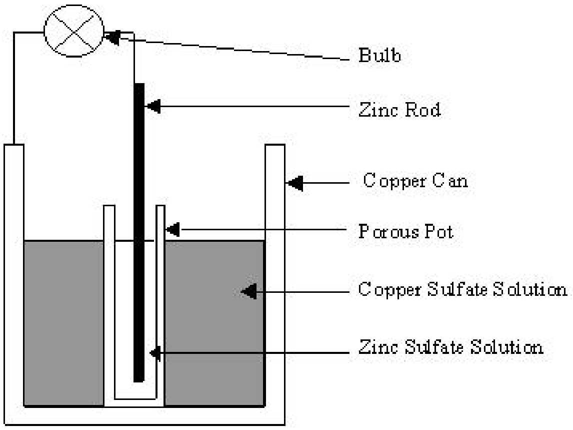
The size of the negative charge depends on how good a reducing agent the metal is. (Reducing agents donate electrons in reactions). So if we take two half cells made of two different metals and join them together, as one will have a greater negative potential than the other, a potential difference is set up between the two metal rods. As a potential difference cause electrons to flow (from the rod with a greater negative charge to the rod with a smaller negative charge), a cell will have been created.

When a copper half cell and a zinc half cell are joined together, they can generate enough current to light a bulb and it is the basis of a cell called the Daniell Cell.

Finally, now you know the theory, here’s how you actually create a Daniell Cell. (See Diagram)

10-Home Made Batteries

(11/2/2008)



Take a copper can filled with copper sulfate solution. Now take a smaller POROUS pot (so that the moving electrons can pass through), full of a zinc sulphate solution, and place it inside the copper can. Ensure that the zinc sulphate does not pour over and mix with the copper sulphate solution. Now place a zinc rod so that it is partially submerged in the zinc solution. Connect a bulb by one of its terminals to the top end of the zinc rod with a wire, and finally connect the other terminal of the bulb to the copper can with another wire. And voila! You have made a Daniell Cell, your very own battery!

http://www.physlink.com/Education/AskExperts/ae314.cfm?CFID=995968&CFTOKEN=22339656

Homemade Batteries How they Work

"When a rod made of a transition metal, such as copper, is dipped into a solution of its own ions, such as copper sulfate, an equilibrium is set up between the metal in its solid state and the metal as aqueous ions. (A certain proportion of the metal atoms exist in the rod as solid atoms and a certain proportion exist in the solution as aqueous copper 2+ ions). When some of the metal on the rod dissolves to become aqueous ions, electrons are given up by the atom (A copper 2+ ion has loses 2 electrons) and build up on the rod giving a negative electrical charge. This is called a half cell. The size of the negative charge depends on how good a reducing agent the metal is. (Reducing agents donate electrons in reactions). So if we take two half cells made of two different metals and join them together, as one will have a greater negative potential than the other, a potential difference is set up between the two metal rods. As a potential difference cause electrons to flow (from the rod with a greater negative charge to the rod with a smaller negative charge), a cell will have been created. When a copper half cell and a zinc half cell are joined together, they can generate enough current to light a bulb and it is the basis of a cell called the Daniell Cell. "

Here is another web page that shows how to make a simple battery that is strong enough to generate 1 Volt or 100 mA, which can power a light or a small motor--
http://www.exo.net/~jyu/activities/Al-air.pdf

http://urbansubsistenceliving.blogspot.com/2008/03/homemade-batteries.html
http://www.utm.edu/departments/cece/cesme/PSAM/PSAM/psam35.pdf
http://www.arizonaenergy.org/AltEnergyClub/homemade%20batteries.pdf

Notes from a User Group

From a user group: Reading about Zinc/air batteries and their relatives got me thinking, the reaction only has to happen with one of the plates. The other plate is to transfer the opposite polar current. Looking at an typical alkaline paste cell, the reaction seems to be with the zinc in the center (negative post). The container is simply to transfer the positive side of the action. Remember nobody has told me if this is right or wrong. But between the experiments and the research, the use of copper tubing, I believe, was not a good choice. I've always been creating a reaction with the zinc plated tubing, but aluminum will be the next replacement for the copper tubing.

Providing enough reservoir space above plates for surplus electrolyte also leaves room for adding a thin (<5mm) layer of mineral oil to keep water evaporation to a minimum. The oil is messy and should only be added once you have a valid design being used for work, it will interfere with dip-tube fluid level checking and creep out into the vent baffles and top of case, etc.
Yes, Edison's nickel/iron (NiFe) battery with alkaline electrolyte were topped off with a thin layer of oil.
http://www.fieldlines.com/story/2008/5/14/12483/2076

OK, I was taught, negative potential (voltage)has essentially an over abundance of free electrons, while positive has a depletion of free electrons.

When a battery discharges the electrolyte permeates or skins the negative or positive plate? When a battery is charged the electrolyte is electrically pumped or possibly "repelled" back out/off of the plate.

The question comes from a battery experiment where it seems a cell can't decide what plate is positive and which plate is negative. I thought a solar trickle charge (2.5v) was building the charge in the cell nicely. Experimenting with a hard charge(4.5v) in the same direction seemed to untrain the cell.

The background on this particular cell: one plate is zinc plated conduit the other plate is aluminum, in a plastic bottle. The electrolyte is approximately 10% sodium hypochlorite. (homemade experimental cell)

When i first introduce the electrolyte the cell seems to decide polarity. I'm concluding this by indication on a DVM. Should i not attempt to charge a cell until the plates discharge some? I wish there was a place where i could get the specific gravities for properly charged aqueous alkaline cells. I've no way of knowing the proper electrolyte solution/dilution.

Answer: Seems to me the chlorine will eat through the thin coating on the conduit easily and take the aluminum with it.
Of course if its bonded to a ground source it will last along time.

Not sure how that would work in a homemade unit though.

To get the proper electrolyte strength I suspect you'd need to calculate the molar weights of the zinc/iron/aluminum/sodium hypochlorite and balance them per your chemical reaction. Probably not much fun, especially with your zinc-plated conduit.

The charge just finished the reaction and a small layer of aluminum oxide forms on the aluminum plate which insulates the plate from any more oxidation .

You're probably doing this on the cheap, but you may want to look into water heater anti-corrosion anodes, which are IIRC mainly zinc. Also, marine anti-corrosion anodes.
Or perhaps 'Z-Strip' from a roofing supply store

Hi, wolliver. I'm fairly new, but I want to be helpful. I'd like to pass along a few things that I "think" I've learned. I'm certain I'll butcher some part of this, hopefully it can be "nipped and tucked" by the community to attain a useful level of accuracy.

"...When a battery discharges the electrolyte permeates or skins the negative or positive plate? When a battery is charged the electrolyte is electrically pumped or possibly "repelled" back out/off of the plate?"...

The electrons from a lead/acid battery come from the acid molecule splitting and re-combining.

Each element's atom desires to hold a certain number of electrons (each electron with a negative charge). However, atoms have the ability to lose a few, or gain a few, creating an electro-magnetic imbalance that is slightly positive or slightly negative. An imbalance in its charge due to an "off" number of electrons makes the atom an "ion", and they actively seek a balance.

Brute force electrolysis is when you pump electrons into water, and when the hydrogen and oxygen ionize with too many, they both become too negative and "like charges repel" so the two ions split.

Part of their bond was that they both shared an electron to balance each of their individual imbalances.

A "fuel cell" reverses that process, it places oxygen (usually from air) on one side of a negatively charged membrane, and hydrogen on the other side. When an electrical circuit is connected to both sides, the oxygen's slight imbalance pulls the hydrogen nuclei through the membrane, but the negative charge of the membrane forces the hydrogen's electrons to take the circuit path (through a motor). As many as are allowed to take these paths, then more water is re-formed.

Acid elements have "just enough" affinity for each other that they will combine to form compounds, but what they really want is to leave each other for a compound that they each prefer. Sulfuric acid is H2SO4. The SO4 (sulfur/oxygen "sulfate" group) is strongly bonded to each other, but the H2 has a weak bond that shares an electron back and forth with the sulfates.

Sulfates like iron very much, so if you pour iron filings into a bucket of sulfuric acid, the sulfates will shed their H2's (which bubble up) and it will violently bond with the iron, making iron sulfate, which falls to the bottom of the bucket.

To get the weak hydrogen bond to split and recombine (releasing or absorbing an electron), we need to find something that sulfates like "a little" better than H2, but only slightly better so the reaction is mild.

I think the two plates in a lead/acid battery are lead, and lead dioxide, which creates just enough of an imbalance to allow a charge and discharge.

As the battery is allowed to discharge (flow nearer to an electrical balance) the split-off sulfates begin coating the plates, leaving less plate surface area for a reaction, resulting in a lower voltage reading.

The freed H2's stay in solution with the water of the electrolyte, standing by to re-combine. With less sulfate and more H2 in the electrolyte, its Specific Gravity (SG) changes, it gets lighter (acid is heavier per volume than water) so stuff that used to float in it will now sink.

Sorry for such a long reply, I hope this helps in some way.

http://www.fieldlines.com/story/2008/5/15/211156/146

http://www.wetheteachers.com/pdf/createpdf.php?id=306

Advanced Battery Materials
http://www.predmaterials.com/en_batt/index.html
http://www.le.ac.uk/slcem/em06/summer/Technician%20Courses.pdf

Electrical Energy

Graduate Fellow: Marc Russell **Master Teachers**: Lori Veteto and Becky Dukarm

Objective: Students will learn about subatomic structure, electrical energy, and electrical circuits through several demonstrations and by building a working battery.

TEKS: 5.1A; 5.2C; 5.8A; 5.8C; 6.1A; 6.2BC; 6.9A **Time Allotment:** 100 minutes

Materials:
Mosaic poster
Cupric sulfate
3 pieces of zinc metal
3 large nails
PVC pipe with curved ends
Periodic table
Two different magnets
3 pieces of copper
6 pieces of copper wiring
6 corks
Salt
B.B.'s
3 pieces of lead
Voltmeters
Cotton wool

10-Home Made Batteries

(11/2/2008)

Nine 250 ml beakers Water

Engage: Use a mosaic poster to show that larger objects are made up of many smaller parts. Relate this to objects in the room by explaining that all matter is made up of atoms, and that these atoms have a subatomic structure made up of even smaller particles called protons, neutrons, and electrons.

Exploration: Explore the subatomic structure of an atom by diagramming different atoms on the board. Relate the diagramed structures to their location on the periodic table.

Write the following equations on the board to explore the redox (reduction and oxidation) chemistry of zinc and copper:

$$Zn_{(s)} \rightarrow Zn^{2+} + 2e^-$$
$$2e^- + Cu^{2+} \rightarrow Cu_{(s)}$$

Then dissolve cupric sulfate in water to form Cu^{2+} ions. To this solution add a piece of zinc metal and leave for 10-15 minutes. The shiny zinc will turn blackish as electrons reduce copper ions, from the zinc metal, to copper metal.

Explore the formation of ions by dissolving salt crystals in water. Use two different powered magnets to model how a chloride atom can pull electrons (metal B.B's) off a weaker sodium atom. Diagram the loss of an outer electron shell electron from sodium and the subsequent acceptance of this electron by chlorine's outer shell (See figure below). See the following webpage for more info: http://www.visionlearning.com/library/science/chemistry-1/CHE1.7-bonding.htm

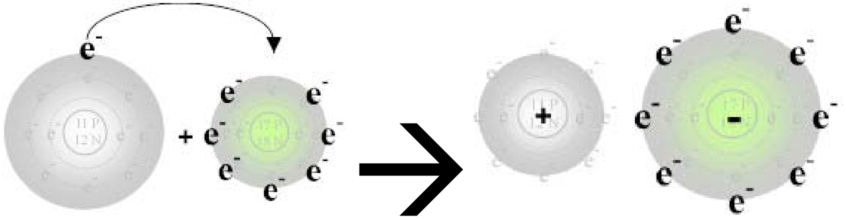


Figure 1. Sodium gives up its extra outer shell electron to chloride so that both have filled outer shells similar to the noble gases.

Pass out all the materials for making three batteries and have the students try to construct a complete circuit. In order to complete the battery they need to hang in a water filled beaker a piece of zinc, lead, iron, etc on a piece of copper wire. This is then connected to a voltmeter and then to a piece of copper metal by another copper wire. The copper must be suspended in a beaker filled with a cupric sulfate solution. The circuit is closed by construction of a salt bridge made of PVC pipe filled with salt water and stopper on both ends by cotton wool and corks with a tiny hole poked through each. This construction will allow electrons to flow out of the zinc into the copper wire and finally into the copper metal. Then the electrons will be accepted by copper ions in the solution. These ions will then become more copper metal. The ionic charge balance is maintained by

negatively charged ions flowing through the salt bridge from the copper side to the zinc side. Go to the following website for a graphical representation of electron flow in the battery: http://www.ausetute.com.au/voltcell.html . One can use regular table salt instead of KCl.
Note: Build the battery prior to introduction to students.

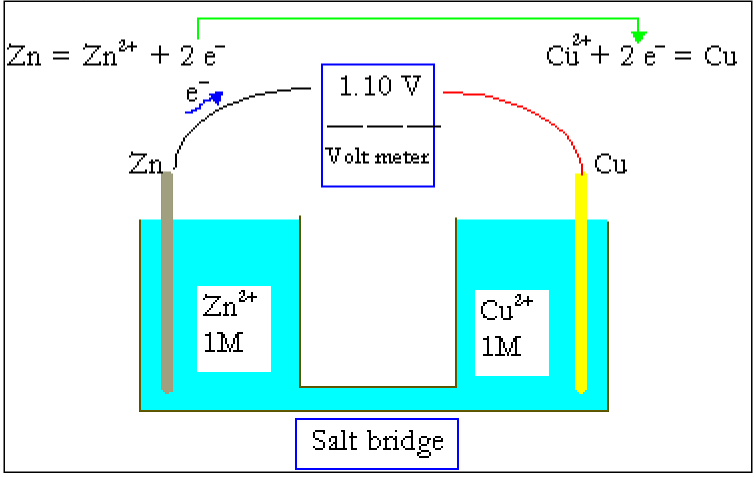


Figure 2. Electrons flow from the zinc across the copper wire producing an electrical current and are accepted by copper ions in solution forming more copper metal. The charge difference is balanced by negative chloride ions moving through the salt bridge to the zinc side.

Have the students explore the voltages produced from different metal combinations by having them exchange their zinc for lead and then a nail. They should record the voltage produced by each.

Explanation: Explain that every element has a unique subatomic structure and that some structures are more stable than others. Noble gases have the most stable and thus un-reactive structures because they have 8 electrons in their outer shell (Helium only has an outer shell which is filled by 2 electrons). Elements close to the noble gases, Groups I and VII on the periodic table of the elements, will either want to gain or lose an electron in order to become more stable (get eight electrons in their outer shell).

Elements located in the center of the table can give or accept electrons depending what other elements are in physical contact. Many of the metals are located in the center of the table and can give up or take electrons into their outer shell. This makes them good conductors of electricity because the electrons are weakly bound to the nucleus of atoms in these elements. Zinc will always give up electrons to copper ions when they are in close proximity and there is water available for ion formation.

Explain that ions are formed when one element accepts an electron from another element leaving positively and negatively charged atoms (ions). Salt is formed when sodium and chloride ions in solution are dried out and are forced back into a solid form.

Explain the parts of a battery by introducing the following terms:

Conductor – a material such as a metal with weakly bound electrons. This weak binding allows electrons to flow through the material. The copper wire is a conductor in this battery.
Insulator – a material that doesn't allow electrons to flow through it. The coating on the wires is an insulator.
Resistor – a material that is intermediate between a conductor and an insulator.

If we were to hook up a light bulb in place of the voltmeter this would act as a resistor and the electron flow would be turned into light and heat energy.

Diagram the flow of electrons on the board for the students. Electrons flow from the zinc through the copper wire to the copper metal and then are accepted by copper ions in the water and these ions turn into copper metal (See figure 2).

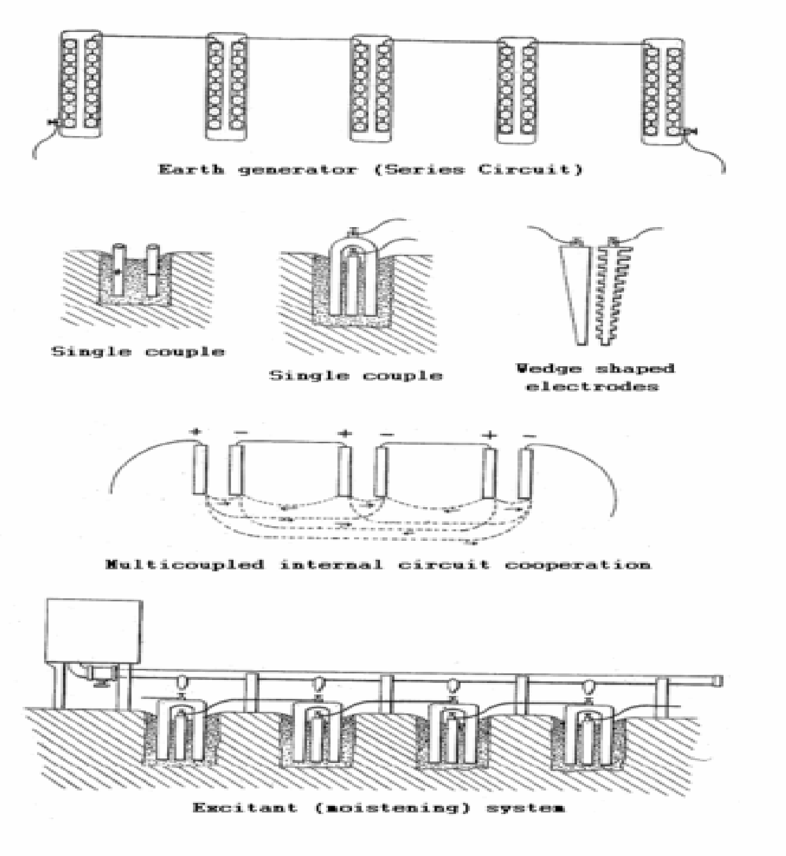
Different metal combinations will result in different amounts of voltage being produced because each metal has more or less tendency to give up their electrons to copper.

Elaboration: Elaborate on the power produced from these homemade batteries and compare it to regular store bought ones. A zinc/copper battery should produce 1.1 volts if everything is hooked up correctly. Lead gives off 0.4 volts, and a nail, which is a combination of iron and other metals, can produce 0.8 volts. Store bought batteries such as a 9-volt battery obviously produce 9 volts. How many of the homemade batteries would it take to make one 9-volt battery?

Elaborate on the finite nature of batteries by explaining that either the ions or one of the metals will eventually run out. Batteries run down when the ions run out in a battery. A corroded battery is one where one of the metals has been overused and the structure of the battery breaks down as the liquid portion leaks out.

Evaluation: Hand out the attached worksheet for the students to complete at the end of class.
http://www.utmsi.utexas.edu/Staff/dunton/GK12/lessons/ElectricalEnergy1.doc

Earth Batteries



M. Emme, "U.S. Patent 495582 Ground generator of electricity".

A simple homemade cell is the **earth battery**. Almost any liquid or moist object that has enough ions to be electrically conductive can serve as the electrolyte for a cell. As a novelty or science demonstration, it is possible to insert two electrodes into a lemon, potato, glass of soft drink, etc. and generate small amounts of electricity. As of 2005, "two-potato clocks" are widely available in hobby and toy stores; they consist of a pair of cells, each consisting of a potato (lemon, etc.) with two electrodes inserted into it, wired in series to form a battery with enough voltage to power a digital clock. Homemade cells of the "potato clock" kind are of no real practical use, because they produce far less current—and cost far more per unit of energy generated—than commercial cells, due to the need for frequent replacement of the fruit or vegetable.

Earth batteries, though, consist of conductive plates from different locations in the electropotential series, buried in the ground so that the soil acts as the electrolyte in a voltaic cell. As such, the device acts as a rechargeable battery. Operating only as electrolytic devices, the devices were not continuously reliable owing to drought condition. These devices were used by early experimenters as energy sources for telegraphy. However, in the process of installing long telegraph wires, engineers discovered that there were electrical potential differences between most pairs of telegraph stations, resulting from natural electrical currents (called telluric currents) flowing through the ground. Some early experimenters did recognise that these currents were, in fact, partly responsible for extending the earth batteries' high outputs and long lifetimes. Later, experimenters would utilize these currents alone and, in these systems, the plates became polarized.

It had been long known that continuous electric currents flowed through the solid and liquid portions of the Earth and the collection of current from an electrically conductive medium in the absence of electrochemical changes (and in the absence of a thermoelectric junction) was established by Lord Kelvin. Lord Kelvin's "sea battery" was not a chemical battery. Lord Kelvin observed that such variables as placement of the electrodes in the magnetic field and the direction of mediums's flow affected the current output of his device. Such variables do not affect battery operation. These metal plates were immersed in a flowing medium and created a magneto-hydrodynamic generator. In the various experiments, metal plates were symmetrically perpendicular to the direction of the medium's flow and were carefully placed with respect to a magnetic field which differentially deflected electrons from the flowing stream. The electrodes can be assymmetrically oriented with respect to the source of energy, though.

To obtain the natural electricity, experimenters would thrust two metal plates into the ground at a certain distance from each other in the direction of a magnetic meridian, or astronomical meridian. The stronger currents flow from south to north. This phenomenon possesses a considerable uniformity of current strength and voltage. As the Earth currents flow from south to north, electrodes are positioned, beginning in the south and ending in the north, to increase the voltage at as large a distance as possible. In many early implementations, the cost was prohibitive because of an overreliance on extreme spacing between electrodes.

It has been found that all the common metals behave relatively similarly. The two spaced electrodes, having a load in an external circuit connected between them, are disposed in an electrical medium, and energy is imparted to the medium in such manner that "free electrons" in the medium are excited. The free electrons then flow into one electrode to a greater degree than in the other electrode, thereby causing electric current to flow in the external circuit through the load. The current flows from that plate whose position in the electropotential series is near the negative end (such as palladium). The current produced is highest when the two metals are most widely separated from each other in the electropotential series and that the material nearer the positive end is to the north, while that at the negative end is towards the south. The plates, one copper and another iron or carbon, are connected above ground by means of a wire with as little resistance as possible. In such an arrangement, the electrodes are not appreciably chemically corroded, even when they are in earth saturated with water, and are connected together by a wire for a long time.

It had been found that to strengthen the current, it was most advantageous to drive the northerly electropositive electrode deeper into the medium than the southerly electrode. The greatest currents and voltages were obtained when the difference in depth was such that a line joining the two electrodes was in the direction of the magnetic dip, or magnetic inclination. When the previous methods were combined, the current was tapped and utilized in any well-known manner. In some cases, a pair of plates with differing electrical properties, and with suitable protective coatings, were buried below the ground. A protective or other coating covered each entire plate. A copper plate could be coated with powered coke, a processed carbonaceous material. To a zinc plate, a layer of felt could be applied. To use the natural electricity, earth batteries fed electromagnets, the load, that were part of a motor mechanism.

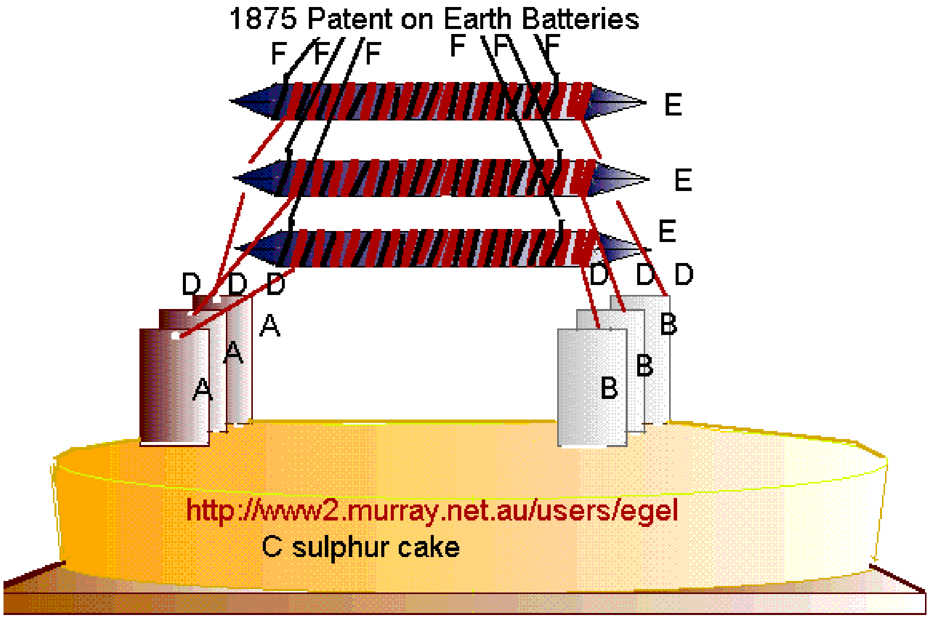
History

In 1898 Nathan Stubblefield received a U.S. Patent 600457 (G.patent; PDF) for a cell made of *cloth-insulated copper wire* and *iron wire wound in a coil*, which was to be *buried in damp earth*: this *electrolytic coil* is referred to as an "***earth battery***". One of the earliest examples of an earth battery was built by Alexander Bain in 1841 in order to drive a prime mover. Bain buried plates of zinc and copper in the ground about one meter apart and used the resulting voltage, of about one volt, to operate a clock. Carl Friedrich Gauss, who had researched the Earth's magnetic field, and Karl A. von Steinheil, who built one of the first electric clocks and developed the idea of an "Earth return" or "ground return", had previously investigated such devices. Lord Kelvin developed a "sea battery" in the latter end of the 1800s.

Daniel Drawbaugh received U.S. Patent 211322 (G.patent; PDF) for an Earth battery for electric clocks (with several improvements in the art of Earth batteries). Another early patent was obtained by Emil Jahr (U.S. Patent 690151 (G.patent; PDF) Method of utilizing electrical Earth currents). In 1875, James C. Bryan received US160152 for his Earth Battery. In 1885, George Dieckmann, received U.S. Patent 329724 (G.patent; PDF) for his Electric Earth battery. In 1898, Nathan Stubblefield received U.S. Patent 600457 (G.patent; PDF) for his electrolytic coil battery, which was a combination of an earth battery and a solenoid.

The Earth battery, in general, generated power early on for telegraph transmissions and formed part of a tuned circuit that amplified the signalling voltage over long distances. [Alleged:] In the mid 1800's, more than half of the telegraph in the U.S. and Europe ran off the power of earth batteries, and were capable of sending messages up to 300 - 400 miles.

http://peswiki.com/index.php/PowerPedia:Earth_battery



James C Bryan of Philadephia January 27 1875

1875 Patent on Earth Batteries

There has recently been a question on Earth batteries on the Free energy newsgroup as so many were unaware of the existence of such a device and must admit that I was ignorant of the device myself until I came across this patent and so I reproduce an except from the patent application below.

"The object of my invention is to produce a current of electricity from an earth battery or batteries capable of generating a constant current of considerable intensity to be used for lightning rod and other purposes where voltaic batteries using solutions are now applied.

It is known that if different elements-for instance sheets of zinc and copper-be buried or placed in the earth ,a current of electricity is generated; but I have discovered that if such elements be partly embedded in sulphur so that the dampness of the earth may act in conjunction with the sulphur on the metals, a more intense will be created.

I utilise this in the following way: The current is collected by insulated wires coiled around nickel plated steel magnets ,which are planted north and south in the earth to receive the magnetic current of the earth; a secondary coil or coils of insulated wire surrounds the coil or coils around the magnets and receives by induction, electricity from both the voltaic and magneto-electro batteries.

In the drawing, the voltaic battery is composed of several pieces or plates of chemically pure zinc **B,** and the same number of copper, A they are embedded in a cake of sulphur **C** and are connected by a large insulated wire **D**, which being the primary coil between dissimilar elements is extended, without insulation to the base of the sulphur cake **C,** and also in a spiral coil or coils around steel magnets **E,** which are pointed magnetised and nickel plated.

These batteries are planted in the earth north and south, to receive the earths current of electricity according to the magnetic poles.

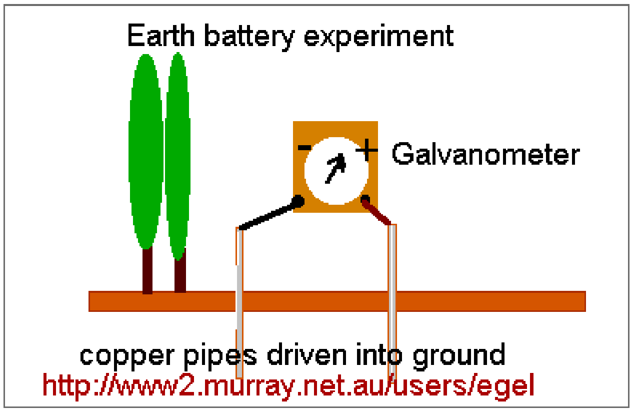
The primary coil or coils **D** are surrounded by secondary insulated wire F, in a spiral coil or coil to receive by induction ,electricity from the batteries current through **D**

end of patent extract

For those that are interested I recommend you getting a copy of the Borderlands Journal issue volume L111 number one first quarter 1997.

Where there is an interesting article giving more details are other related research into this interesting field..

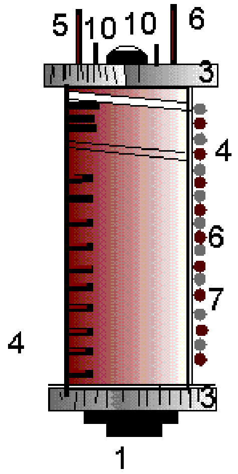
In the article it is suggested that if you want to try the idea of earth batteries for yourself



If you want to try it then get two copper rods or pipe and drive them into the ground and then connect a galvanometer(place them near a tree for better results.) apparently the needle always points positive although it may take time for the current and voltage to build up.

It seems that early engineers and telegraph operators knew of the effects of these ground currents when their Edison batteries they had used went flat and long time depleted and their telegraph kept giving out sparks sometimes of greater intensity than when they had been using batteries.

Fig one



Electrical Battery by

NATHAN B.STUBBLEFIELD OF MURRAY KENTUCKY

The following is a reproduction of Nathan B. Subblefield Patent the drawing may be inaccurate due to some difficulty in reading of the patent drawings Geoff

ASSIGNOR OF ONE HALF TO WILLIAM G.LOVE OF SAME PLACE

Specification forming part of letters patent no 600,457 dated march 9 1898

Application filed October 24,1896 serial number 609969 no model

To all whom it may concern.

Be it known that I Nathan B Stubblefield a citizen of the United states of America, residing at Murray in the county of Calloway and

[5] State of Kentucky have invented a new and useful Electrical Battery of which the following is a specification.

This invention relates to electrical batteries and it has for its objects to provide a

[10] novel and practical battery for generating electrical currents of sufficient force for practical use, and also providing means for generating not only a constant primary current but also an induced momentary secondary

[15] current. it is well know that if any voltaic couple be immersed in water placed in moist earth the positive element of the couple will undergo a galvanic action of sufficient intensity

[20] to produce current when the terminals of the couple are bought in contact , and this form of battery is commonly as the "water Battery ", usually employed for charging electrometers , but are not capable of giving

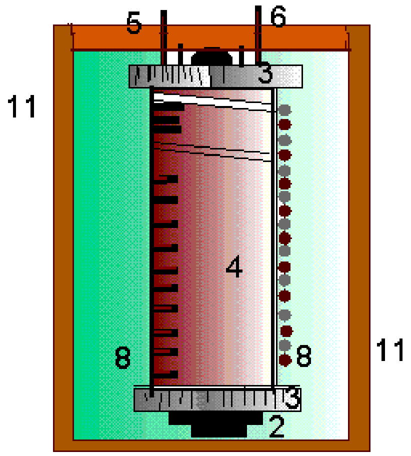
[25] any considerable current owing to their great internal resistance . Now the principle involved in this class of batteries is utilised to some extent in carrying out the present invention , but I contemplate, in connection

[30] with water or moisture as the electrolyte ,t he use of a novel voltaic couple constructed in such a manner as to greatly multiply or increase the electrical output of ordinary voltaic cells , while at the same time producing in

[35] operation a magnetic field having a sufficiently strong inductive effect to induce a current in a solenoid or secondary coil..To this end the invention contemplates a form of voltaic battery having a magnetic.

[40]

Fig 2



induction properties of sufficient intensity , so as to be capable of utilisation for practical purposes , and in the accomplishment of the results sought for the invention further provides a construction of battery capable of

[45] producing a current of practically constant electromotive force and being practically free of the rapid polarization common in all galvanic or voltaic batteries . With these and many other objects in view

[50] the invention ,combination , arrangement of arts herein after more fully described, illustrated and claimed.

In the drawings Figure 1 is a side elevation of an electrical battery constructed in

[55] accordance with this invention . Fig 2 is a central longitudinal sectional view of the battery , showing the same immersed in water as the electrolyte. Fig 3 is an enlarged sectional view of a portion of the battery ,showing

[60] more clearly the manner of winding the voltaic couple or in other words , the wires comprising the couple . Fig 4 is a vertical sectional view of the battery , shown modified for use with an induction-coil.

[65] referring to the accompanying drawings the numeral 1 designates a soft-iron core-piece extending longitudinally of the entire battery and preferably in the form of a bolt having at one end a nut 2 which permits of

[70] the parts of the battery being readily assembled together and also quite readily taken apart for the purpose of repair , as will be readily understood. The central longitudinally-arranged core-piece 1 of the battery has

[75] removably fitted on the opposite ends thereof the oppositely - located end heads 3,confining there between the magnetic coil-body 4 of the battery , said heads 3 being of wood or equivalent material. The coil -body 4 of the battery

[80] is compactly formed by closely-wound coils of a copper and iron wire 5 and 6 ,respectively ,which wires form the electrodes of the voltaic couple , and while necessarily insulated from each other ,so as to have no metallic

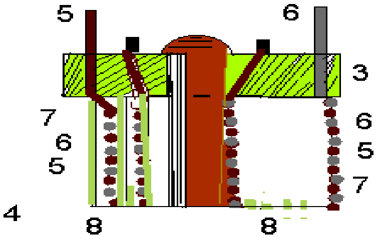
[85] contact ,are preferably wound in the manner clearly illustrated in fig 3 of the drawings.

In the preferred winding of the wires 5 and 6 copper wire 5 is incased in an insulating covering 7,while the iron wire 6

[90] is a bare or naked wire ,so as to be more exposed to the action of the electrolyte and at the same time to intensify the magnetic field that is created and maintained within and around the coil-body 4 when the battery is in operation

[95] and producing an electrical current . While the iron wire is preferably bare or naked for the reasons stated , this wire may also be insulated without destroying the operativeness of the battery , and in order to secure

Fig 3



[100]

the best results the wires 5 and 6 are wound side by side in each coil or layer of the windings, as clearly shown in FIG 3 of the drawings ,so that in each coil or layer of the windings

[2] there will be alternate convolutions of the copper and iron wires forming

[5] the voltaic couple , and it will of course be understood that there may be ant number of separate coils or layers of the wires according to the required size and capacity of the battery. Each coil or layer of the windings

[10] is separated from the adjacent coils or layers by an interposed layer of cloth or equivalent insulating material 8 and in a similar layer of insulating material 9 also surrounds the longitudinal core-piece 1 to insulate from this core-piece

[15] the innermost coil or layer of the windings. The terminals 10 of the copper and iron wires 5 and 6 are disconnected so as to preserve the character of the wires as the electrode of the

[20] voltaic couple; but the other or remaining terminals of the wires are bought into contact through the interposition of any electrical instrument or device with which they may be connected to cause the electric currents

[25] generated in the coil-body 4 to flow through such instrument or device. In the use of the battery constructed as described the same may be immersed in a cell or jar 11, containing water as the electrolyte

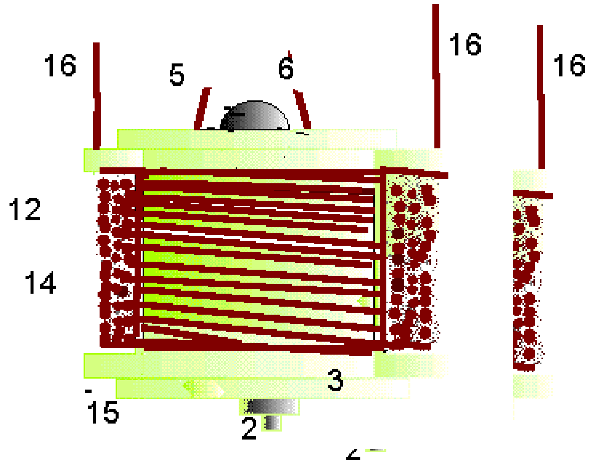
[30] but it is simply necessary to have the coil-body 4 moist to excite the necessary action for the production of a current in the couple , and it is also the contemplation of the invention to place the battery in moist earth, which

[35] alone is sufficient to provide the necessary electrolytic influence for producing an electric current. It has been found that by reason of winding the couple of copper and iron wires into a

[40] coil-body the current traversing the windings of this body will produce a magnetic field within and around the body of sufficiently strong inductive effect for practical utilisation by means of a solenoid or secondary coil 12 as illustrated in Fig 4 of the drawings.The solenoid or

[45] secondary coil 12 is of an ordinary construction, comprising a wire closely wound into a coil of any desired size on

Fig 4



an ordinary spool 13 and increased within a protective covering 14 of mica, celluliod or equivalent material. The spool 13 of the solenoid or secondary coil may be conveniently secured directly on the exterior of the coil-body 4 between the heads 3 with a suitable layer or wrapping of insulated material 15, interposed between the spool and the body 4, and the terminals 16 of the solenoid or secondary coil may be connected up with any instrument usually operated by a secondary currents- such for instance as a microphone-transmitter or telegraphic relay. The magnetic field produced by the current traversing the coil-body 4 induces a secondary current in the solenoid or secondary coil 12 when the ordinary make and break of the primary current produced within the coil 4 is made between the terminals of said coil 4. It will therefore be seen that the construction of the battery illustrated in FIG 4 is practically a self generating induction-coil, and it cab be used for every purpose that a coil of this character is used, for as long as the coil-body 4 is wet or damp with moisture electric currents will be produced in the manner described. It will also be obvious that by reason of the magnetic inductive properties of the coil-body 4 the core-piece 1 will necessarily be magnetised while a current is going through the body 4 so that the battery may be used as a self-generating electromagnet, if so desired, it being observed that to secure this result is simply required connecting the extended terminals of the wires 5 and 6 together after wetting or dampening he coil-body.

Many other uses of the herein-described battery will suggest themselves to those skilled in the art, and I will have it understood that any changes in the form, proportion and the

[90] minor details of construction may be resorted to without departing from the principle or sacrificing any of the advantages of this invention.

Having thus described the invention what

[95] is claimed and desired to be secured by letters Patent is-

1 A combined electrical battery and electomagnet, for use with water as an electrolyte ,comprising a soft -iron core-piece and a

[100] voltaic couple of copper and iron wires insulated from each other and closely and compactly wound together in separate insulated layers wound together in separate insulated layers to produce a solid coil-body surrounding the soft-iron core-piece, substantially as

[105] set forth.

2 An electrical battery for use with water as an electrolyte comprising a voltaic couple of insulated copper wire and bare iron wire closely wound into a coil-body substantially

[110] as described.

3 An electrical battery for use with water as an electrolyte comprising a voltaic couple of insulated copper and bare iron wire wound side by side in separate insulated layers

[115] to produce a coil-body, substantially as described.

4 An electrical battery ,for use with water as an electrolyte ,comprising a voltaic couple having its separate electrodes insulated from

[120] each other and closely wound into a compact coil-body forming a self-generating primary coil when moistened and a solenoid or secondary coil fitted on the coil-body of the couple, substantially as set forth.

[125] In testimony that I claim the foregoing as my own I have hereto affixed my signature in the presence of two witnesses.

NATHAN B STUBBLEFIELD If anyone has experimented and had experience with this energy source could you let me know what you did and how you went and inform yours truly of some of the results you achieved

http://www.linux-host.org/energy/tearth.htm

From a user Group -This weekend I played around a little.

I took a 9" long 6" dia HVAC duct (available at most hardware stores) and shoved it into the ground. In the middle of that, I shoved a 3/4" copper pipe (from a left over plumbing project). This resulted in 0.975 volts. Putting 2 of these in series right next to each other showed 1.3 volts at 0.7 milliamps. Not enough amps to light a light bulb but a fun experiment non-the-less. BTW, it was raining and just touching the copper and tin with the volt meter I got the 0.9 volts even before I put the metals in the ground.

http://www.fieldlines.com/story/2003/5/14/13753/0057

I did a test of this but from Stublefeilds patent, and the model was poor and weak and the results were week. from the way the polarity tested, it is not a galvanic action although there may some of a galvanic presence there by default. This was the coil of wire method which takes copper and iron wire, the copper must be insulated and the wires are wound together parallel, at each new layer the coils are insulated (as the iron is not insulated and it is parallel so it (the iron) never touches itself or shorts itself as the coil is built up. There is definitely something to research here, but the practicality is I can buy a microcrystaine solar cell for 4 dollars a watt and the cost is the same or better per watt than the large amount of copper and zinc involved, not to mention the work of digging.

http://www.fieldlines.com/story/2003/5/14/13753/0057

History

One of the earliest examples of an earth battery was built by Alexander Bain in 1841 in order to drive a prime mover . Bain, his achievements relatively unknown, exploited his electric patents in operation in the United States in competition with Morse. Bain was the one of the first people to construct an electromagnetic clock (patented 1840) and to devise a unique system to run the mechanical device . Bain buried plates of zinc and copper in the ground about one meter apart and used the resulting voltage, of about one volt, to operate a clock. Carl Friedrich Gauss, who had researched the Earth's magnetic field, and Karl A. von Steinheil, who built one of the first electric clocks and developed the idea of an "Earth return" or "ground return", had previously investigated such devices. Lord Kelvin developed a "sea battery" in the latter end of the 1800s. The Leclanche battery was a copy of the earth battery.

Daniel Drawbaugh received U.S. Patent 211,322 for an Earth battery for electric clocks (with several improvements in the art of Earth batteries). Another early patent was obtained by Emil Jahr U.S. Patent 690,151 Method of utilizing electrical Earth currents). In 1875, James C. Bryan received U.S. Patent 160,152 for his Earth Battery. In 1885, George Dieckmann, received US patent U.S. Patent 329,724 for his Electric Earth battery. In 1898, Nathan Stubblefield [4] received U.S. Patent 600,457 for his electrolytic coil battery, which was a combination of an earth battery and a solenoid.(For more information see US patents 155209, 182802, 495582, 728381, 3278335, 3288648, 4153757 & 4457988) The Earth battery, in general, generated power for early telegraph transmissions and formed part of a tuned circuit that amplified the signalling voltage over long distances.

Metals and Soils

Potential Differences of metals
(Soil Galvanic series)

Metal ...	Potential V Cu/CuSO4 electrode
Magnesium (pure)	-1.75
Magnesium (alloy)	-1.60
Zinc	-1.10
Aluminum (alloy)	-1.05
Aluminum (pure)	-0.8
Steel (clean)	-0.50 to -0.80
Steel (rusted)	-0.20 to -0.50
Cast Iron	-0.50
Lead	-0.50
Steel (concrete)	-0.20
Copper	-0.20
Brass	-0.20
Bronze	-0.20
Steel (mill scale)	-0.20
Cast iron (high silicon)	-0.20
Carbon	+0.30
Graphite	+0.30
Coke	+0.30

Notes:

- Non-uniform conditions at node surface results in different voltages

Ref.: Engineering Tutorials: Potential of Metals in Soils

Operation and utilization

The simplest earth batteries consist of conductive plates from different locations in the electropotential series, buried in the ground so that the soil acts as the electrolyte in a voltaic cell. As such, the device acts as a rechargeable battery. When operated only as electrolytic devices, the devices were not continuously reliable, owing to drought condition. These devices were used by early experimenters as energy sources for telegraphy. However, in the process of installing long telegraph wires, engineers discovered that there were electrical potential differences between most pairs of telegraph stations, resulting from natural electrical currents (called telluric currents) flowing through the ground. Some early experimenters did recognize that these currents were, in fact, partly responsible for extending the earth batteries' high outputs and long lifetimes. Later, experimenters would utilize these currents alone and, in these systems, the plates became polarized.

It had been long known that continuous electric currents flowed through the solid and liquid portions of the Earth[6], and the collection of current from an electrically conductive medium in the absence of electrochemical changes (and in the absence of a thermoelectric junction) was established by Lord Kelvin.[7][2] Lord Kelvin's "sea battery" *was not* a chemical battery.[2] Lord Kelvin observed that such variables as placement of the electrodes in the magnetic field and the direction of the medium's flow affected the current output of his device. Such variables do not affect battery operation. When metal plates are immersed in a liquid medium, energy can be obtained and generated,[8] including (but not limited to) methods known via magneto-hydrodynamic generators. In the various experiments by Lord Kelvin, metal plates were symmetrically perpendicular to the direction of the medium's flow and were carefully placed with respect to a magnetic field which differentially deflected electrons from the flowing stream. The electrodes can be asymmetrically oriented with respect to the source of energy, though.

To obtain the natural electricity, experimenters would thrust two metal plates into the ground at a certain distance from each other in the direction of a magnetic meridian, or astronomical meridian. The stronger currents flow from south to north. This phenomenon possesses a considerable uniformity of current strength and voltage. As the Earth currents flow from south to north, electrodes are positioned, beginning in the south and ending in the north, to increase the voltage at as large a distance as possible.[9] In many early implementations, the cost was prohibitive because of an over-reliance on extreme spacing between electrodes.

It has been found that all the common metals behave relatively similarly. The two spaced electrodes, having a load in an external circuit connected between them, are disposed in an electrical medium, and energy is imparted to the medium in such manner that "*free electrons*" in the medium are excited. The free electrons then flow into one electrode to a greater degree than in the other electrode, thereby causing electric current to flow in the external circuit through the load. The current flows from that plate whose position in the electropotential series is near the negative end (such as palladium). The current produced is highest when the two metals are most widely separated from each other in the electropotential series, and when the material nearer the positive end is to the north, while that at the negative end is towards the south. The plates, one copper and another iron or carbon, are connected above ground by means of a wire with as little resistance as possible. In such an arrangement, the electrodes are not appreciably chemically corroded, even when they are in earth saturated with water, and are connected together by a wire for a long time.

It had been found that to strengthen the current, it was most advantageous to drive the northerly electropositive electrode deeper into the medium than the southerly electrode. The greatest currents and voltages were obtained when the difference in depth was such that a line joining the two electrodes was in the direction of the magnetic dip, or magnetic inclination. When the previous methods were combined, the current was tapped and utilized in any well-known manner.

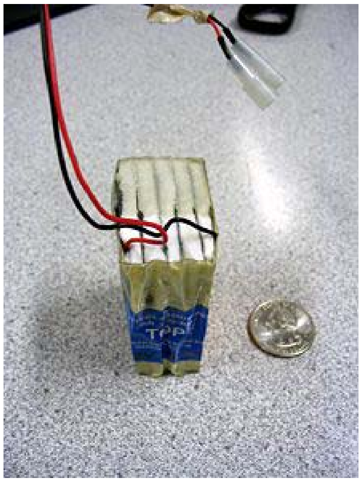
In some cases, a pair of plates with differing electrical properties, and with suitable protective coatings, were buried below the ground. A protective or other coating covered each entire plate. A copper plate could be coated with powdered coke, a processed carbonaceous material. To a zinc plate, a layer of felt could be applied. To use the natural electricity, earth batteries fed electromagnets, the load, that were part of a motor mechanism.

http://en.wikipedia.org/wiki/Earth_battery

Water-activated battery

A **Water-activated battery** is a disposable battery that does not contain an electrolyte and hence produces no voltage until it is soaked in water for several minutes.

Description



Side-view of water-activated radiosonde battery

Radiosonde battery still in protective wrapper

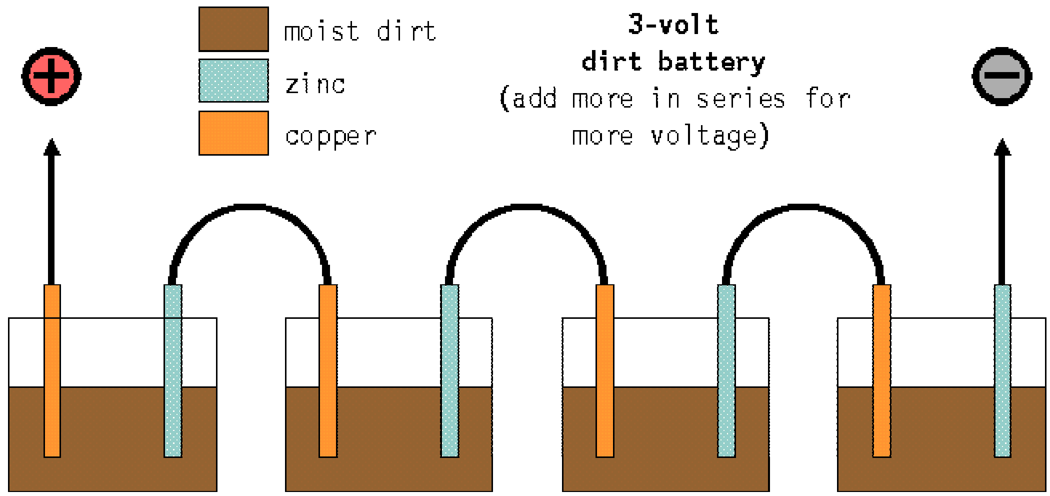
Typically, a large variety of aqueous solutions can be used in place of plain water. This battery type is specifically designed to be more environmentally friendly due to an absence of heavy metals. Water-activated batteries are used most commonly in radiosondes which cannot contain heavy metals because they regularly fall to the ground or ocean surface and remain there indefinitely.

A carbon-magnesium battery, named *NoPoPo*, coming in AA and AAA sizes, was released in Japan in 2007. The batteries come with a syringe to inject water or electrolyte, such as juice. Diagnostic kits using copper-magnesium cells activated by water or the liquid sample itself are also in development.

Aluminum anodes are used on many water-activated batteries designed for use with seawater and its high salinity.

A new kind of water-powered battery is the HydroPak, a portable power generator that uses water-activated disposable fuel cartridges. It is a high energy alternative to lead acid battery packs and portable generators that works by adding water to sodium borohydride which releases hydrogen fuel for a proton exchange membrane fuel cell. It can be re-charged simply by replacing the fuel cartridge rather than the lengthy recharging that other batteries require, however the cartridges cost $20 each.

http://en.wikipedia.org/wiki/Water-activated_battery



Dirt makes pretty good batteries. It seems like moist dirt packed tightly works the best. Add just enough water but not too much. I guess if the dirt dries up, you'll have to water the batteries along with the rest of the plants. The soda can version works but I haven't tested extensively. You don't really have to use a penny, just has to be copper. Perhaps other common materials would work better. Each cell gives you a useless 0.5 volts. But if you link them in series you can get more. I was able to light up an LED decently with 4 cells. Not quite as bright as Alkalines, but you get what you pay for I guess. While it's probably not the easiest way to get power, it's basically free, and it works on a small scale. Larger, higher current versions may be possible, but you'll probably need to still connect several together to attain a usable voltage level.

I have the idea of hammering 2 tubes in the ground, a slightly larger alluminum tube with a copper plumbing pipe inside, like this:

```
 _____
/  _  \
| (_)-|----copper (+0.75 volts)
\_____/----alluminum or zinc (-)
```

It works just like a regular battery except the electrolyte is damp dirt. And you get a quick recharge with each and every acid-rain. The first dirt batteries I made indoors in paper cups worked almost as good as commercial AA's, so I think the process is scaleable to larger amounts of power. I'm guessing that chaining about 32 of them in series would provide a steady 24 volts at a pretty decent amount of current. Maybe each cell would be 2 feet deep or so. Connect the copper of the first cell to the aluminum of the next, and so on. (Just like AA batteries in the radio) Since it's so simple I thought I'd post the idea in case someone had the stuff laying around and wanted to give it a whirl. Offered by Joe.

I suspect a good acid soil will work best. If not, urine is acidic. Offered by Steve.

I think one inside the other may be difficult to hammer in the ground and keep the pipes from touching, causing an electrical short. I suspect one could pick up used copper and zinc plated steel pipes out of wrecked houses after the pole shift. It should work to run the two pipes parallel to each other in a shallow trench near the earth's surface. A good test would be to determine the optimum distance apart to get the most power output for different soils. This would be good data for all to have. We could put an insulator to keep them apart 1/4-1/2 inch, or will 1-2 ft. work just as well? Or can one house be built with copper plumbing and another next to it with galvanized steel being 20-100 ft apart and still have it work without digging up the pipes? Offered by Mike.
http://www.zetatalk.com/energy/tengy09v.htm

User group notes

The earth cell I tried some 1' lengths of 1/2 copper pipe, got about .8 to .95 V from each section. But each time I tried to hook up in series it did not work, even when I hooked each section to a capacitor.

Isolation: I recall reading somewhere that you need to isolate each cell of an earth battery if they are in close proximity with another cell.(within 6-7 ft.) I have tried simply putting each cell inside a length of pvc pipe, leave the bottom open. you could use the cheap thin walled drain pvc.

http://www.energeticforum.com/renewable-energy/2141-earth-batteries-first-tests.html

11-Lead-Acid Batteries

(11/3/2008)

Survival Overview: Lead acid batteries are currently one of the most cost effective solutions for primary electrical storage. If after long term storage the battery terminal voltage is not above 2 volts/cell, then sulfation is possible and it may not take and hold a charge. Need to raise the voltage above 2.5 volts/cell when charging a mildly sulfated battery. If too much sulfation for too long a time (months) it may not be able to be charged at all. See latter on for more recovery techniques. Keep Lead-Acid batteries charged while in storage. Check the voltage regularly. Depending on temperature, check and/or charge at least once every 6 months for gel cells and more often for wet cells.

Battery Voltage

There is much confusion about proper "battery voltage" because in truth a battery has more than one voltage depending on the situation. Often the literature is lax in defining which voltage is being discussed at the time.

Float Voltage – This is the voltage of a fully charged battery or cell at close to zero charging current. If the current is adjusted to a low trickle charge just sufficient to just match the internal discharge rate of a fully charged battery then we say this is the minimum float voltage for this battery.

Resting Charged Voltage – This is sometimes called the nominal voltage. This is the resulting voltage after 12-24 hours after the battery has been fully charged. One waits for the so called “surface charge” to go away. This voltage is slightly less than the Float Voltage.

Charging Voltage - The voltage a battery measures while being charged at a given current flow rate. Typically this is measured as a fraction of C (capacity in amp-hr).

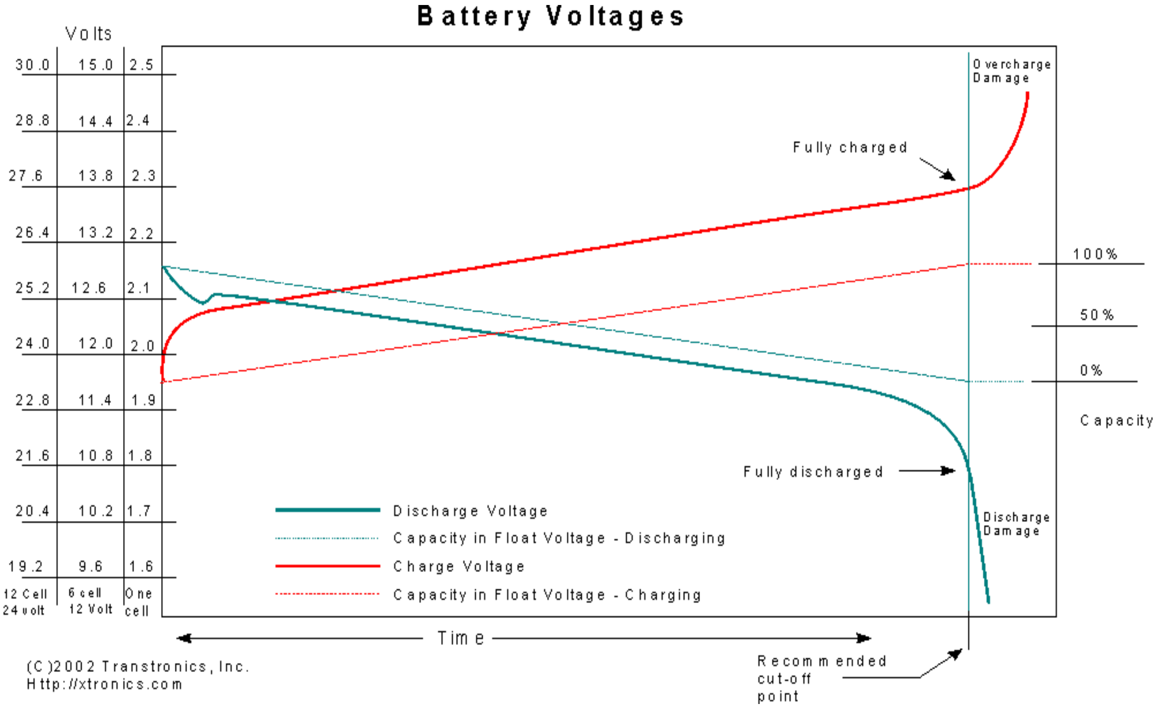
Discharging Voltage – This is the voltage of a battery while discharging. This voltage is determined by the charge state and the current flowing. One looks the voltage up in a table to determine state or percent of charge. Both charging and discharging voltage is dependent on internal resistance of the battery (both chemically and electrically).

Discharged Voltage – This is the resting voltage after which the cell is considered to be discharged. This varies with the type of cell. Some cells will recharge better if charged before fully discharged. So the concept exists of fully discharged and discharged enough to be nearly fully recharged and there respective voltages.

Number of Cells	Nominal Voltage	Fully-Charged Float Voltage	Fully-Discharged Resting Voltage	Discharge Voltage at C/20	Charge Voltage at C/5
1	2	2.15	1.9	2.0 - 1.7	2.1 - 2.30
6	12	12.9	11.4	12 - 10.2	12.6 - 13.8
12	24	25.8	22.8	24 - 20.4	25.2 - 27.6

11-Lead-Acid Batteries

(11/3/2008)



General Voltage Ranges for six-cell lead-acid batteries

All voltages are at 20C, and must be adjusted for temperature changes. Float voltage recommendations vary, according to the manufacturers' recommendation. Precise (+/-0.05V) float voltage is critical to longevity; too low (sulfation) is almost as bad as too high (corrosion & electrolyte loss). See http://en.wikipedia.org/wiki/Lead-acid_battery

- Open-circuit (no load for 12 hours) at full charge: 12.6 - 12.8 V
- Open-circuit at full discharge: 11.8 - 12.0 V
- Loaded at full discharge: 10.5 V. (about 1.75 volts/cell)
- Continuous-preservation (float) charging: 13.8V for gelled electrolyte; 13.5V for AGM (Absorbed Glass Mat) and 13.4V for flooded.
- Typical (daily) charging: 14.2 - 14.5 V (depending on manufacturer's recommendation).
- Equalization charging (for flooded lead acids): 15 - 16 V
- Gassing threshold: 14.4 V
- After full charge the terminal voltage will drop quickly to 13.2 V and then slowly to 12.6 V.

Typically new lead-acid cells Low self-discharge at about 40% in one year. They have no memory effect. Should not be overheating during charging

Battery Efficiency

Energy efficiency is calculated on the amount of power used from the battery while discharging divided by the amount of power delivered to the battery while charging, multiplied by 100 to yield percent. P_{out} x 100 /P_{in} . A lead-acid battery has an efficiency of only 75-85%. The energy lost appears as heat and warms the battery. Keeping the charge and discharge rate of a battery low, helps keep a battery cool, improves the battery life, and energy efficiency.

The above losses don't include losses in the charging circuit which may have an efficiency of anywhere from 60% to 80% - thus the overall- total efficiency is the product of these efficiencies and ends up being 45% to 68%. To further this example - suppose the controls and motors on an electric vehicle or a power tool were 85% - the over all efficiency is now only 38 - 58%. This is why batteries are best used where storage of electricity is absolutely needed, or only intermittent very low power is required. If one can use the energy without storage in a battery one is better off.

In a survival situation its efficiency that counts. To further explain – If for example the electricity is generated from a gasoline engine running on wood gas - and that energy is converted to electricity, and then converted through a transformer to DC, and then converted to chemical energy, and then converted back to electrical energy, and then converted to rotary mechanical energy - it is clear that many losses have occurred. If the same gasoline engine running on wood gas were providing the rotary energy directly to the drive train of a tractor or vehicle or power tool it would be much more efficient.

Battery Capacity

Battery capacity refers to the total amount of energy stored within a battery. Rated capacity is in Ampere-hours (AH), which is the product of the current times the number of hours to total discharge. The capacity is normally compared with a time of 20 hours and a temperature of 68F (20C). There are five factors that dictate the capacity of a given battery:

- **Size** The volume and plate area of a battery increases with capacity
- **Temperature** As a battery gets colder, its capacity decreases.
- **Cut off voltage** To prevent damage, the cut-off voltage should be limited to 1.67V or 10V for a 12 Volt battery.
- **Discharge rate** This is the rate of discharge, measured in amperes. As the rate goes up, the capacity goes down.
- **History** Deep discharging, excessive cycling, age, over charging, under charging, all reduce capacity.

Choosing Battery Capacity

Specifying battery capacity involves a bit more than multiplying the load current by the backup time in hours. You must first de-rate the battery for capacity tolerance, temperature, and discharge rate.

- First, multiply the average load current by the hours of operation you need.
- Next, add 15% to cover loss of capacity from tolerance and un-cycled batteries.
- For every 10C (18F) below room temperature (72F) your worst case low temperature is add 10%.
- If your run time is less than 20 hours, add 10%
- Finally, add 40% to provide for an economic life cycle. A battery with 60% of its capacity left is considered worn out.

Example -- 10 Hours @ 200 MA, average current, worst case temp is 0C

- 10 hour run time at .2 Amperes 2.0 AH
- 15% from step 2 .3 AH
- 0C add 20% from step 3 .4 AH
- Add 10% from step 4 .2 AH
- add 40% from step 5 .8 AH

Total 3.7 AH

In a primitive survival situation, do not chouse a storage battery that is very much larger than your weekly charging capability. As an example: If one can only provide 100AH per week of charging current, than don't plan to have a storage capacity that is much more than say twice that. Put in storage any extra capacity that is not needed. Self-discharge rate is the limiting factor. Self-discharge rate is low for high quality 20 year valve regulated cells and low for 5 year wet cells. In the above example the estimated amount usable power per day due to inefficiencies of changing and self-discharge rate would be of the order of 10 AH/day. From time to time one should overcharge the battery to equalize the charge on all cells.

Deep Discharge

Discharging a battery even slightly below its fully discharged voltage shortens its life. Letting a battery sit and self discharge to 0 destroys the battery. Fully discharging a battery to zero volts, just once, will render a battery unusable.

Also, consider that some equipment does not stop working "gracefully" as its voltage supply gets lower and lower. Some electronic equipment may work erratically and cause more current flow instead of less.

11-Lead-Acid Batteries

(11/3/2008)

Temperature

Store batteries at a low temperature if possible - 5deg C is ideal. Although capacity goes up with temperature, the life of a battery goes down.

The self discharge rate goes down with temperature. At room temperature, recharge stored batteries every 6 months; storage at 5C lets you wait 18 months before recharging.

Constant Voltage -- Taper Charging

Taper charging is the default charging mechanism of most chargers. The power supply is adjusted to give 13.8 VDC (27.6 VDC for the 24 volt model). The battery will charge rapidly at first and then slow down as it reaches full charge. After charging the battery fully, you should use a trickle charging current that is equal to the capacity in Amp hours divided by 100 to 200. For example: Using an 8 AH Battery ~ 8/200 = .040; therefore the final charge current should be 40 MA

The advantage to a Constant Voltage system is simplicity. On the other hand, it is a slow way to recharge a battery. Increasing the voltage to speed up the charge rate will cause the battery to overcharge and fail. Instead, speed up battery recharge with a constant current charge system.

Constant Current Charging

This is the usual method of charging Lead acid low maintenance batteries. Charge current is limited to a maximum Current AND voltage. The table below is based on I = Ah/4

Nominal Capacity Ah	1.2	1.9	2.6	4	7	17	21	33
Maximum Initial Charge rate A	0.3	0.475	0.65	1	1.75	4.25	5.25	8.25

Modeling Lead-Acid batteries

No load - fully charged voltage	2.03V/cell
Charging over-voltage	0.3V/cell
Discharge drop-voltage	0.05V/cell
Full charge with float current	2.3V/cell
Fully discharged Battery	1.6 - 1.8V /cell
dE/dT Fully charged battery	0
dE/dT full discharged Battery	-0.00043 V/C per cell

A 12V battery will typically show 13.8V on a trickle charge and drop to 12V to 12.6V with just the slightest load. With a practical load it drops another .05V per cell or about 0.3 volt to put a 12V battery at 11.7V. Thus there is a dead band (a kind of surface charge) in the battery that has little to do with internal resistance.

What is interesting is that the no load voltage stays pretty much the same until the battery is really discharged. This is why one measure state of charge by measuring voltage with the battery under a load. The reverse is true for charging a battery, the zero current flow voltage is always very close to 12V to 12.6V but as the battery reaches full charge the voltage goes up rapidly. A batteries internal resistance is not linear with Ah capacity, but can be assumed linear at low power levels. See:
http://xtronics.com/reference/batterap.htm

Battery specifications	
Energy/weight	30-40 Wh/kg
Energy/size	60-75 Wh/L
Power/weight	180 W/kg
Charge/discharge efficiency	70%-92%
Energy/consumer-price	7(sld)-18(fld) Wh/US$ [1]
Self-discharge rate	3%-20%/month [2]
Time durability	
Cycle durability	500-800 cycles
Nominal Cell Voltage	2.0 V

Sulfation

Sulfation refers to the process whereby a lead-acid battery (such as a car battery) loses its ability to hold a charge after it is kept in a discharged state too long due to the crystallization of lead sulfate.

Lead-acid batteries generate electricity through a double sulfate chemical reaction. Lead and lead dioxide, which are the active materials on the battery's plates, react with sulfuric acid in the electrolyte to form lead sulfate. When formed, the lead sulfate is in a finely divided, amorphous form, which is easily converted back to lead, lead oxide and sulfuric acid when the battery is recharged.

Over time, lead sulfate converts to the more stable crystalline form, coating the battery's plates. Crystalline lead sulfate does not conduct electricity and cannot be converted back into lead and lead oxide under normal charging conditions. As batteries are "cycled" through numerous discharge and charge sequences, lead sulfate that forms during normal discharge is slowly converted to a very stable crystalline form. This process is known as sulfation.

Sulfation is a natural, normal process that occurs in all lead-acid batteries during normal operation. Sulfation clogs grids, impedes recharging and ultimately can expand and crack the plates as it accumulates, destroying the battery. Crystalline lead sulfate is resistant to normal charging current, and does not re-dissolve completely. Thus, not all the lead is returned to the battery plates, and the amount of usable active material necessary for electricity generation declines over time. In addition, the sulfate portion (of the lead sulfate) is not returned to the electrolyte as sulfuric acid.

Sulfation also affects the charging cycle, resulting in longer charging times, less efficient and incomplete charging, excessive heat generation (higher battery temperatures). Higher battery temperatures cause longer cool-down times and can accelerate corrosion.

The process can often be at least partially prevented and/or reversed by devices known as *desulfators*, which repeatedly send short but powerful current surges through the damaged battery. Over time, this procedure tends to break down and dissolve the sulfate crystals, restoring some of the battery's capacity. See: http://en.wikipedia.org/wiki/Sulfation

Corrosion of terminals and cables is another common problem with lead-acid batteries. Look for this and use water or a basic solution like backing soda mixed with water to keep all connections clean. Grease can be used to help keep them from recorroding.

Is Repair Possible in a Primitive Environment?

If you have a 12 volt battery that looses a cell what can you do? Typically a cell will begin to leak internally from negative plate to positive plate until it will not hold a charge for very long. Look for a bulging case that would indicate sulfation building up enough to cause the budge. If this is the case one can drain the cell and put distilled water in it and charge the cell slowly after sitting for one hour at 4 amps for auto size battery.

Sulfate is converted into sulfuric acid as it charges and the current is adjusted to keep it from going too high. Keep the temperature below 110 degree F by shutting off the processes as needed. Keep a slow charge going as long as the specific gravity keeps rising. After the gravity stops rising empty out the electrolyte and replace with fresh solution. This will not work with all batteries.

If it doesn’t work then plan to use the remaining cells and short out the one that is bad. The best way is to bypass the cell by shorting it with a jumper. If the terminals do not show above the top then one can open the battery acid add hole and bride the plates by screwing a wood screw between them into the separator. Another way is screw a wood screw through the top plastic or tar into each of the terminal posts and run a jumper wire between.

The remaining battery instead of ranging from the typical 13.2 volt full charge to 11.5 volt discharged becomes an 11 volt charged to 9.6 volt discharged unit. This is plenty for running LED Lighting. Just don't plan on charging this battery in parallel with a good 12 volt battery. It will kill the good ones. Set this 10 volt battery aside as a special purpose battery.

Use a maximum charging rate of one half to 1/5 of the amp-hour capacity. For 100 amp-hour that would be 20 to 50 amps.

How To Test A Battery

There are six simple steps in testing a deep cycle battery: inspect, recharge, remove surface charge, measure the state-of-charge, load test, and recharge. If you have a non-sealed battery, it is highly recommended that you use a good quality temperature compensated hydrometer; these can be purchased at an auto parts store for between $5 and $20. A hydrometer is a float type device used to determine the state-of-charge by measuring the specific gravity of the electrolyte in each cell. It is a very accurate way of determining a battery's state-of-charge and its weak or dead cells. To troubleshoot charging or electrical systems or if you have a sealed battery, you will need a digital voltmeter with 0.5% or better accuracy. A digital voltmeter can be purchased at an electronics store like Radio Shack or from http://search.harborfreight.com/cpisearch/websearch.html. In this case multimeter 92020-1VGA or 98025-1VGA sells for $4.99 each. Analog voltmeters are usually not accurate enough to measure the millivolt differences of a battery's state-of-charge or the output of the charging system. Load testers also can be used. Harbor Freight has several 90636-2VGA that sell for around $15.

Visual Inspection

Visually inspect for obvious problems. For example, is there a loose or broken lead wires, electrolyte levels below the top of the plates, corroded or swollen cables, corroded terminal clamps, dirty or wet battery top, loose hold-down clamps, loose cable terminals, or leaking or damaged battery case? If the electrolyte levels are low in non-sealed batteries, allow the battery to cool and add distilled water to the level indicated by the battery manufacturer. If this is not indicated, use 1/4 inch (7 mm) below the bottom of the plastic filler tube (vent wells). The plates need to be covered at all times. Avoid overfilling, especially in hot climates, because heat will cause the electrolyte to expand and overflow.

Recharge the battery to 100% state-of-charge. If the battery has a difference of .03 specific gravity reading between the lowest and highest cell, then you should equalize it.

Remove Surface Charge

Surface charge is the uneven mixture of sulfuric acid and water within the surface of the plates as a result of charging or discharging. It will make a weak battery appear good or a good battery to appear bad. You need to eliminate the surface charge by one of the following methods:

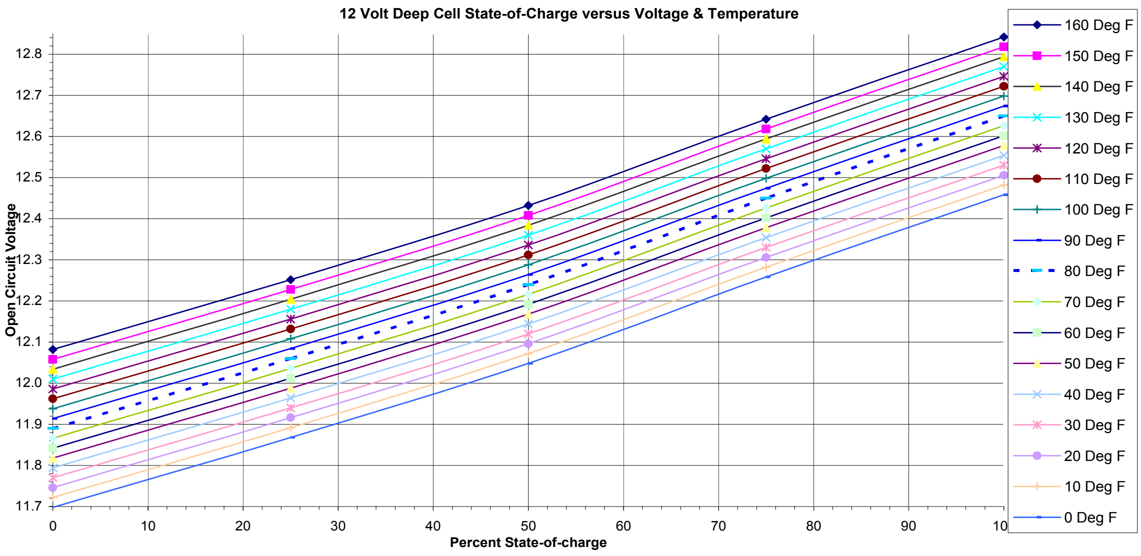
- Allow the battery to sit for four to twelve hours to allow for the surface charge to dissipate.
- Apply a load that is 33% of the ampere-hour capacity for five minutes and wait five to ten minutes.
- With a battery load tester, apply a load of at least one half the battery's CCA rating for 15 seconds and wait five to ten minutes.

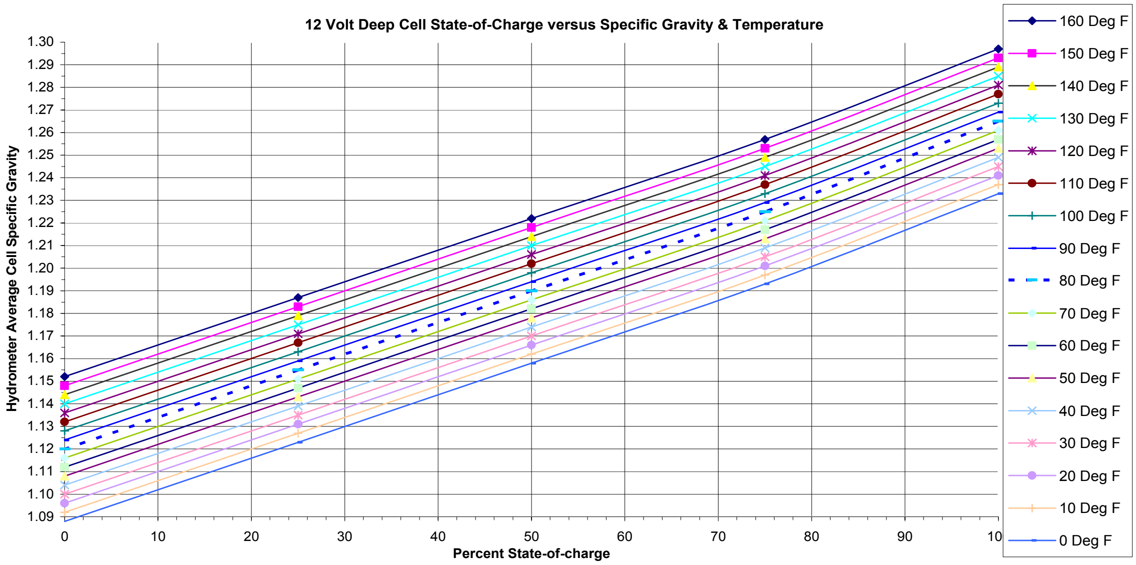
Measuring the State-Of-Charge

If the battery's electrolyte is above 110° F (43.3° C), allow it to cool. For example: To determine the battery's state-of-charge with the battery's electrolyte temperature at 80° F (26.7° C), use the following table. The table assumes that a 1.265 specific gravity reading is a fully charged, wet, lead acid battery. For other electrolyte temperatures, use the Temperature Compensation table below to adjust the Open Circuit Voltage or Specific Gravity readings. The Open Circuit Voltage will vary for gel cell and AGM type batteries, so check the manufacturer's specifications.

Testing the state of charge of Lead-Acid batteries will be a much-needed skill after the PS. Use the following plotted graphs or charts for easer reference.

Print these out along with the instructions and have them available when you need to do the measurements. A good idea would be to laminate it and keep it with your batteries.


12 Volt Deep Cell State-of-Charge versus Voltage & Temperature
Open Circuit Voltage
12.8
12.7
12.6
12.5
12.4
12.3
12.2
12.1
12.0
11.9
11.8
11.7
0
10
20
30
40
50
60
70
80
90
10
Percent State-of-charge
160 Deg F
150 Deg F
140 Deg F
130 Deg F
120 Deg F
110 Deg F
100 Deg F
90 Deg F
80 Deg F
70 Deg F
60 Deg F
50 Deg F
40 Deg F
30 Deg F
20 Deg F
10 Deg F
0 Deg F


12 Volt Deep Cell State-of-Charge versus Specific Gravity & Temperature
Hydrometer Average Cell Specific Gravity
1.30
1.29
1.28
1.27
1.26
1.25
1.24
1.23
1.22
1.21
1.20
1.19
1.18
1.17
1.16
1.15
1.14
1.13
1.12
1.11
1.10
1.09
0
10
20
30
40
50
60
70
80
90
10
Percent State-of-charge
160 Deg F
150 Deg F
140 Deg F
130 Deg F
120 Deg F
110 Deg F
100 Deg F
90 Deg F
80 Deg F
70 Deg F
60 Deg F
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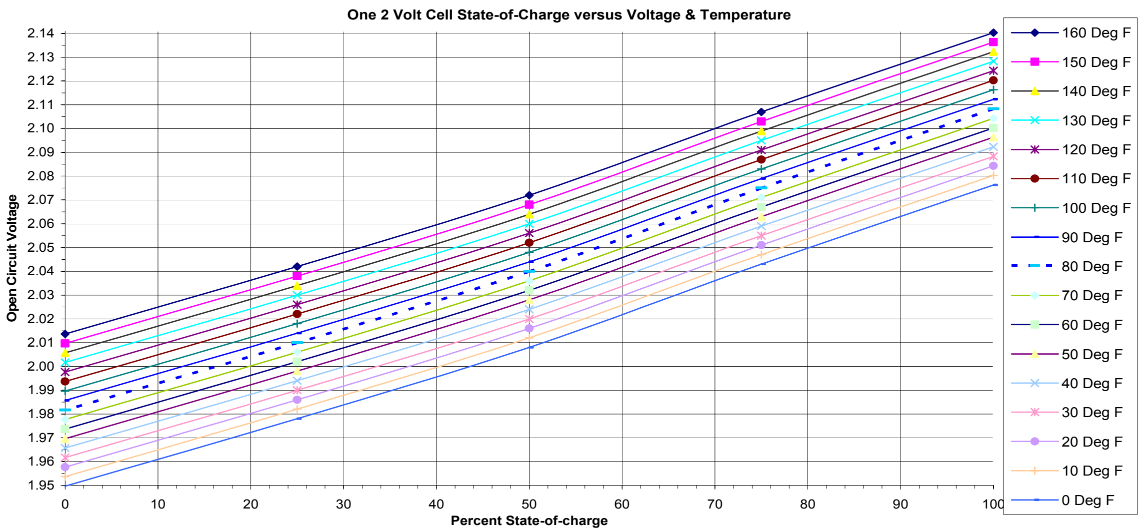
30 Deg F
20 Deg F
10 Deg F
0 Deg F


One 2 Volt Cell State-of-Charge versus Voltage & Temperature
Open Circuit Voltage
2.14
2.13
2.12
2.11
2.10
2.09
2.08
2.07
2.06
2.05
2.04
2.03
2.02
2.01
2.00
1.99
1.98
1.97
1.96
1.95
0
10
20
30
40
50
60
70
80
90
100
Percent State-of-charge
160 Deg F
150 Deg F
140 Deg F
130 Deg F
120 Deg F
110 Deg F
100 Deg F
90 Deg F
80 Deg F
70 Deg F
60 Deg F
50 Deg F
40 Deg F
30 Deg F
20 Deg F
10 Deg F
0 Deg F

Temperature Compensation

For non-sealed batteries, check the specific gravity in each cell with a hydrometer and average the readings. If you are using a non-temperature compensated HYDROMETER, make the adjustments indicated in the table above. For example, at 30° F (-1.1° C), the specific gravity reading would be 1.245 for a 100% State-of-Charge. At 100° F (37.8° C), the specific gravity would be 1.273 for 100% State-of-Charge. This is why using a temperature compensated hydrometer is highly recommended and more accurate than other means.

For sealed batteries, measure the Open Circuit Voltage across the battery terminals with an accurate digital voltmeter. This is the only way you can determine the State-of-Charge. If you are using a DIGITAL VOLTMETER, make the adjustments indicated in the table above. For example, at 30° F (-1.1° C), the voltage reading would be 12.53 for a 100% State-of-Charge. At 100° F (37.8° C), the voltage would be 12.698 for 100% State-of-Charge.

Any differences between measurements and the table can be noted as an offset error to be added or subtracted for your specific measuring instruments. It may take time and experience to come up with this.

If the State-of-Charge is below 75% using either the specific gravity or voltage test or the built-in hydrometer indicates bad (usually dark), then the battery needs to be recharged before proceeding.

You should replace the battery, if one or more of the following conditions occur:

- If there is a .05 (sometimes expressed as 50 points) or more difference in the specific gravity reading between the highest and lowest cell, you have a weak or dead cell(s). If you are really lucky, applying an EQUALIZING charge may correct this condition.

- If the battery will not recharge to a 75% or more state-of-charge level or if the built-in hydrometer still does not indicate good (usually green, which is 65% state-of-charge or better). If you know that a battery has spilled or bubbled over and the electrolyte has been replaced with water, you can replace the old electrolyte with new electrolyte and go back to previous step above. Battery electrolyte is a mixture of 25% sulfuric acid and distilled water. It is cheaper to replace the electrolyte than to buy a new battery.

- If a digital voltmeter indicates 0 volts, you have an open cell. This is one that is not connected so electrons can flow.

- If the digital voltmeter indicates 10.45 to 10.65 volts or lower, you probably have a shorted cell or a severely discharged battery. A shorted cell is caused by plates touching, sediment (mud) build-up or treeing between the plates.

Load Testing

If the battery is fully charged or has a good hydrometer indication, then you can test the capacity of the battery by applying a known load and measuring the time it takes to discharge the battery until 20% capacity is remaining. Normally a discharge rate that will discharge a battery in 20 hours can be used. For example, if you have an 80-ampere-hour rated battery, then a load of four amps would discharge the battery in approximately 20 hours (or 16 hours down to the 20% level). New batteries can take up to 50 charge/discharge cycles before they reach their rated capacity. Depending on your application, batteries with 80% or less of their original capacity are considered to be bad.

If the battery passes the load test, you should recharge it as soon as possible to restore it to peak performance and to prevent lead sulfation.

Frequently Asked Questions (FAQ)

1) HOW LONG WILL A DEEP CYCLE BATTERY LAST ON A SINGLE CHARGE?
Discharging, like charging, depends on a number of factors such as: The initial state-of-charge, depth-of-discharge, age, capacity, load, and temperature. For a fully charged battery at 70° F (21.1° C), the ampere-hour rating divided by the load in amps will provide the estimated life of that cycle. For example, a new, 72-ampere-hour battery with a 10-amp load should last approximately 7.2 hours. As the battery ages, the capacity is reduced.

2) HOW CAN ONE REVIVE A SULFATED BATTERY?
Lead sulfation occurs when a lead sulfate compound is deposited on the lead electrodes of a storage battery; this is a problem if the lead sulfate compound cannot be converted back into charged material and is created when discharged batteries stand for a long time. When the state-of-charge drops below 80%, the plates become coated with a hard and dense layer of lead sulfate, which fill up the pores. The positive plates will be light brown and the negative plates will be dull off-white. Over time, the battery loses capacity and cannot be recharged.

- Light Sulfation: Apply a constant current from one to two amps for 48 to 120 hours at 14.4 VDC, depending on the electrolyte temperature and capacity of the battery. Cycle (discharge to 50% and recharge) the battery a couple of times and test capacity. You might have to increase the voltage in order to break down the hard lead sulfate crystals. If the battery gets above 110° F (43.3° C) then stop charging and allow the battery to cool down before continuing.

- Heavy Sulfation: Replace the electrolyte with distilled water, let stand for one hour, apply a constant current of four amps at 13.8 VDC until there is no additional rise in specific gravity. Remove this electrolyte, wash the sediment out, replace with fresh electrolyte, and recharge. If the specific gravity exceeds 1.300, then remove the old electrolyte, wash the sediment out, and start over with distilled water. If the battery electrolyte rises above 110° F (43.3° C), then stop charging and allow the battery to cool down before continuing. Cycle (discharge to 50% and recharge) the battery a couple of times and test capacity. The sulfate crystals are more soluble in distilled water than in electrolyte. As they are dissolved, the sulfate is converted back into sulfuric acid and the specific gravity rises. These techniques will only work with some batteries.

- Pulse chargers: Work over several cycles of charging and discharging the battery to dissolve the hard sulfate crystals back into solution. Depending on the battery not being shorted internally, these units are said to work very well. For more info on the most successfully types see: http://www.r-charge.com/products.html

3) HOW CAN ONE REDUCE RECHARGING TIME?
To reduce the amount of time that your charger is running, only recharge the battery to 90% state-of-charge at the amp hour rate not exceeding the number of ampere-hours that need to be replaced. For example, if you have consumed 50-ampere-hours from a 100-amp hour battery, then you do not want to recharge it at rate any greater than 40 amps in one hour. At a 10-amp, charging rate, it should take approximately 4.3 hours to get to a 90% state-of-charge. Please note that it will take almost the same amount of time, at a reduced current, to recharge the battery the remaining 10% to bring it to 100% state-of-charge as it took to recharge it originally from the 50% to the 90% level. If you recharge to the 90% state-of-charge level, you should charge to 100% at least every 10th cycle.

Rules of Thumb for a Primitive Environment

After several years of working with 6 and 12 volt batteries at a seldom visited remote site, we have finally learned a few valuable lessons worth sharing. When building and using a battery bank for remote power the following practical general rules would apply.

General Rule: 1) Do not connect a number of 12 volt batteries in parallel to make a long term use high capacity battery bank. We found this is a good way to kill off good batteries in short order. Sooner or latter there is enviably one weak cell in the bunch. This week cell will drain the charge of the rest of the good batteries and untimely make them all bad. A weak cell is one that losses it charge rapidly (due to internal leakage) the resulting individual 12 volt battery becomes around 11 volts if allowed to set for a week or so. Excessive internal leakage can be a result of over sulfation in the cell.

Most 12 volt batteries are sealed on the top and do not allow for measurement of individual cell voltage. Using a parallel connection of many 12Volt batteries, a bad cell is very difficult to find. One has to charge the parallel combination and then disconnect all batteries and let them set for a few days to a week. The batteries with bad cells will ultimately show up with voltages below 12 volts. In a low tech survival environment where one needs to use all of the batteries daily this becomes impractical.

A better approach is to use one battery at a time for power. From time to time completely charging it and rotating it out to then use another. Watch the voltage of the ones sitting idle to get an idea how good or bad they are. This is done by compare the voltage of each cell or battery. The one with the consistent lowest voltage is the one most likely to go bad. It will be the one with the greatest internal leakage.

If you really are on top of it and watching it and need the extra immediate power then go for several 12 volt batteries in parallel at the most. Try to match up batteries that have the same internal leakage or self discharging rate when doing this. Just don't leave it hooked up this way for the long term.

Bottom line it is better to let a good battery set idle when charged than to put it in parallel with other 12 volt batteries of unknown condition. The weakest one will pull down all the rest and make the majority go bad before there normal life time is up. Thus the rule --- do not connect 12 volt batteries in parallel to make a long term high capacity use battery bank.

Rule: 2) The deeper the discharged state of a battery the shorted the time one should wait to charge it. If one leaves a 12 volt discharged battery (measures below 12 volts) for a month or longer it will not fully charge due to sulfation. This also promotes dead or leaky cells. The longer it is left the less capacity it will have if it holds a change at all. If a battery is partly discharged say it is 30 % discharge then the battery can set for much longer (Say 6 months) before it sulfates very much. Sulfation forms when a cell is discharged. Non-reversible sulfation results when the battery sits for too long a time in a partly discharged condition. The sulfation crystals become hard and irreversible with time. They then do not go back into solution during charging. The battery is considered to be sulfated.

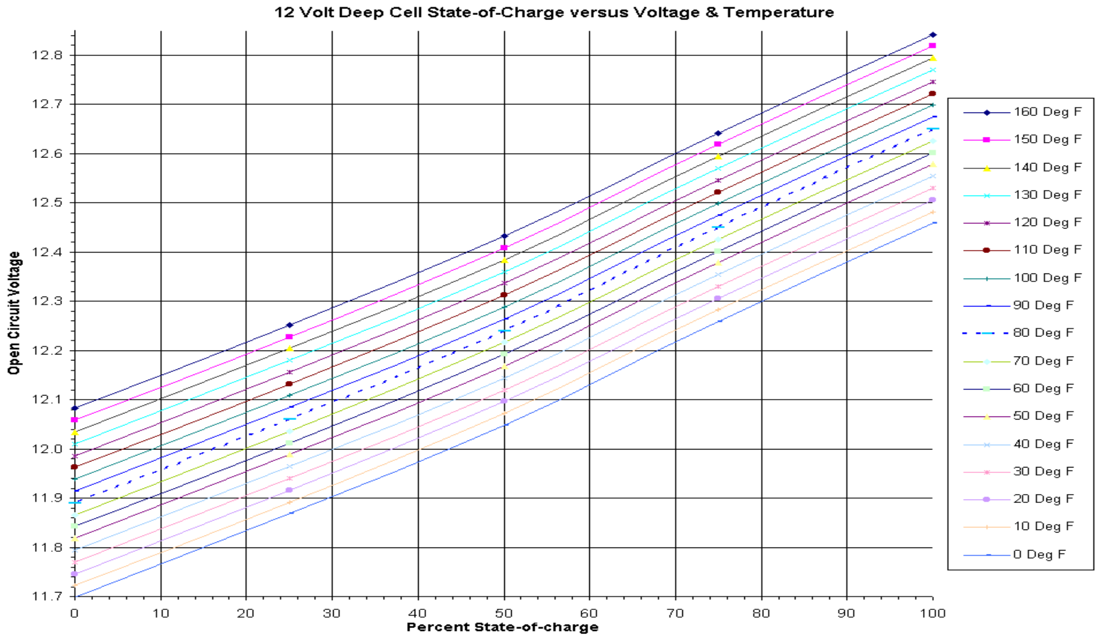
A sulfated battery can sometimes be cured by over charging it for over a week or so at over 15 or more volts for a 12 volt battery. Radio frequency pulse chargers work well at dissolving the crystals of sulfate. See http://www.r-charge.com/products.html.

Due to lack of power this can be hard to do in a primitive survival situation. Another way is to drain the battery acid and put distilled water in the cells. Let it sit for one hour. Charge at about 4 amp rate until hydrometer readings do not change over a period of time. This attempts to dissolve most of the sulfate crystals into solution. Then drain and save this new wash acid. Wash the sediment out of the cell with more distilled water. Replace with new acid if you have it. If in a primitive environment, boil down the wash acid to make it stronger and then combine the original saved acid with the newly created wash acid and continue to slowly boil it down to an amount that will just fit back into the original battery. Filter this through some fiber glass insulation packed into a plastic funnel to remove small particles. Use a non-corrosive or glass or plastic container to accomplish this. If the specific gravity gets up close to 1.3 then you have enough acid left to do the job.

Rule: 3) If you are purchasing a long term use battery bank use 6 high capacity single 2 volt cells in series to make a single 12 volt battery. Get one extra cell to replace one that may go bad in the future. Chouse an amp-hr rating that matches your charging capability. If you use a wind-mill and only get a small amount of Amp-hours out of your wind don't chouse a high capacity battery bank. You will never keep it charged, the internal leakage will too much. Use sealed valve regulated or gel type batteries that have a long life.

Rule: 4) When using a gasoline generator and a battery charger --- determine you're charging rate in amps and divide that into the amp-hour ratting of the battery to get how many hours you need to run your generator. For example 40 amps divided into 200 amp-hours for a battery = 5 hours for a full charge. From time to time say every month or two over charge the battery bank to balance out the cells. This is called equalization. It insures each cell is fully charged. Cells become unbalanced with respect to state of charge with time if never fully charged, due to different internal leakage rates of each cell.

Rule: 5) Determine your state of charge by measuring voltage for a battery in a resting state. This is a state of not being charged and not discharging and has not been actively being changed for more than 12 hours. Bottom line, wait 12 hours or more after charging and turn off all load and measure the voltage. Using the current temperature and rest voltage of the battery determine the state of charge by use of the attached chart.


12 Volt Deep Cell State-of-Charge versus Voltage & Temperature

Do not bother to purchase expensive meters that measure state of charge. They end up from personal experience being more trouble than they are worth. A simple low cost digital volt meter from Harbor Freight will work fine. See http://search.harborfreight.com/cpisearch/websearch.html. Multimeter 92020-1VGA or 98025-1VGA sells for $4.99 each. Both are a “7 function multi-tester” and will work fine.

Internal leakage and sulfation are the variables that determine useful battery life time that one need to become familiar with and watch for.

Watch for Hidden Power Leakage

From time to time measure the current flow with everything turned off for the 12 volt battery supply at your survival site. Things can creep into use that draw power even when turned off. We recently found that a 12 volt TV will use about 1 watt (.08amp) all the time, even when off. This is the sensor circuit that is constantly listening for the wireless remote. If you purchase any 12 Volt items with infrared remotes it will draw current while turned off. Avoid this. Measuring the current flow with everything turned off once in a while will point out the power wasters for you.

How to make a low cost DC Amp Meter

A simple low cost amperage measuring digital meter can be made using a $4.99 digital voltmeter item 92020-1VGA or 98025-1VGA from http://www.harborfreight.com/.

An alligator clip set at a given distance (see below) apart clipped onto your existing 12 volt feed wire can then be used to measure amps flow. The direction of flow is determined by the plus or minus sine for the 1 mv voltage scale.

The electricity passes through this feed wire to your site from the source battery producing a voltage drop across them. This voltage drop across this low resistance lead wire is then measured by the digital meter and what it reads is then read on the meter as amps flow. The length to place the alligator clips is critical and listed below.

The following table of common sizes shows length for given that input wire size

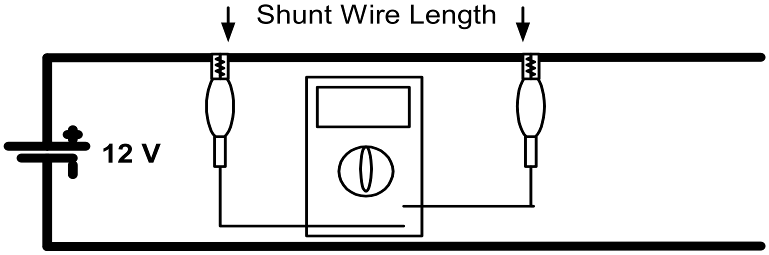
AWG Gauge	Inches of wire with clip at each end measuring voltage
2	76.7
4	48.3
6	30.3
8	19.1
10	12.0
12	7.5

More sizes are listed below:

AWG gauge	Diameter Inches	Diameter mm	Ohms per 1000 ft	Ohms per km	Maximum amps for chassis wiring	Maximum amps for power transmission	Shunt length in Inches for 1 mv = 1 amp	Shunt length in CM for 1 mv = 1 amp
OOOO	0.4600	11.6840	0.0490	0.1607	380	302	244.898	622.200
OOO	0.4096	10.4038	0.0618	0.2027	328	239	194.175	493.330
OO	0.3648	9.2659	0.0779	0.2555	283	190	154.044	391.371
0	0.3249	8.2525	0.0983	0.3224	245	150	122.075	310.151
1	0.2893	7.3482	0.1239	0.4064	211	119	96.852	246.068
2	0.2576	6.5430	0.1563	0.5127	181	94	76.775	195.060
3	0.2294	5.8268	0.1970	0.6462	158	75	60.914	154.760
4	0.2043	5.1892	0.2485	0.8151	135	60	48.290	122.687
5	0.1819	4.6203	0.3133	1.0276	118	47	38.302	97.312
6	0.1620	4.1148	0.3951	1.2959	101	37	30.372	77.165
7	0.1443	3.6652	0.4982	1.6341	89	30	24.087	61.196
8	0.1285	3.2639	0.6282	2.0605	73	24	19.102	48.532
9	0.1144	2.9058	0.7921	2.5981	64	19	15.150	38.490
10	0.1019	2.5883	0.9989	3.2764	55	15	12.013	30.521
11	0.0907	2.3038	1.2600	4.1328	47	12	9.524	24.197
12	0.0808	2.0523	1.5880	5.2086	41	9.3	7.557	19.199
13	0.0720	1.8288	2.0030	6.5698	35	7.4	5.991	15.221
14	0.0641	1.6281	2.525	8.282	32	5.9	4.752	12.074
15	0.0571	1.4503	3.184	10.444	28	4.7	3.769	9.575
16	0.0508	1.2903	4.016	13.172	22	3.7	2.988	7.592
17	0.0453	1.1506	5.064	16.610	19	2.9	2.370	6.020
18	0.0403	1.0236	6.385	20.943	16	2.3	1.879	4.775
19	0.0359	0.9119	8.051	26.407	14	1.8	1.490	3.787
20	0.0320	0.8128	10.150	33.292	11	1.5	1.182	3.004
21	0.0285	0.7239	12.800	41.984	9	1.2	0.938	2.382
22	0.0254	0.6452	16.140	52.939	7	0.92	0.743	1.889
23	0.0226	0.5740	20.360	66.781	4.7	0.729	0.589	1.497
24	0.0201	0.5105	25.670	84.198	3.5	0.577	0.467	1.188
25	0.0179	0.4547	32.37	106.17	2.7	0.457	0.371	0.942
26	0.0159	0.4039	40.81	133.86	2.2	0.361	0.294	0.747
27	0.0142	0.3607	51.47	168.82	1.7	0.288	0.233	0.592
28	0.0126	0.3200	64.90	212.87	1.4	0.226	0.185	0.470
29	0.0113	0.2870	81.83	268.40	1.2	0.182	0.147	0.373
30	0.0100	0.2540	103.20	338.50	0.86	0.142	0.116	0.295
31	0.0089	0.2261	130.10	426.73	0.7	0.113	0.092	0.234
32	0.0080	0.2032	164.10	538.25	0.53	0.091	0.073	0.186
Metric 2.0	0.0079	0.2000	169.39	555.61	0.51	0.088	0.071	0.180
33	0.0071	0.1803	206.90	678.63	0.43	0.072	0.058	0.147
Metric 1.8	0.0071	0.1800	207.50	680.55	0.43	0.072	0.058	0.147
34	0.0063	0.1600	260.90	855.75	0.33	0.056	0.046	0.117
Metric 1.6	0.0063	0.1600	260.90	855.75	0.33	0.056	0.046	0.117
35	0.0056	0.1422	329.0	1079.1	0.27	0.044	0.036	0.093

Metric 1.4	0.0055	0.1400	339.0	1114.0	0.26	0.043	0.035	0.090
36	0.0050	0.1270	414.8	1360.0	0.21	0.035	0.029	0.074
Metric1.25	0.0049	0.1250	428.2	1404.0	0.2	0.034	0.028	0.071
37	0.0045	0.1143	523.1	1715.0	0.17	0.0289	0.023	0.058
Metric1.12	0.0044	0.1120	533.8	1750.0	0.163	0.0277	0.022	0.057
38	0.0040	0.1016	659.6	2163.0	0.13	0.0228	0.018	0.046
Metric 1	0.0039	0.1000	670.2	2198.0	0.126	0.0225	0.018	0.045
39	0.0035	0.0889	831.8	2728.0	0.11	0.0175	0.014	0.037
40	0.0031	0.0787	1049.0	3440.0	0.09	0.0137	0.011	0.029

The “Shunt Length” column in the above table can be used to determine the length of cable to be used to make a heavy duty DC amp meter. The way the result works is one measures the voltage drop across a given length of the cable that is currently in use supplying the 12 volts from the battery. This voltage drop is measure ideally by use of a digital meter; however an analog meter can also be used. One mili-volt measured is equal to one amp of current. If this meter is used on the 200 mv scale then one can read in tenths of an amp up to 200 amps. For small wire sizes if one uses 10 times the length as shown in the table above then the readings will be down to one hundredth of an amp. One simply clips, solders, or clamps the volt meter leads onto the proper length of existing 12 volt supply cable.



If an analog meter is used that is close to 1 ma full scale (meter movement about 81 ohms) and planned to be used to measure 20 amps full scale instead of a digital meter, then multiply the length found above by a factor of 4. For other configurations see: http://www.uoguelph.ca/~antoon/gadgets/shunts/shunts.html

Wire size Load Carrying Capacities (see table above)

The above chart is also a guideline of ampacity (amperage capacity) or copper wire current carrying capacity following the *Handbook of Electronic Tables and Formulas* for American Wire Gauge. As you might guess, the rated ampacities are just a rule of thumb. In careful engineering the insulation temperature limit, thickness, thermal conductivity, and air convection and temperature should all be taken into account. The Maximum Amps for Power Transmission uses the 700 circular mils per amp rule, which is very very conservative. The Maximum Amps for Chassis Wiring is also a conservative rating, but is meant for wiring in air, and not in a bundle. For short lengths of wire, such as is used in battery packs you should trade off the resistance and load with size, weight, and flexibility. See: http://www.powerstream.com/Wire_Size.htm This table is quite useful and has been included in the above table as a reference.

11-Lead-Acid Batteries

(11/3/2008)

In a long term survival situation it becomes vital to be able to rebuild batteries from parts of old batteries. To that end the following excerpts from an old book written on rebuilding batteries is included:

RADIO BATTERIES, FARM LIGHTING BATTERIES

A practical book for the repairman. Gives in nontechnical language, the theory, construction, operation, manufacture, maintenance, and repair of the lead-acid battery.

BY **0. A. WITTE**
Chief Engineer, American Bureau of Engineering, Inc.
Published 1922 by
THE AMERICAN BUREAU OF ENGINEERING, INC. CHICAGO, ILLINOIS, U. S. A.

Any one serious about rebuilding batteries, Get the full book at
http://groups.yahoo.com/group/tt-forum/files/

CHAPTER 3.

MANUFACTURE OF STORAGE BATTERIES.

A starting and lighting battery consists of the following principal parts:

1. **Plates**
2. **Separators**
3. **Electrolyte**
4. **Jars**
5. **Covers**
6. **Cell Connectors and Terminals**
7. **Case**

Plates

Of the two general types of battery plates, Faure and Plante, the Faure, or pasted type, is universally used on automobiles. In the manufacture of pasted plates there are several steps which we shall describe in the order in which they are carried out.

Casting the Grid. The grid is the skeleton of the plate. It performs the double function of supporting the mechanically weak active material and of conducting the current. It is made of a lead antimony alloy which is melted and poured into a mould. Pure lead is too soft and too easily attacked by the electrolyte, and antimony is added to give stiffness, and resistance to the action of the electrolyte in the cell. The amount of antimony used varies in different makes but probably averages 8 to 10%.

The casting process requires considerable skill, the proper composition of the metal and the temperature of both metal and moulds being of great importance in securing perfect grids, which are free from blowholes, and which have a uniform structure and composition. Some manufacturers cast two grids simultaneously in each mould, the two plates being joined to each other along the bottom edge.

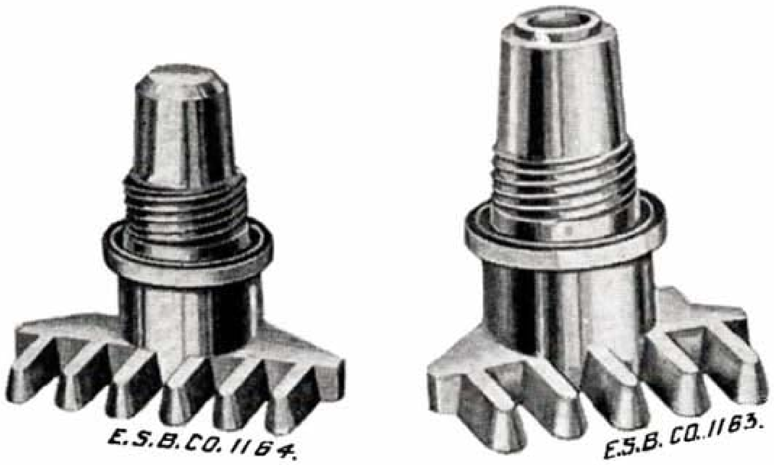
Trimming the Grids. When the castings have cooled, they are removed from the moulds and passed to a press or trimming machine which trims off the casting gate and the rough edges. The grids are given a rigid inspection, those having shrunken or missing ribs or other defects being rejected. The grids are now ready for pasting.

Fig. 4. Grid, Trimmed, and Ready for Pasting

Fig. 4 shows a grid ready for pasting. The heavy lug at one upper corner is the conducting lug, for carrying the current to the strap, Fig. 5, into which the lugs are burned when the battery is assembled. The straps are provided with posts, to which the intercell connectors and terminal connectors are attached. The vertical ribs of the grids extend through the plate, providing mechanical strength and conductivity, while the small horizontal ribs are at the surface and in staggered relation on opposite faces. Both the outside frames and the vertical ribs are reinforced near the lug, where the greatest amount of current must be carried.

The rectangular arrangement of ribs, as shown in Fig. 4, is most generally used, although, there are other arrangements such as the Philadelphia "Diamond" grid in which the ribs form acute angles, giving diamond shaped openings, as shown in Fig. 6.

Pastes. There are many formulas for the pastes, which are later converted into active material, and each is considered a trade secret by the manufacturer using it. The basis of all, however, is oxide of lead, either Red Lead (Pb_30_4), Litharge (PbO), or a mixture of the two, made into a paste with a liquid, such as dilute sulphuric acid. The object of mixing the oxides with the liquid is to form a paste of the proper consistency for application to the grids, and at the same time introduce the proper amount of binding, or setting agent which will give porosity, and which will bind together the active material, especially in the positive plate. Red lead usually predominates in the positive paste, and litharge in the negative, as this combination requires the least energy in forming the oxides to active material.



Negative Strap Positive Strap

Fig. 5. Plate Straps and Posts

The oxides of lead used in preparing the pastes which are applied to the grids are powders, and in their dry condition could not be applied to the grids, as they would fall out. Mixing them with a liquid to make a paste gives them greater coherence and enables them to be applied to the grids. Sulphuric acid puts the oxides in the desired pasty condition, but has the disadvantage of causing a chemical action to take place which changes a considerable portion of the oxides to lead sulphate, the presence of which makes the paste stiff and impossible to apply to the grids. When acid is used, it is therefore necessary to work fast after the oxides are mixed with sulphuric acid to form the paste.

In addition to the lead oxides, the pastes may contain some binding material such as ammonium or magnesium sulphate, which tends to bind the particles of the active material together. The paste used for the negatives may contain lamp black to give porosity.

Applying the Paste. After the oxides are mixed to a paste they are applied to the grids. This is done either by hand, or by machine In the hand pasting process, the pastes are applied from each face of the grid by means of a wooden paddle or trowel, and are smoothed off flush with the surface of the ribs of the grid. This work is done quickly in order that the pastes may not stiffen before they are applied.

U. S. L. plates are pasted in a machine which applies the paste to the grid, subjecting it at the same time to a pressure which forces it thoroughly into the grid, and packs it in a dense mass.

Drying the Paste. The freshly pasted plates are now allowed to dry in the air, or are dried by blowing air over them. In any case, the pastes set to a hard mass, in which condition the pastes adhere firmly to the grids. The plates may then be handled without a loss of paste from the grids.

Forming. The next step is to change the paste of oxides into the active materials which make a cell operative. This is called "forming" and is really nothing but a prolonged charge, requiring several days. In some factories the plates are mounted in tanks, positive and negative plates alternating as in a cell. The positives are all connected together in one group and the negatives in another, and current passed through just as in charging a battery. In other factories the positives and negatives are formed in separate tanks against "dummy" electrodes.

The passing of the current slowly changes the mixtures of lead oxide and lead sulphate, forming brown peroxide of lead (PbO_2), on the positive plate and gray spongy metallic lead on the negative. The formation by the current of lead peroxide and spongy lead on the positive and negative plates respectively would take place if the composition of the two pastes were identical. The difference in the composition of the paste for positive and negative plates is for the purpose of securing the properties of porosity and physical condition best suited to each.

When the forming process is complete, the plates are washed and dried, and are then ready for use in the battery. If the grids of two plates have been cast together, as is done by some manufacturers, these are now cut apart, and the lugs cut to the proper height. The next step is to roll, or press the negatives after they are removed from the forming bath so as to bring the negative paste, which has become roughened by gassing that occurred during the forming process, flush with the surface of the ribs of the grid. A sufficient amount of sulphate is left in the plates to bind together the active material. Without this sulphate the positive paste would simply be a powder and when dry would fall out of the grids like dry dust. Fig. 7 shows a formed plate ready to be burned to the strap.

Separators

In batteries used both for starting and for lighting, separators made of specially treated wood are largely used. See Fig. 8. The Willard Company has adopted an insulator made of a rubber fabric pierced by thousands of cotton threads, each thread being as long as the separator is thick. The electrolyte is carried through these threads from one side of the separator to the other by capillary action, the great number of these threads insuring the rapid diffusion of electrolyte which is necessary in batteries which are subjected to the heavy discharge current required in starting.

In batteries used for lighting or ignition, sheets of rubber in which numerous holes have been drilled are also used, these holes permitting diffusion to take place rapidly enough to perform the required service satisfactorily, since the currents involved are much smaller than in starting motor service.

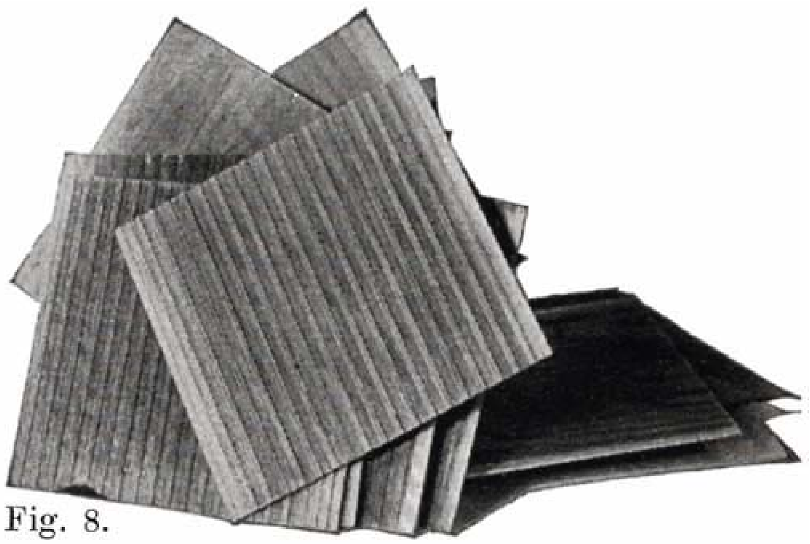


Fig. 8.

Fig. 8. A Pile of Prepared Wooden Seperators Ready to be Put Between the Positive and Negative Plates to Form the Complete Element.

For the wooden separators, porous wood, such as Port Orford cedar, basswood, cypress, or cedar is used. Other woods such as redwood and cherry are also used. The question is often asked "which wood makes the best separators?" This is difficult to answer because the method of treating the wood is just as important as is the kind of wood. The wood for the separators is cut into strips of the correct thickness. These strips are passed through a grooving machine which cuts the grooves in one side, leaving the other side smooth. The strips are next sawed to the correct size, and are then boiled in a warm alkaline solution for about 24 hours to neutralize any organic acid, such as acetic acid, which the wood naturally contains. Such acids would cause unsatisfactory battery action and damage to the battery.

The Vesta separator, or "impregnated mat," is treated in a bath of Barium salts which form compounds with the wood and which are said to make the separators strong and acid-resisting.

Some batteries use a double separator, one of which is the wooden separator, while the other consists of a thin sheet of hard rubber containing many fine perforations. This rubber sheet is placed between the positive plate and the wooden separator. A recent development in the use of an auxiliary rubber separator is the Philco slotted retainer which is placed between the separators and the positives in Philadelphia Diamond Grid Batteries. Some Exide batteries also use slotted rubber separators. The Philco slotted retainer consists of a thin sheet of slotted hard rubber as shown in Fig. 9. The purpose of the retainer is to hold the positive active material in place and prevent the shedding which usually occurs. The slots in the retainer are so numerous that they allow the free passage of electrolyte, but each slot is made very narrow so as to hold the active material in the plates.

Electrolyte

Little need be said here about the electrolyte, since a full description is given elsewhere. See page 222. Acid is received by the battery manufacturer in concentrated form. Its specific gravity is then 1.835. The acid commonly used is made by the "contact" process, in which sulphur dioxide is oxidized to sulphur trioxide, and then, with the addition of water, changed to sulphuric acid. The concentrated acid is diluted with distilled water to the proper specific gravity.

Jars

The jars which contain the plates, separators, and electrolyte are made of a tough, hard rubber compound. They are made either by the moulding process, or by -wrapping sheets of rubber compound around metal mandrels. In either case the jar is subsequently vulcanized by careful heating at the correct temperature.

The battery manufacturers do not, as a rule, make their own jars, but have them made by the rubber companies who give the jars a high voltage test to detect any flaws, holes, or cracks which would subsequently cause a leak. The jars as received at the battery maker's factory are ready for use.

Across the bottom of the jar are several stiff ribs which extend up into the jar so as to provide a substantial support for the plates, and at the same time form several pockets below the plates in which the sediment resulting from shedding of active material from the plates accumulates.

Covers

No part of a battery is of greater importance than the hard rubber cell covers, from the viewpoint of the repairman as well as the manufacturer. The repairman is concerned chiefly with the methods of sealing the battery, and no part of his work requires greater skill than the work on the covers. The manufacturers have developed special constructions, their aims being to design the cover so as to facilitate the escape of gas which accumulates in the upper part of a cell during charge, to provide space for expansion of the electrolyte as it becomes heated, to simplify inspection and filling with pure water, to make leak proof joints between the cover and the jar and between the cover and the lead posts which project through it, and to simplify the work of making repairs.

Single and Double Covers. Modern types of batteries have a single piece cover, the edges of which are made so as to form a slot or channel with the inside of the jar, into which is poured sealing compound to form a leak proof joint. Exide batteries are also made with a double flange cover, in which the top of the jar fits between the two flanges. In single covers, a comparatively small amount of sealing compound is used, and repair work is greatly simplified.

In the Eveready battery, Fig. 262, compound is poured over the entire cover instead of around the edges. This method requires a considerable amount of sealing compound.

The use of double covers is not as common as it was some years ago. This construction makes use of two flat pieces of hard rubber. In such batteries a considerable amount of sealing compound is used. This compound is poured on top of the lower cover to seal the battery, the top cover serving to cover up the compound and brace the posts. Fig. 10 illustrates this construction.

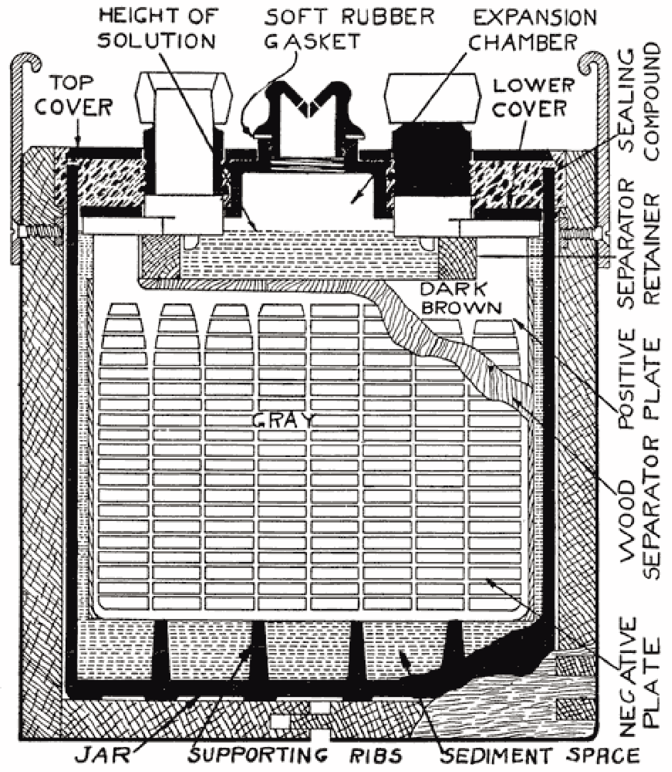


Fig. 10. Cross-Section of Gould Double Cover Battery

Sealing Around the Posts. Much variety is shown in the methods used to secure a leak proof joint between the posts and the cover. Several methods are used. One of these uses the sealing compound to make a tight joint. Another has lead bushings which are screwed up into the cover or moulded in the cover, the bushings being burned together with the post and cell connector. Another method has a threaded post, and uses a lead alloy nut with a rubber washer to make a tight joint. Still another method forces a lead collar down over the post, and presses the cover down on a soft rubber gasket.

Using Sealing Compound. Some of the batteries which use sealing compound to make a tight joint between the cover and the post have a hard rubber bushing shrunk over the post. This construction is used in Gould batteries, as shown in Fig. 10, and -in the old Willard double cover batteries. The rubber bushing is grooved horizontally to increase the length of the sealing surface.

Other batteries that use sealing compound around the posts have grooves or "petticoats" cut directly in the post and have a well around the post into which the sealing compound is poured. This is the construction used in the old Philadelphia Diamond Grid battery, as shown in Fig. 254.

Using Lead Bushings. U. S. L. batteries have a flanged lead bushing which is moulded directly into the cover, as shown in Fig. 11. In assembling the battery, the cover is placed over the post, and the cell connector is burned to both post and bushing.

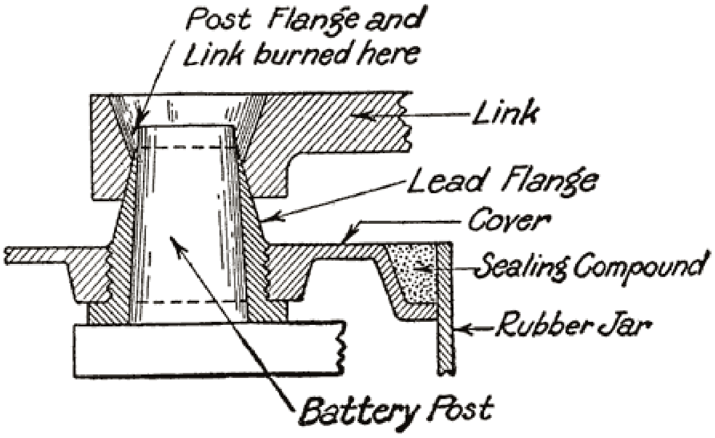


Fig. 12. Lead Bushing Screwed into Cover

In older type U. S. L. batteries a bushing was screwed up through the cover, and then burned to the post and cell connector.

An old type Prest-O-Lite battery used a lead bushing which screwed up through the cover similarly to the U. S. L. batteries. Fig. 12 illustrates this construction. The SJWN and SJRN Willard Batteries used a lead insert. See page 424.

The modern Vesta batteries use a soft rubber gasket under the cover, and force a lead collar over the post, which pushes the cover down on the gasket. The lead collar and post "freeze" together and. make an acid proof joint. See page 413. The Westinghouse battery uses a three part seal consisting of a lead washer which is placed around the post, a U shaped, soft gum washer which is placed between the post and cover, and a tapered lead sleeve, which presses the washer against the post and the cover. See page 417.

The Prest-O-Lite Peened Post Seal. All Prest-O-Lite batteries designated as types WHN, RHN, BHN and JFN, have a single moulded cover which is locked directly on to the posts. This is done by forcing a solid ring of lead from a portion of the post down into a chamfer in the top of the cover. This construction is illustrated in Fig. 247.

Batteries Using Sealing Nuts. The Exide batteries have threaded posts. A rubber gasket is placed under the cover on a shoulder on the post. The nut is then turned down on the post to force the cover on the gasket. This construction is illustrated in Fig. 239. The Titan battery uses a somewhat similar seal, as shown in Fig. 293.

Some of the older Willard batteries have a chamfer or groove in the under, side of the cover. The posts have a ring of lead in the base which fits up into the. groove in the cover to make a tight joint. This is illustrated in Fig. 13. The later Willard constructions, using a rubber gasket seal and a lead cover insert, are illustrated in Figs. 278 and 287.

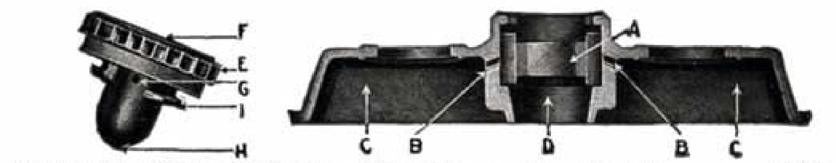
Filling Tube or Vent Tube Construction. Quite a number of designs have been developed in the construction of the filling or vent tube. In double covers, the tube is sometimes a separate part which is screwed into the lower cover. In other batteries using double covers, the tube is an integral part of the cover, as shown in Fig. 10. In all single covers, the tube is moulded integral with the cover.

Several devices have been developed to make it impossible to overfill batteries. This has been done by the U. S. L. and Exide companies on older types of batteries, their constructions being described as follows:

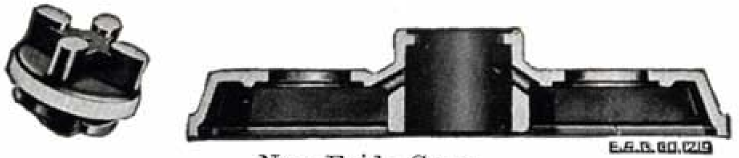
In old U. S. L. batteries, a small auxiliary vent tube is drilled, as shown in Fig. 14. When filling to replace evaporation, this vent tube prevents overfilling.

A finger is placed over the auxiliary vent tube shown in Fig. 14. The water is then poured in through the filling or vent tube. When the water reaches the bottom of the tube, the air imprisoned in the expansion chamber can no longer escape. Consequently the water can rise no higher in this chamber, but simply fills up the tube. Water is added till it reaches the top of the tube. The finger is then removed from the vent tube. This allows the air to escape from the expansion chamber. The water will therefore fall in the filling or vent tube, and rise slightly in the expansion chamber. The construction makes it impossible to overfill the battery, provided that the finger is held on the vent hole as directed.

Figure 15 shows the Non-Flooding Vent and Filling Plug used in the older type Exide battery, and in the present type LXRV. The new Exide cover, which does not use the non-flooding feature, is also shown. The old construction is described as follows:



Sectional View of Cover, Plug Removed. Air Passages (BB) Closed and Air Lock (A) in Position to Prevent Overfilling
Old Exide Cover



New Exide Cover

Fig. 15. Old and New Exide Covers

From the illustrations of the vent and filling plug, it will be seen that they provide both a vented stopper (vents F, G, H), and an automatic device for the preventing of overfilling and flooding. The amount of water that can be put into the cell is limited to the exact amount needed to replace that lost by evaporation. This is accomplished by means of the hard rubber valve (A) within the cell cover and with which the top of the vent plug (E) engages, as shown in the illustrations. The action of removing the plug (E) turns this valve- (A), closing the air passage (BB), and forming an air tight chamber (C) in the top of the cell. When water is poured in, it cannot rise in this air space (C) so as to completely fill the cell. As soon as the proper level is reached, the water rises in the filling tube (D) and gives a positive indication that sufficient water has been added. Should, however, the filling be continued, the excess will be pure water only, not acid. On replacing the plug (E), valve (A) is automatically turned, opening the air passages (BB), leaving the air chamber (C) available for the expansion of the solution, which occurs when the battery is working.

Generally the filling or vent tube is so made that its lower end indicates the correct level of electrolyte above the plates, In adding water, the level of the electrolyte is brought up to the bottom of the filling tube. By looking down into the tube, it can be seen when the electrolyte reaches the bottom of the tube.

Vent Plugs, or Caps. Vent plugs, or caps, close up the filling or vent tubes in the covers. They are made of hard rubber, and either screw into or over the tubes, or are tightened by a full or partial turn, as is done in Exide batteries. In the caps are small holes which are so arranged that gases generated within the battery may escape, but acid spray cannot pass through these holes. It is of the utmost importance that the holes in the vent caps be kept open to allow the gases to escape.

Case

The wooden case in which the cells are placed is usually made of kiln dried white oak or hard maple. The wood is inspected carefully, and all pieces are rejected that are weather-checked, or contain worm-holes or knots. The wood is sawed into -various thicknesses, and then cut to the proper lengths and widths. The wood is passed through other machines that cut in the dovetails, put the tongue on the bottom for the joints, stamp on the part number, drill the holes for the screws or bolts holding the handles, cut the grooves for the sealing compound, etc. The several pieces are then assembled and glued together. The finishing touches are then put on, these consisting of cutting the cases to the proper heights, sandpapering the boxes, etc. The cases are then inspected and are ready to be painted.

A more recent development in case construction is a one-piece hard rubber case, in which the jars and case are made in one piece, the cell compartments being formed by rubber partitions which form an integral part of the case. This construction is used in several makes of Radio "A" batteries, and to some extent in starting batteries.

Fig. 16. Battery Case

Asphaltum paint is generally used for wooden cases, the bottoms and tops being given three, coats, and the sides, two. The number of coats of paint varies, of course, in the different factories. The handles are then put on by machinery, and the case, Fig. 16, is complete, and ready for assembling.

Assembling and Sealing

The first step in assembling a battery is to burn the positive and negative plates to their respective straps, Fig. 5, forming the positive and negative "**groups**," Fig. 2. This is done by arranging a set of plates and a strap in a suitable rack which holds them securely in proper position, and then melting together the top of the plate lugs and the portion of the strap into which they fit with a hot flame.

A positive and a negative group are now slipped together and the separators inserted. The grooved side of the wood separator is placed toward the positive plate and when perforated rubber sheets are used these go between the positive and the wood separator.

The positive and negative "groups" assembled with the separators constitute the "**element**," Fig. 3.

Before the elements are placed in the jars they are carefully inspected to make sure that no separator has been left out. For this purpose the "Exide" elements are subjected to an electrical test which rings a bell if a separator is missing, this having been found more infallible than trusting to a man's eyes.

In some batteries, such as the Exide, Vesta, and Prest-O-Lite batteries, the cover is placed on the element and made fast before the elements are placed in the jars. In other batteries, such as the U. S. L. and Philadelphia batteries, the covers are put on after the elements are placed in the jars.

After the element is in the jar and the cover in position, sealing compound is applied hot so as to make a leak proof joint between jar and cover.

Fig. 17. Inter-Cell Connector

The completed cells are now assembled in the case and the cell connectors, Fig. 17, burned to the strap posts. After filling with electrolyte the battery is ready to receive its "initial charge," which may require from one day to a week. A low charging rate is used, since the plates are generally in a sulphated condition when assembled. The specific gravity is brought up to about 1.280 during this charge. Some makers now give the battery a short high rate discharge test (see page 266), to disclose any defects, and just before sending them out give a final charge. The batteries are often "**cycled**" after being assembled, this consisting in discharging and recharging the batteries several times to put the active material in the best working condition. If the batteries are to be shipped "wet," they are ready for shipping after the final charge and inspection. Batteries which are shipped "dry" need to have more work done upon them.

HOMEMADE BATTERIES

If the repairman who "fabricates" batteries takes chances, the man who attempts to actually make his own battery plates is certainly risking his business and reputation. There are several companies which sell moulds for making plate grids. One even sells cans of lead oxides to enable the repairman to make his own plate paste. Even more foolhardy than the man who wishes to mould plate grids is the man who wishes to mix the lead oxides himself. Many letters asking for paste formulas have been received by the author. Such formulas can never be given, for the author does not have them. Paste making is a far more difficult process than many men realize. The lead oxides which are used must be tested and analyzed carefully in a chemical laboratory and the paste formulas varied according to the results of these tests. The oxides must be carefully weighed, carefully handled, and carefully analyzed. The battery service station does not have the equipment necessary to do these things, and no repairman should ever attempt to make plate paste, as trouble is bound to follow such attempts. A car owner may buy a worthless battery once, but the next time he will go to some other service station and buy a good battery

No doubt many repairmen are as skillful and competent as the workers in battery factories, but the equipment required to make grids and paste is much too elaborate and expensive for the service station, and without such equipment it is impossible to make a good battery.

The only battery parts which may safely be made in the service station are plate straps and posts, intercell connectors, and cell terminals. Moulds for making such parts are on the market, and it is really worth while to invest in a set. The posts made in such moulds are of the plain tapered type, and posts which have special sealing and locking devices, such as the Exide, Philadelphia, and Titan cannot be made in them.

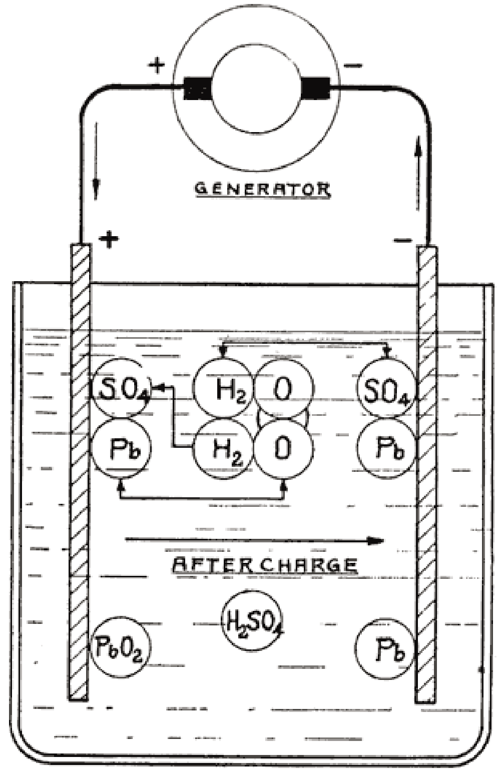
CHAPTER 4

CHEMICAL CHANGES IN THE BATTERY

Before explaining what happens within one storage cell, let us look into the early history of the storage battery, and see what a modest beginning the modern heavy duty battery had. Between 1850 and 1860 a man named Plante began his work on the storage battery. His original cell consisted of two plates of metallic lead immersed in dilute sulphuric acid. The acid formed a thin layer of lead sulphate on each plate which soon stopped further action on the lead. If a current was passed through the cell, the lead sulphate on the "**anode**" or lead plate at which the current entered the cell was changed into peroxide of lead, while the sulphate on the other lead plate or "**cathode**" was changed into pure lead in a spongy form. This cell was allowed to stand for several days and was then "discharged," lead sulphate being again formed on each plate. Each time this cell was charged, more "spongy" lead and peroxide of lead were formed. These are called the "active" materials, because it is by the chemical action between them and the sulphuric acid that the electricity is produced. Evidently, the more active materials the plates contained, the longer the chemical action between the acid and active materials could take place, and hence the greater the "capacity," or amount of electricity furnished by the cell. The process of charging and discharging the battery so as to increase the amount of active material, is called "**forming**" the plates.

Plante's method of forming plates was very slow, tedious, and expensive. If the spongy lead, and peroxide of lead could be made quickly from materials which could be spread over the plates, much time and expense could be saved. It was Faure who first suggested such a plan, and gave us the "**pasted**" plate of today, which consists of a skeleton framework of lead, with the sponge lead and peroxide of lead filling the spaces between the "ribs" of the framework. Such plates are known as "pasted" plates, and are much lighter and more satisfactory, for automobile work than the heavy solid lead plates of Plante's. Chapter 3 describes more fully the processes of manufacturing and pasting the plates.

We know now what constitutes a storage battery, and what the parts are that "generate" the electricity. How is the electricity produced? Theoretically, if we take a battery which has been entirely discharged, so that it is no longer able to cause a flow of current, and examine and test the electrolyte and the materials on the plates, we shall find that the electrolyte is pure water, and both sets of plates composed of white lead sulphate. On the other hand, if we make a similar test and examination of the plates and electrolyte of a battery through which a current has been sent from some outside source, such as a generator, until the current can no longer cause chemical reactions between the plates and electrolyte, we will find that the electrolyte is now composed of water and Sulphuric acid, the acid comprising about 30%, and the water 70% of the electrolyte. The negative set of plates will be composed of pure lead in a spongy form, while the positive will consist of peroxide of lead.



Chemical Action in a Storage Cell During Charge
Fig. 19

The foregoing description gives the final products of the chemical changes that take place in the storage battery. To understand the changes themselves requires a more detailed investigation. The substances to be considered in the chemical actions are sulphuric acid, water, pure lead, lead sulphate, and lead peroxide. With the exception of pure lead, each of these substances is a chemical compound, or composed of several elements. Thus sulphuric acid is made up of two parts of hydrogen, which is a gas; one part of sulphur, a solid, and four parts of oxygen, which is also a gas; these combine to form the acid, which is liquid, and which is for convenience written as H_2SO_4, H_2 representing two parts of hydrogen, S one part of sulphur, and 0_4, four parts oxygen. Similarly, water a liquid, is made up of two parts of hydrogen and one part of oxygen, represented by the symbol H_2O. Lead is not a compound, but an element whose chemical symbol is Pb, taken from the Latin name for lead. Lead sulphate is a solid, and consists of one part of lead, a solid substance, one part of sulphur, another solid substance, and four parts of oxygen, a gas. It is represented chemically by Pb SO_4. Lead peroxide is also a solid, and is made up of one part of lead, and two parts of oxygen. In the chemical changes that take place, the compounds just described are to a certain extent split up into the substances of which they are composed. We thus have lead (Pb), hydrogen (H), oxygen (0), and sulphur (S), four elementary substances, two of which are solids, and two gases. The sulphur does not separate itself entirely from the substances with which it forms the compounds H_2SO_4 and Pb SO_4. These compounds are split into H_2 and SO_4 and Pb and SO_4 respectively. That is, the sulphur always remains combined with four parts of oxygen.

Let us now consider a single storage cell made up of electrolyte, one positive plate, and one negative plate. When this cell is fully charged, or in a condition to produce a current of electricity, the positive plate is made up of peroxide of lead (PbO_2), the negative plate of pure lead (Pb), and the electrolyte of dilute sulphuric acid (H_2SO_4). This is shown diagrammatically in Fig. 19. **The chemical changes that take place when the cell is discharging and the final result of the changes are as follows:**

(a). At the Positive Plate: Lead peroxide and sulphuric acid produce lead sulphate, water, and oxygen, or**:**

$$\text{(a).}\quad PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O$$

(b). At the Negative Plate: Lead and sulphuric acid produce lead sulphate and Hydrogen, or:

$$\text{(b).}\quad Pb + H_2SO_4 = PbSO_4 + H_2$$

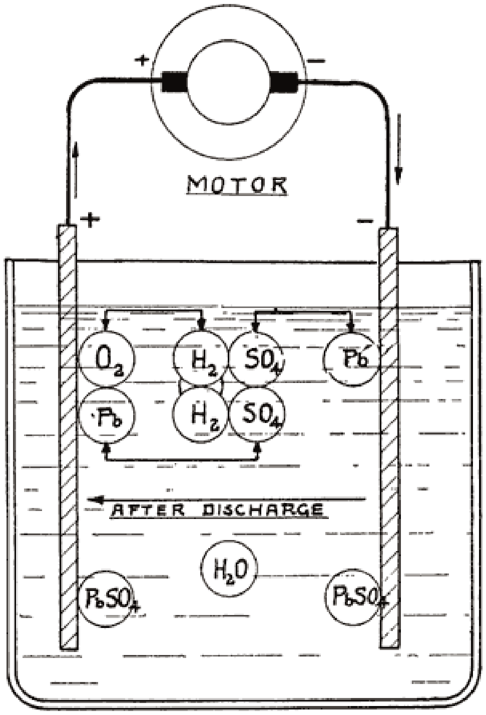
The oxygen of equation **(a)** and the hydrogen of equation **(b)** combine to form water, as may be shown by adding these two equations, giving one equation for the entire discharge action:

$$\text{(c).}\quad PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O$$

In this equation we start with the active materials and electrolyte in their original condition, and finish with the lead sulphate and water, -which are the final products of a discharge. Examining this equation, we see that the sulphuric acid of the electrolyte is used up in forming lead sulphate on both positive and negative plates, and is therefore removed from the electrolyte. This gives us the easily remembered rule for remembering discharge actions, which, though open to question from a strictly scientific viewpoint, is nevertheless convenient:

During discharge the acid goes into the plates.

The chemical changes described in **(a)**, **(b)**, and **(c)** are not instantaneous. That is, the lead, lead peroxide, and sulphuric acid of the fully charged cell are not changed into lead sulphate and water as soon as a current begins to pass through the cell. This action is a gradual one, small portions of these substances being changed at a time. The greater the current that flows through the cell, the faster will the changes occur. Theoretically, the changes will continue to take place as long as any lead,,. lead peroxide, and sulphuric acid remain. The faster these are changed into lead sulphate and water, the shorter will be the time that the storage cell can furnish a current, or the sooner it will be discharged.



Chemical Action in a Storage Cell During Discharge
Fig. 20

Taking the cell in its discharged condition, let us now connect the cell to a generator and send current through the cell from the positive to the negative plates. This is called "charging" the cell. The lead sulphate and water will now gradually be changed back into lead, lead peroxide, and sulphuric acid. The lead sulphate which is on the negative plate is changed to pure lead; the lead sulphate on the positive plate is changed to lead peroxide, and sulphuric acid will be added to the water. **The changes at the positive plate may be represented as follows:**

Lead sulphate and water produce. sulphuric acid, hydrogen and lead peroxide, or**:**

$$\text{(d).}\quad PbSO_4 + 2H_2O = PbO_2 + H_2SO_4 + H_2$$

The changes at the negative plate may be expressed as follows: Lead sulphate and water produced sulphuric acid, oxygen, and lead, or:

$$\text{(e).}\quad PbSO_4 + H_2O = Pb + H_2SO_4 + O$$

The hydrogen (H_2) produced at the positive plate, and the oxygen (0) produced at the negative plate unite to form water, as may be shown by the equation:

$$\text{(f).}\quad 2PbSO_4 + 2H_2O = PbO_2 + Pb + 2H_2SO_4$$

Equation **(f)** starts with lead sulphate and water, which, as shown in equation **(c)**, are produced when a battery is discharged. It will be observed that we start with lead sulphate and water. Discharged plates may therefore be charged in water. In fact, badly discharged negatives may be charged better in water than in electrolyte. The electrolyte is poured out of the battery and distilled water poured in. The acid remaining on the separators and plates is sufficient to make the water conduct the charging current.

In equation **(f)**, the sulphate on the plates combines with water to form sulphuric acid. This gives us the rule:

During charge, acid is. driven out of the plates.

This rule is a convenient one, but, of course, is not a strictly correct statement.

The changes produced by sending a current through the cell are also gradual, and will take place faster as the current is made greater. When all the lead sulphate has been 'used up by the chemical changes caused by the current, no further charging can take place. If we continue to send a current through the cell after it is fully charged, the water will continue to be split up into hydrogen and oxygen. Since, however, there is no more lead sulphate left with which the hydrogen and oxygen can combine to form lead, lead peroxide, and sulphuric acid, the hydrogen and oxygen rise to the surface of the electrolyte and escape from the cell. This is known as "**gassing**," and is an indication that the cell is fully charged.

Relations Between Chemical Actions and Electricity.

We know now that chemical actions in the battery produce electricity and that, on the other hand, an electric current, sent through the battery from an outside source, such as a generator, produces chemical changes in the battery. How are chemical changes and electricity related? The various chemical elements which we have in a battery are supposed to carry small charges of electricity, which, however, ordinarily neutralize one another. When a cell is discharging, however, the electrolyte, water, and active materials are separated into parts carrying negative and positive charges, and these "charges" cause what we call an electric current to flow in the apparatus attached to the battery.

Similarly, when. a battery is charged, the charging current produces electrical "charges" which cause the substances in the battery to unite, due to the attraction of position and negative charges for one another. This is a brief, rough statement of the relations between chemical reactions and electricity in a battery. A more thorough study of the subject would be out of place in this book. It is sufficient for the repairman to remember that the substances in a battery carry charges of electricity which become available as an electric current when a battery discharges, and that a charging current causes electric charges to form, thereby "charging" the battery.

CHAPTER 5

WHAT TAKES PLACE DURING DISCHARGE

Considered chemically, the discharge of a storage battery consists of the changing of the spongy lead and lead peroxide into lead sulphate, and the abstraction of the acid from the electrolyte. Considered electrically, the changes are more complex, and require further investigation. The voltage, internal resistance, rate of discharge, capacity, and other features must be considered, and the effects of changes in one upon the others must be studied. This proceeding is simplified considerably if we consider each point separately. The abstraction. of the acid from the electrolyte gives us a method of determining the condition of charge or discharge in the battery, and must also be studied.

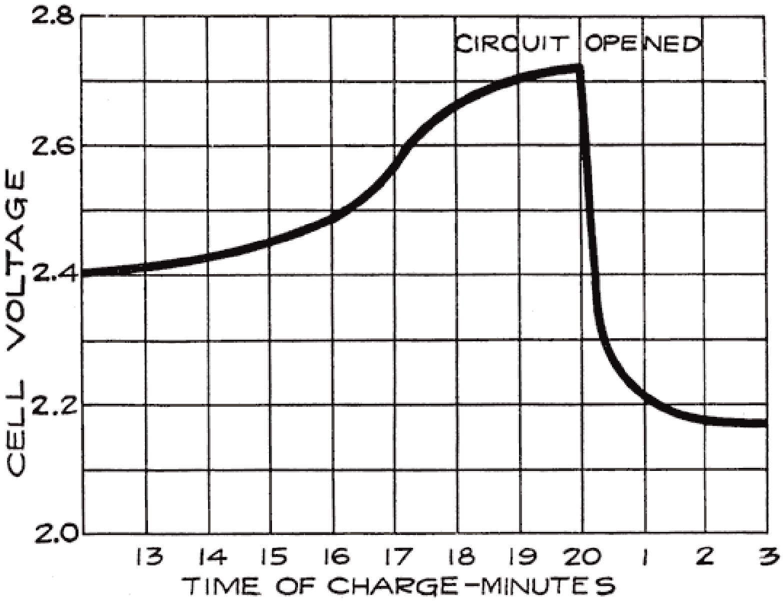


Fig. 21. Voltage Changes During Last Eight Minutes of Charge and First Three Minutes After End of Charge

Voltage Changes During Discharge. At the end of a charge, and before opening the charging circuit, the voltage of each cell is about 2.5 to 2.7 volts. As soon as the charging circuit is opened, the cell voltage drops rapidly to about 2.1 volts, within three or four minutes. This is due to the formation of a thin layer of lead sulphate on the surface of the negative plate and between the lead peroxide and the metal of the positive plate. Fig. 21 shows how the voltage changes during the last eight minutes of charge, and how it drops rapidly as soon as the charging circuit is opened. The final value of the voltage after the charging circuit is opened is about 2.15-2.18 volts. This is more fully explained in Chapter 6. If a current is drawn from the battery at the instant the charge is stopped, this drop is more rapid. At the beginning of the discharge the voltage has already had a rapid drop from the final voltage on charge, due to the formation of sulphate as explained above. When a current is being drawn from the battery, the sudden drop is due to the internal resistance of the cell, the formation of more sulphate, and the abstracting of the acid from the electrolyte which fills the pores of the plate. The density of this acid is high just before the discharge is begun. It is diluted rapidly at first, but a balanced condition is reached between the density of the acid in the plates and in the main body of the electrolyte, the acid supply in the plates being maintained at a lowered density by fresh acid flowing into them from the main body of electrolyte. After the initial drop, the voltage decreases more slowly, the rate of decrease depending on the amount of current drawn from the battery. The entire process is shown in Fig. 22.

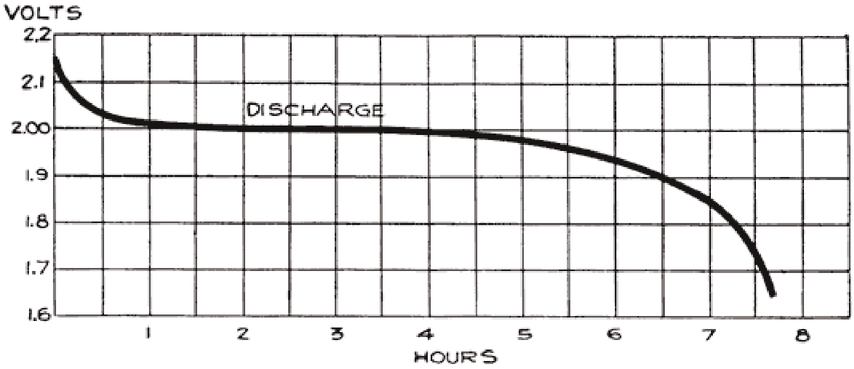


Fig. 22. Voltage Changes During Discharge

Lead sulphate is being formed on the surfaces, and in the body of the plates. This sulphate has a higher resistance than the lead or lead peroxide, and the internal resistance of the cell rises, and contributes to the drop in voltage. As this sulphate forms in the body of the plates, the acid is used up. At first this acid is easily replaced from the main body of the electrolyte by diffusion. The acid in the main body of the electrolyte is at first comparatively strong, or concentrated, causing a fresh supply of acid to flow into the plates as fast as it is used up in the plates. This results in the acid in the electrolyte growing weaker, and this, in turn, leads to a constant decrease in the rate at which the fresh acid flows, or diffuses into the plates. Furthermore, the sulphate, which is more bulky than the lead or lead peroxide fills the pores in the plate, making it more and more difficult for acid to reach the interior of the plate. This increases the rate at which the voltage drops.

The sulphate has another effect. It forms a cover over the active material which has not been acted upon, and makes it practically useless, since the acid is almost unable to penetrate the coating of sulphate. We thus have quantities of active material which are entirely enclosed in sulphate, thereby cutting down the amount of energy which can be taken from the battery. Thus the formation of sulphate throughout each plate and the abstraction of acid from the electrolyte cause the voltage to drop at a constantly increasing rate.

Theoretically, the discharge may be continued until the voltage drops to zero, but practically, the discharge should be stopped when the voltage of each cell has dropped to 1.7 (on low discharge rates). If the discharge is carried on beyond this point much of the spongy lead and lead peroxide have either been changed into lead sulphate, or have been covered up by the sulphate so effectively that they are almost useless. Plates in this condition require a very long charge in order to remove all the sulphate.

The limiting value of 1.7 volts per cell applies to a continuous discharge at a moderate rate. At a very high current flowing for only a very short time, it is not only' safe, but advisable to allow a battery to discharge to a lower voltage, the increased drop being due to the rapid dilution of the acid in the plates.

The cell voltage will rise somewhat every time the discharge is stopped. This is due to the diffusion of the acid from the main body of electrolyte into the plates, resulting in an increased concentration in the plates. If the discharge has been continuous, especially if at a high rate, this rise in voltage will bring the cell up to its normal voltage very quickly on account of the more rapid diffusion of acid which will then take place.

The voltage does not depend upon the area of the plate surface but upon the nature of the active materials and the electrolyte. Hence, although the plates of a cell are gradually being covered with sulphate, the voltage, measured when no current is flowing, will fall slowly and not in proportion to the amount of energy taken out of the cell. It is not until the plates are pretty thoroughly covered with sulphate, thus making it difficult for the acid to reach the active material, that the voltage begins to drop rapidly. This is shown clearly in Fig. 22, which shows that the cell voltage has dropped only a very small amount when the cell is 50% discharged. With current flowing through the cell, however, the increased internal resistance causes a marked drop in the voltage. Open circuit voltage is not useful, therefore to determine how much energy has been taken from the battery.

Acid Density. The electrolyte of a lead storage battery is a mixture of chemically pure sulphuric acid, and chemically pure water, the acid forming about 30 per cent of the volume of electrolyte when the battery is fully charged. The pure acid has a "specific gravity" of 1.835, that is, it is 1.835 times as heavy as an equal volume of water. The mixture of acid and water has a specific gravity of about 1.300. As the cell discharges, acid is abstracted from the electrolyte, and the weight of the latter must therefore grow less, since there will be less acid in it. The change in the weight, or specific gravity of the electrolyte is the best means of determining the state of discharge of a cell, provided that the cell has been used properly. In order that the value of the specific gravity may be used as an indication of the amount of energy in a battery, the history of the battery must be known. Suppose, for instance, that in refilling the battery to replace the water lost by the natural evaporation which occurs in the use of a battery, acid, or a mixture of acid and water has 'been used. This will result in the specific gravity being too high, and the amount of energy in the battery will be less than that indicated by the specific gravity. Again, if pure water is used to replace electrolyte which has been spilled, the specific gravity will be lower than it should be. In a battery which has been discharged to such an extent that much of the active material has been covered by a layer of tough sulphate, or if a considerable amount of sulphate and active material has been loosened from the plates and has dropped to the bottom of the cells, it will be impossible to bring the specific gravity of the electrolyte up to 1.300, even though a long charge is given. There. must, therefore, be a reasonable degree of certainty that a battery has been properly handled if the specific gravity readings are to be taken as a true indication of the condition of a battery. Where a battery does not give satisfactory service even though the specific gravity readings are satisfactory, the latter are not reliable as indicating the amount of charge in the battery.

As long as a discharge current is flowing from the battery, the acid within the plates is used up and becomes very much diluted. Diffusion between the surrounding electrolyte and the acid in the plates keeps up the supply needed in the plates in order to, carry on the chemical changes. When the discharge is first begun, the diffusion of acid into the plates takes place rapidly because there is little sulphate clogging the pores in the active material, and because there is a greater difference between the concentration of acid in the electrolyte and in the plates than will exist as the discharge progresses. As the sulphate begins to form and fill up the pores of the plates, and as more and more acid is abstracted from the electrolyte, diffusion takes place more slowly.

If a battery is allowed to stand idle for a short time after a partial discharge, the specific gravity of the electrolyte will decrease because some, of the acid in the electrolyte will gradually flow into the pores of the plates to replace the acid used up while the battery was discharging. Theoretically the discharge can be continued -until all the acid has been used up, and the electrolyte is composed of pure water. Experience has shown, however, that the discharge of the battery should not be continued after the specific gravity of the electrolyte has fallen to 1.150. As far as the electrolyte is concerned, the discharge may be carried farther with 'safety. The plates determine the point at which the discharge should be stopped. When the specific gravity has dropped from 1.300 to 1.150, so much sulphate has been formed that it fills the pores in the active material on the plates. Fig. 23 shows the change in the density of the acid during discharge.

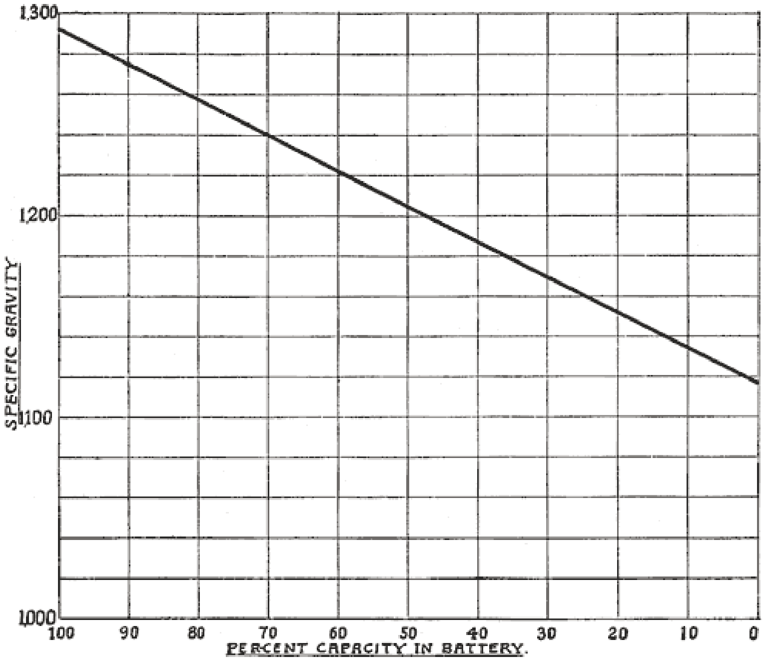


Fig. 23. Variation of Capacity with Specific Gravity

Changes at the Negative Plate. Chemically, the action at the negative plate consists only of the formation of lead sulphate from the spongy lead. The lead sulphate is only slightly soluble in the electrolyte and is precipitated as soon as it is formed, leaving hydrogen ions, which then go to the lead peroxide plate to form water with oxygen ions released at the peroxide plate. The sulphate forms more quickly on the surface of the plate than in the inner portions because there is a constant supply of acid available at the surface, whereas the formation of sulphate in the interior of the plate requires that acid diffuse into the pores of the active materials to replace that already used up in the formation of sulphate. In the negative plate, however, the sulphate tends to form more uniformly throughout the mass of the lead, because the spongy lead is more porous than the lead peroxide, and because the acid is not diluted by the formation of water as in the positive plate.

Changes at the, Positive Plate. In a fully charged positive plate we have lead peroxide as the active material. This is composed of lead and oxygen. From this fact it is plainly evident that during discharge there is a greater chemical activity at this plate than at the negative plate, since we must find something to combine with the oxygen in order that the lead may form. lead sulphate with the acid. In an ideal cell, therefore, the material which undergoes the greater change should be more porous than the material which does not involve as great a chemical reaction. In reality, however, the peroxide is not as porous as the spongy lead, and does not hold together as well.

The final products of the discharge of a positive plate are lead sulphate and water. The lead peroxide must first be reduced to lead, which then combines with the sulphate from the acid to form lead sulphate, while the oxygen from the peroxide combines with the hydrogen of the acid to form water. There is, therefore, a greater activity at this plate than at the lead plate, and the formation of the water dilutes the acid in and around the plate so that the tendency is for the chemical actions to be retarded.

The sulphate which forms on discharge causes the active material to bulge out because it occupies more space than the peroxide. This causes the lead peroxide at the surface to begin falling, to the bottom of the jar in fine dust-like particles, since the peroxide here holds together very

CHAPTER 6

WHAT TAKES PLACE DURING CHARGE

Voltage. Starting with a battery which has been discharged until its voltage has decreased to 1.7 per cell, we pass a current through it and cause the voltage to rise steadily. Fig. 24 shows the changes in voltage during charge. Ordinarily the voltage begins to rise immediately and uniformly. If, however, the battery has been left in a discharged condition for some time, or has been "over discharged," the voltage rises very rapidly for a fraction of the first minute of charge and then drops rapidly to the normal value and thereafter begins to rise steadily to the end of the charge. This rise at the beginning of the charge is due to the fact that the density of the acid in the pores of the plates rises rapidly at first, the acid thus formed being prevented from diffusing into the surrounding electrolyte by the coating of sulphate. As soon as this sulphate is broken through, diffusion takes place and the voltage drops.

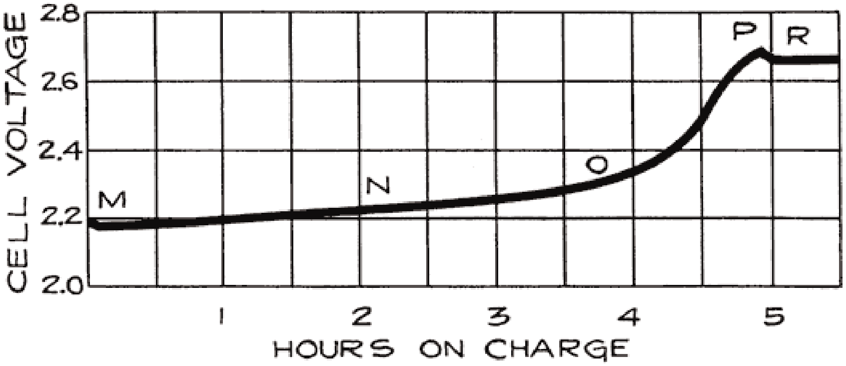


Fig. 24. Voltage Changes During Charge

As shown in Fig. 24, the voltage remains almost constant between the points M and N. At N the voltage begins to rise because the charging chemical reactions are taking place farther and farther in the inside parts of the plate, and the concentrated acid formed by the chemical actions in the plates is diffusing into the main electrolyte. This increases the battery voltage and requires a higher charging voltage.

At the point marked 0, the voltage begins to rise very rapidly. This is due to the fact that the amount of lead sulphate in the plates is decreasing very rapidly, allowing the battery voltage to rise and thus increasing the charging voltage. Bubbles of gas are now rising through the electrolyte.

At P, the last portions of lead sulphate are removed, acid is no longer being formed, and hydrogen and oxygen gas are formed rapidly. The gas forces the last of the concentrated acid out of the plates and in fact, equalizes the acid concentration throughout the whole cell. Thus no further changes can take place, and the voltage becomes constant at R at a voltage of 2.5 to 2.7.

Density of Electrolyte. Discharge should be stopped when the density of the electrolyte, as measured with a hydrometer, is 1.150. When we pass a charging current through the battery, acid is produced by the chemical actions which take place in the plates. This gradually diffuses with the main electrolyte and causes the hydrometer to show a higher density than before. This increase in density continues steadily until the battery begins to "gas" freely.

The progress of the charge is generally determined by the density of the electrolyte. For this purpose in automobile batteries, a hydrometer is placed in a glass syringe having a short length of rubber tubing at one end, and a large rubber bulb at the other. The rubber tube is inserted in the cell and enough electrolyte drawn up into the syringe to float the hydrometer so as to be able to obtain a reading. This subject will be treated more fully in a later chapter.

Changes at Negative Plate. The charging current changes lead sulphate into spongy lead, and acid is formed. The acid is mixed :with the diluted electrolyte outside of the plates. As the charging proceeds the active material shrinks or contracts, and the weight of the plate actually decreases on account of the difference between the weight and volume of the lead sulphate and spongy lead. If the cell has had only a normal discharge and the charge is begun soon after the discharge ended, the charge will proceed quickly and without an excessive rise in temperature. If, however, the cell has been discharged too far, or has been in a discharged- condition for some time, the lead sulphate will not be in a finely divided state as it should be, but will be hard and tough and will have formed an insulating coating over the active material, causing the charging voltage to be high, and the charge will proceed slowly. When most of the lead sulphate has been reduced to spongy lead, the charging current will be greater than is needed to carry on the chemical actions, and will simply decompose the water into hydrogen and oxygen, and the cell "gasses. " Spongy lead is rather tough and coherent, it, and the 'bubbles of gas which form in the pores of the negative plate near the end of the charge force their way to the surface without dislodging any of the active material.

Changes at the Positive Plate. When a cell has been discharged, a portion of the lead peroxide has been changed to lead sulphate, which has lodged in the pores of the active material and on its surface. During charge, the lead combines with oxygen from the water to form lead peroxide, and acid is formed. This acid diffuses into the electrolyte as fast as the amount of sulphate will permit. If the discharge has been carried so far that a considerable amount of sulphate has formed in the pores and on the surface of the plate, the action proceeds very slowly, and unless a moderate charging current is used, gassing begins before the charge is complete, simply because the sulphate cannot absorb the current. The gas bubbles which originate in the interior of the plate force their way to the surface, and in so doing cause numerous fine particles of active material to break off and fall to the bottom of the jar. This happens because the lead peroxide is a granular, non-coherent substance, with the particles held together very loosely, and the gas breaks off a considerable amount of active material.

CHAPTER 8

INTERNAL RESISTANCE

The resistance offered by a storage battery to the flow of a current through it results in a loss of voltage, and in heating. Its value should be as low as possible, and, in fact, it is almost negligible even I in small batteries, seldom rising above 0.05 ohm. On charge, it causes the charging voltage to be higher and 'on discharge causes a loss of voltage. Fig. 26 shows the variation in resistance.

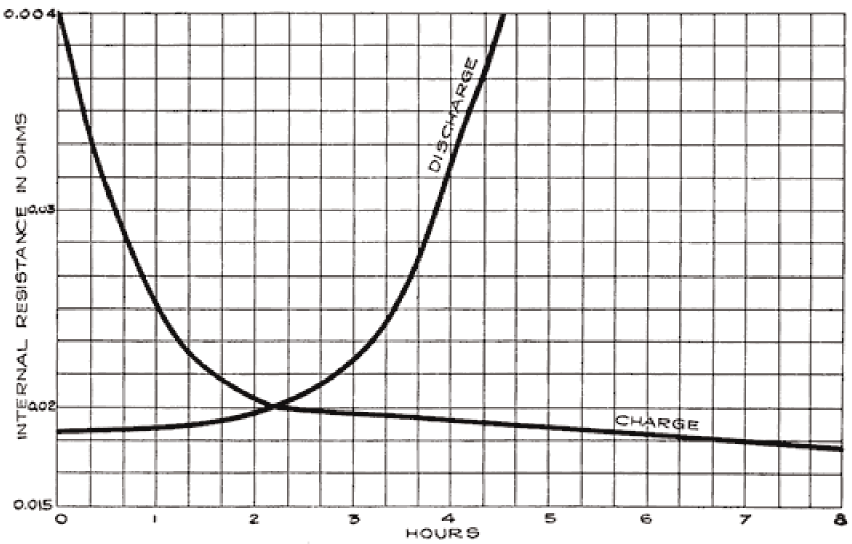


Fig. 26. Changes in Internal Resistance During Charge and Discharge

The resistance as measured between the terminals of a cell is made up of several factors as follows:

1. Grids. This includes the resistance of the terminals, connecting links, -and the framework upon which the active materials are pasted. 'This is but a small part of the total resistance, and does not undergo any considerable change during charge -and discharge. It increases slightly as the temperature of the grids rises.

2. Electrolyte. This refers to the electrolyte between the plates, and varies with the amount of acid and with temperature. As mentioned in the preceding chapter, a mixture of acid and water in which the acid composes thirty per cent of the electrolyte has the minimum resistance. Diluting or increasing the concentration of the electrolyte will both cause an increase in resistance from the minimum I value. The explanation probably lies in the degree to which the acid is split up into "ions" of hydrogen (H), and sulphate (SO_4). These "ions" carry the current through t he electrolyte. Starting with a certain amount of acid, let us see how the ionization progresses. With very concentrated acid, ionization does not take place, and hence, there are no ions to carry current. As we mix the acid with water, ionization occurs. The more water used, the more ions, and hence, the less the resistance, because the number of ions available to carry the current increases. The ionization in creases to a certain maximum degree, beyond which no more ions are formed. It is probable that an electrolyte containing thirty per cent of acid is at its maximum degree of ionization and hence its lowest resistance. If more water is now added, no more ions are formed. Furthermore, the number of ions per unit volume of electrolyte will now decrease on account of the increased amount of water. There Will therefore be fewer ions per unit volume to carry the current, and the resistance of the electrolyte increases.

With an electrolyte of a given concentration, an increase of temperature will cause a decrease in resistance. A decrease in temperature will, of' course, cause an increase in resistance. It is true, in general, that the resistance of the electrolyte is about half of the total resistance of the cell. The losses due to this resistance generally form only one per cent of the total losses, and area practically negligible factor.

3. Active Material. This includes the resistance of the active materials and the electrolyte in the pores of the active materials. This varies considerably during charge and discharge. It has been found that the resistance of the peroxide plate changes much more than that of the lead plate. The change in resistance of the positive plate is especially marked near the end of a discharge. The composition of the active material, and the contact between it and the grid affect the resistance considerably.

During charge, the current is sent into the cell from an external source. The girds therefore carry most of the current. The active material which first reacts with the acid is that near the surface of the plate, and the acid formed by the charging current mixes readily with the main body of electrolyte. Gradually, the charging action takes place in the inner portions of the plate, and concentrated acid is formed in the pores of the plate. As the sulphate is removed, however, the acid has little difficulty in mixing with the main body of electrolyte. The change in resistance on the charge is therefore not considerable.

During discharge, the chemical action also begins at the surface of the plates and gradually moves inward. In this case, however, sulphate is formed on the surface first, and it becomes increasingly difficult for the fresh acid from the electrolyte to diffuse into the plates so as to replace the acid which has been greatly diluted there by the discharge actions. There is therefore an increase in resistance because of the dilution of the acid at the point of activity. Unless a cell is discharged too far, however, the increase in resistance is small.

If a battery is allowed to stand idle for a long time it gradually discharges itself, as explained in Chapter 10. This is due to the formation of a tough coating of crystallized lead sulphate, which is practically an insulator. These crystals gradually cover and enclose the active material. The percentage change is not high, and generally amounts to a few per cent only. The chief damage caused by the excessive sulphation is therefore not an increase in resistance, but consists chiefly of making a poor contact between active material and grid, and of removing much of the active material from action by covering it.

CHAPTER 10

STORAGE BATTERY TROUBLES

The Storage Battery is a most faithful servant, and if given even a fighting chance, will respond instantly to the demands made upon it. Given reasonable care and consideration, it performs its duties faithfully for many months. When such care is lacking, however, it is soon discovered that the battery is subject to a number of diseases, most of which are "preventable," and all of which, if they do not kill the battery, at least, greatly impair its efficiency.

In discussing these diseases, we may consider the various parts of which a battery is composed, and describe the troubles to which they are subject. Every battery used on an automobile is composed of :

1. **Plates**
2. **Separators**
3. **Jars in which Plates, Separators, and Electrolyte are placed**
4. **Wooden case**
5. **Cell Connectors, and Terminals**
6. **Electrolyte**

Most battery diseases are contagious, and if one part fails, some of the other parts are Affected. These diseases may best be considered in the order in which the parts are given in the foregoing list.

PLATE TROUBLES

Plates are the "vitals" of a battery, and their troubles affect -the life of the battery more seriously than those of the other parts. It is often difficult to diagnose their troubles, and the following descriptions are given to aid in the diagnosis.

Sulphation

1. Over discharge. Some battery men say that a battery is suflphated whenever anything is wrong with it. Sulphation is the formation of lead sulphate on the plates. **As a battery of the lead acid type discharges, lead sulphate must form.** There can be no discharge of such a battery without the formation of lead sulphate, which is the natural product of the chemical reactions by virtue of which current may be drawn from the battery. This sulphate gradually replaces the lead peroxide of the positive plate, and the spongy lead of the negative plate. When a battery has been discharged until the voltage per cell has fallen to the voltage limits, considerable portions of the lead peroxide and spongy lead remain on the plates. The sulphate which is then present is in a finely divided, porous condition, and can readily be changed back to lead peroxide and spongy lead by charging the battery.

If the discharge is continued after the voltage has fallen to the voltage limits, an excessive amount of sulphate forms. It fills up the pores in the active materials, and covers up much of the active material which remains, so that it is difficult to change the sulphate back to active material. Moreover, the expansion of active material which takes place as the sulphate forms is then so great that it causes the active material to break off from the plate and drop to the bottom of the jar.

2. Allowing a Battery to Stand Idle. When lead sulphate is first formed, it is in a finely divided, porous condition, and the electrolyte soaks through it readily. If a battery which has been discharged is allowed to stand idle without being charged, the lead sulphate crystals grow by the combination of the crystals to form larger crystals. The sulphate, instead of having a very large surface area, upon which the electrolyte may act in changing the sulphate to active material, as it does when it is first formed, now presents only a very small surface to the electrolyte, and it is therefore only with great difficulty that the large crystals of sulphate are changed to active material. The sulphate is a poor conductor, and furthermore, it covers up much of the remaining active material so that the electrolyte cannot reach it.

A charged battery will also become sulphated if allowed to stand idle, because it gradually becomes discharged, even though no wires of any kind are attached to the battery terminals. How this takes place is explained later. The discharge and formation of sulphate continue until the battery is completely discharged. The sulphate then gradually forms larger crystals as explained in the preceding paragraph, until all of the active material is either changed to sulphate, or is covered over by the sulphate so that the electrolyte cannot reach it. The sulphate thus forms a high resistance coating which hinders the passage of charging current through the battery and causes heating on charge. **It is for this reason that sulphated plates should be charged at a low rate.** The chemical actions which are necessary to change the sulphate to active material can take place but very slowly, and thus only a small current can be absorbed. Forcing a large current through a sulphated battery causes heating since the sulphate does not form uniformly throughout the plate, and the parts which are the least sulphated will carry the charging current, causing them to become heated. The heating damages the plates and separators, and causes buckling, as explained later.

If batteries which have been discharged to the voltage limits are allowed to stand idle without being charged, they will, of course, continue to discharge themselves just as fully charged batteries do when allowed to stand idle.

3. Starvation. If a battery is charged and discharged intermittently, and the discharge is greater than the charge, the battery will never be fully charged, and lead sulphate will always be present. Gradually this sulphate forms the large tough crystals that cover the active material and remove it from action. This action continues until all parts of the plate are covered with the crystalline sulphate and we have the same condition that results when a battery is allowed to stand idle without any charge.

4. Allowing Electrolyte to Fall Below Tops of Plates. If the electrolyte is allowed to fall below the tops of the plates, so that the active materials are exposed to the air, the parts thus exposed will gradually become sulphated. The spongy lead of the negative plate, being in a very finely divided state, offers a very large surface to the oxygen of the air, and is rapidly oxidized, the chemical action causing the active material to become hot. The charging current, in passing through the parts of the plates not covered by the electrolyte also heats the active materials. The electrolyte which occasionally splashes over the exposed parts of the plates and which rises in the pores of the separators, is heated also, and since hot acid attacks the active materials readily, sulphation takes place quickly. The parts above the electrolyte, of course, cannot be charged and sulphate continues to form. Soon the whole exposed parts are sulphated as shown in Fig. 209.

As the level of the electrolyte drops, the electrolyte becomes stronger, because it is only the water which evaporates, the acid remaining and becoming more and more concentrated. The remaining electrolyte and the parts of the plates covered by it become heated by the current, because there is a smaller plate area to carry the current, and because the resistance of the electrolyte increases as it grows more concentrated. Since hot acid attacks the active materials, sulphation also takes place in the parts of the plates still covered by the electrolyte.

The separators in a battery having the electrolyte below the tops of the plates suffer also, as will be explained later. See page 346.

5. Impurities. These are explained later. See page 76.

6. Adding Acid Instead of Water. The sulphuric acid in the electrolyte is a heavy, oily liquid that does not evaporate. It is only the water in the electrolyte which evaporates. Therefore, when the level of the electrolyte falls, only water should be added to bring the electrolyte to the correct height. There are, however, many car owners who still believe that a battery may be charged by adding acid when the level of the electrolyte falls. Batteries in which this is done then contain too much acid. This leads to two troubles. The first is that the readings taken with a hydrometer will then be misleading. A specific gravity of 1.150 is always taken to indicate that a battery is discharged, and a specific gravity of 1.280 that a battery is charged. These two values of specific gravity indicate a discharged and charged condition of the battery **ONLY WHEN THE PROPORTION OF ACID IN THE ELECTROLYTE IS CORRECT.** It is the condition of the plates, and not the specific gravity of the electrolyte which determines when a battery is either charged or discharged. With the correct proportion of acid in the electrolyte, the specific gravity of the electrolyte is 1.150 when the plates are discharged and 1.280 when the plates are charged, and that is why specific gravity readings are generally used as an' indication of the condition of the battery.

If there is too much acid in the electrolyte, the plates will be in a discharged condition before the specific gravity of the electrolyte drops to 1.150, and will not be in a charged condition until after the specific gravity has risen beyond the usual value. As a result of these facts a battery may be over-discharged, and never fully charged, this resulting in the formation of sulphate.

The second trouble caused by adding acid to the electrolyte is that the acid will then be too concentrated and attacks both plates and separators. This will cause the plates to become sulphated, and the separators rotted.

7. Overheating. This was explained in Chapter 9. See page 66.

Buckling

Buckling is the bending or twisting of plates due to unequal expansion of the different parts of the plate, Figs. 207 and 208. It is natural and unavoidable for plates to expand.

As a battery discharges, lead sulphate forms. This sulphate occupies more space than the lead peroxide and spongy lead, and the active materials expand. Heat expands both active materials and grids. As long as all parts of a plate expand equally, no buckling will occur. Unequal expansion, however, causes buckling.

1. Over discharge. If discharge is carried too far, the expansion of the active material on account of the formation of lead sulphate will bend the grids out of shape, and may even break them.

2. Continued Operation with Battery in a Discharged Condition. When a considerable amount of lead sulphate has, formed, and current is still drawn from the battery, those portions of the plate which have the least amount of sulphate will carry most of the current, and will therefore become heated and expand. The parts covered with sulphate will not expand, and the result is that the parts that do expand will twist the plate out of shape. A normal rate of discharge may be sufficient to cause buckling in a sulphated plate.

3. Charging at High Rates. If the charging rate is excessive, the temperature will rise so high that excessive expansion will take place. This is usually unequal in the different parts of the plate, and buckling results. With a battery that has been over discharged, the charging current will be carried by those parts of the plates which are the least sulphated. These parts will therefore expand while others will not, and buckling results.

4. Non-Uniform Distribution of Current Over the Plates. Buckling may occur in a battery which has not been over-discharged, if the current carried by the various parts of the plate is not uniform on account of faulty design, or careless application of the paste. This is a fault of the manufacturers, and not the operating conditions.

5. Defective Grid Alloy. If the metals of which the grids are composed are not uniformly mixed throughout the plate, areas of pure lead may be left here and there, with air holes at various points. The electrolyte enters the air holes, attacks the lead and converts the grid partly into active material. This causes expansion and consequent distortion and buckling.

Buckling will not necessarily cause trouble, and batteries with buckled plates may operate satisfactorily for a long time. If, however, the expansion and twisting has caused much of the active material to break away from the grid, or has loosened the active material from the grids, much of the battery capacity is lost. Another danger is that the lower edges of a plate may press against the separator with sufficient force to cut through it, touch the next plate, and cause a short-circuit.

Shedding, or Loss of Active Material

The result of shedding, provided no other troubles occur, is simply to reduce the capacity of the plates. The positives, of course, suffer more from shedding than the negatives do, shedding being one of the chief weaknesses of the positives. There is no remedy for this condition. When the shedding has taken place to such an extent that the capacity of the battery has fallen very low, new plates should be installed. After a time, the sediment space in the bottom of the jar becomes filled with sediment, which touches the plates. This short-circuits the cell, of course, and new plates must be installed, and the jars washed out thoroughly.

1. Normal Shedding. It is natural and unavoidable for the positives to shed. Lead Peroxide is a powder-like substance, the particles of which do not hold together. A small amount of sulphate will cement the particles together to a considerable extent. At the surface of the plate, however, this sulphate is soon changed to active material, and the peroxide loses its coherence. Particles of peroxide drop from the plates and fall, into the space in the bottom of the jar provided for this purpose.

Bubbles of gas which occur at the end of a charge blow some of the peroxide particles from the plate. The electrolyte moving about as the battery is jolted by the motion of the car washes particles of peroxide from the positive plates. Any slight motion between positive plates and separators rubs some peroxide from the plates. It is therefore entirely natural for shedding to occur, especially at the positives. The spongy lead of the negatives is much more elastic than the peroxide, and hence very little shed. ding occurs at the negative plates. **The shedding at the positives explains why the grooved side of the separator is always placed against the positive plate.** The grooves, being vertical, allow the peroxide to fall to the bottom of the jar, where it accumulates as sediment, or "mud."

2. Excessive Charging Rate, or Overcharging. If a battery is charged at too high a rate, only part of the current is used to produce the chemical actions by which the battery is charged. The balance of the current decomposes the water of the electrolyte into hydrogen and oxygen, causing gassing. As the bubbles of gas force their way out of the plates, they blow off particles of the active material.

When a battery is overcharged, the long continued gassing has the same effect as described in the preceding paragraph.

3. Charging Sulphated Plates at too High a Rate. In sulphated plates, the chemical actions which take place as a battery is charged can proceed but very slowly, because the sulphate, besides being a poor conductor, has formed larger crystals which present only a small surface for the electrolyte to act upon, and has also covered up much of the remaining active material. Since the chemical actions take place slowly, the charging current must be kept at a low value. If too heavy a charging current is used, the battery will be overheated, and some of the current will simply cause gassing as explained in No. 2 above. The gas bubbles will break off pieces of the sulphate, which then fall to the bottom of the jars as "mud."

4. Charging Only a Part of the Plate. If the electrolyte falls below the tops of the plates, and the usual charging current is sent into the battery, the current will be too great for the plate area through which it passes, and hence gassing and shedding will result as already explained.

The same condition exists in a battery in which one or more plates have been broken from the strap, either because of mechanical vibration or because of impurities such as acetic acid in improperly treated separators. The remaining plates are called upon to do more work, and carry the entire charging current. Gassing and shedding will result.

5. Freezing. If a battery is given any care whatever, there is little danger of freezing. The electrolyte of a fully charged battery with a specific gravity of 1.280 freezes at about 92° below zero. With a specific gravity of 1.150, the electrolyte freezes at about 5° above zero. A frozen battery therefore indicates gross neglect.

As the electrolyte freezes, the water of the electrolyte expands. Since there is electrolyte in all the inner parts of the plate, the expansion as the water in the paste freezes forces the pastes out of the grids. The expansion also cracks the rubber jars, and sometimes bulges out the ends of the battery case

Loose Active Material

This refers to a condition in which the active materials are no longer in contact with the grid. Corrosion, or sulphation, of the grids themselves is generally present at the same time, since the chemical actions are shifted from the active material to the grids themselves.

1. Over discharge. As a battery discharges, the lead sulphate which forms causes an expansion of the active material. If a battery is repeatedly over-discharged, this results in the positives shedding. In the negatives, the spongy lead is puffed out, resulting in the condition known as "bulged negatives" as illustrated in Fig 122.

2. Buckling. As a plate grid is bent out of shape, the active material, especially the peroxide, breaks loose from the grid, since the peroxide cannot bend as much as the grids. This occurs in the negatives also, though not to such an extent as in the positives.

If the plates are buckled to such an extent that the element will not go back into the jar, the positives should be discarded. If the positives are buckled, the negatives will be also, but not to the extent that the positives are.

In the case of the positives, there is no remedy, and the plates should be discarded. The negatives, however, may be fully charged, and then straightened, and the active material forced back flush with the grids by pressings, as described in Chapter 15.

Impurities

Impurities may be divided into two general classes. The first class includes those which do not attack the separators or grids, but merely cause internal self-discharge. The second class includes those which attack the grids or separators.

1. Impurities Which Merely Cause Self-discharge. This includes metals other than lead. If these metals are in solution in the electrolyte, they deposit on the negative plate, during charge, in their ordinary metallic state, and form small cells with the spongy lead. These small cells discharge as soon as the charging circuit is opened, and some of the lead is changed to lead sulphate. This, of course, causes a loss in capacity. Free hydrogen is given off by this local discharge, and so much of it is at times given off that the **hydrogen bubbles give the electrolyte a milky appearance.**

Silver, gold, and platinum are the most active in forming small local cells. These metals form local cells which have comparatively high voltages, and which take away a considerable portion of the energy of a cell. Platinum is especially active, and a small amount of platinum will prevent a negative plate from taking a charge. Gradually, however, the spongy lead covers up the foreign metal and prevents it from forming local cells.

Iron also forms local cells which rob the cell of a considerable portion of its capacity. This may be brought into the cell by impure acid or water. Iron remains in solution in the electrolyte, and is not precipitated as metallic iron. The iron in solution travels from the positive to the negative plate, and back again, causing a local discharge at each plate. It is, moreover, very difficult to remove the iron, except by pouring out all of the electrolyte. Manganese acts the same as the iron.

2. Impurities Which Attack the Plates. In general, this class includes acids other than sulphuric acid, compounds formed from such acids, or substances which will readily form acids by chemical action in the cell. Nitric acid, hydrochloric or muriatic acid, and acetic acid belong in this class of impurities. Organic matter in a state of decomposition attacks the lead grids readily.

Impurities in the second class dissolve the lead grids, and the plate disintegrates and falls to pieces, since its backbone is destroyed. When a battery which contains these impurities is opened, it will be found that the plates crumble and fall apart at the slightest touch. See Fig. 210.

Separators which have not been treated properly introduce acetic acid into a cell. The acetic acid attacks and rots the lead, especially the lugs projecting above the electrolyte, and the plate connecting straps. The plates will generally be found broken from the connecting strap, with the plate lugs broken and crumbled.

As for remedies, there is not much to be done. Impurities in the first class merely decrease the capacity of the battery. If the battery is fully charged, and the negatives then washed thoroughly, some of the impurities may be removed. Impurities of the second class have generally damaged the plates beyond repairs by the time their presence is suspected.

The best thing to do is to keep impurities out of the battery. This means that only distilled water, which is known to be absolutely free from impurities should be used.

Impurities which exist in the separators or acid cannot be detected readily, but in repairing a battery, separators furnished by one of the reliable battery makers should be used. Pure acid should also be used. This means that only chemically pure, or "C. P." acid, also known as battery acid should be used. In handling the acid in the shop, it should always be kept in its glass bottle, and should be poured only into a glass, porcelain, earthenware, lead, or rubber vessel. Never use a vessel made of any other material.

Corroded Grids

When the grids of a plate are attacked chemically, they become thin and weak, and may be spoken of as being corroded.

1. Impurities. Those impurities which attack the lead grids, such as acids other than sulphuric acid, compounds formed from these acids, or substances which will readily form acids dissolve some of the lead which composes the grids. The grids gradually become weakened. The decrease in the amount of metal in the grids increases the internal resistance of the cell and give a tendency for temperatures to be higher in the cell. The contact between grids and active material is in time made poor. If the action of the impurities continues for any length of time, the plate becomes very weak, and breaks at the slightest touch.

2. High Temperatures. Anything that raises the temperature of the electrolyte, such as too high a charging rate, causes the acid to attack the grids and form a layer of sulphate on them. The sulphate is changed to active material on charge, and the grids are thereby weakened.

3. Age. Grids gradually become weak and brittle as a battery remains in service. The acid in the electrolyte, even though the electrolyte has the correct gravity and temperature, has some effect upon the grids, and in time this weakens them. During the life of a battery it is at times subjected to high temperatures, impurities, sulphation, etc., the combined effects of which result in a gradual weakening of the grids.

Granulated Negatives

1. Age. The spongy lead of the negative plate gradually assumes a "grainy" or "granulated" appearance. The lead then seems to be made up of small grains, like grains of sand, instead of being a smooth paste. This action is a natural one, and is due to the gradual increase in the size of the particles of the lead. The plate loses its porosity, the particles cementing together and closing the pores in the lead. The increase in the size of the particles of the spongy lead decreases the amount of surface exposed to the action of the electrolyte, and the plate loses capacity. Such plates should be thrown away, as charging and discharging will not bring the paste back to its original state.

2. Heat will also cause the paste to become granulated, and its surface to become rough or even blistered.

Heating of Negatives Exposed to the Air

When charged negatives are exposed to the air, there is a decided increase in their temperature. Spongy lead is in an extremely finely divided state, the particles of lead being very minute, and forming a very porous mass. When the plate is exposed to the air, rapid oxidation takes place because the oxygen of the air has a very large surface to act upon. The oxidation causes the lead to become heated. The heating, of course, raises the temperature of the electrolyte, and the hot acid attacks both grids and lead.

Fully charged negatives should therefore be watched carefully when removed from a battery. When they become heated and begin to steam, they should be dipped in water until they have cooled. They may then be removed from the water, but should be dipped whenever they begin to steam. After they no longer heat, they may be left exposed to the air.

This method of dipping the negatives to prevent overheating has always been followed. However, the Electric Storage Battery Company, which makes the Exide batteries, does not take any steps to prevent the heating of the negatives when exposed to the air, stating that their plates are not injured by the heating which takes place.

Negatives With Very Hard Active Material

This is the characteristic condition of badly sulphated negatives. The active material may be as hard as a stone. The best method of treating such negatives is to charge them in distilled water. See Chapter 15.

Bulged Negatives

This is a characteristic of a repeatedly over-discharged negative. The lead sulphate which forms as a battery discharges is bulkier than the spongy lead, and the lead expands and bulges out between the ribs of the grid.

Negative With Soft, Mushy Active Material

1. High Gravity. Gravity above 1.300 causes the acid to act upon the spongy lead and soften it.

2. Heat will soften the spongy lead also. The softened spongy lead is loosened and falls from the grids, as shown in Fig. 211. Little can be done for such 'negatives.

Negatives With Roughened Surface

This is caused by slight overheating, and is not a serious condition.

Frozen Positives

A battery which is allowed to stand in a cold place while completely discharged will freeze. The water in the electrolyte expands as it freezes, cracking the rubber jars and bulging out the end of the wooden case. As the electrolyte which fills the pores of the positive plates freezes and expands, it breaks the active material loose from the grids. When the battery thaws, the active material does not go back into the grids. When such a battery is opened, and the groups separated, the positive active material sticks to the separators in large pieces, Fig. 112, and that remaining in the grids falls out very easily. The active material has a pinkish color and is badly shrunken.

Rotted, Disintegrated Positives

1. Impurities. This has already been discussed. See page 76.

2. Overheating. The hot electrolyte dissolves the lead of the grids and that which is dissolved is never converted back to lead. Continued overheating wears out the grids, and the active material also, and the plate falls to pieces at the slightest pressure.

3. Age. Positives gradually disintegrate due to the prolonged action of the electrolyte on the grids, an occasional overheating, occasional use of impure water, etc.

Positives which are rotted and disintegrated are, of course, hopeless, and must be junked.

Buckled Positives

As previously described, buckling is caused by unequal expansion. If the buckling is only slight, the plates may be used as they are. If the plates are badly buckled, the active material will be found to be loose, and the plates cannot be straightened. Such positives should be discarded.

Positives That Have Lost Considerable Active Material

This is the result of continued shedding, the causes of which have already been given. If the shedding is only slight, and the plate is good otherwise, it may be used again. If such active material has been lost, the plates must be discarded.

Positives With Soft Active Material

Continued operation at high temperatures, will soften the peroxide, and make the plates unfit for further use. Old positives are soft, clue to the natural deterioration of the paste with age.

Positives With Hard, Shiny Active Material

This condition is found in batteries that have been charged with the acid below the tops of the plates. The part of the plate above the acid is continually being heated by the charging current. It becomes hard and shiny, and has cracks running through it. The peroxide becomes orange or brick colored, and the grid deteriorates. The part of the plate below the electrolyte suffers also, as explained more fully on page 71. Such plates should be discarded if any considerable portion of the plates is affected. Plates in which 1/2 to 1 inch of the upper parts are affected may be used again if otherwise in good condition.

Plates Which Have Been Charged in Wrong Direction

Such plates have been partly reversed, so that there is lead peroxide and spongy lead on both positive and negative plates, and such plates are generally worthless. If the active materials have not become loosened from the grids, and the grids have not been disintegrated and broken, the plates may sometimes be reversed by a long charge at a low rate in the right direction. If this does not restore the plates, discard them.

SEPARATOR TROUBLES

Separators form the weakest part of a battery, but at the same time perform a very important duty. New separators should therefore be installed whenever a battery is opened for repairs. Repairs should never be attempted on separators.

1. Not Properly Expanded Before Installation. Separators in stock must be kept moist. This not only prevents them from becoming dry and brittle, but keeps them fully expanded. If separators which have been kept dry in stock are installed in a battery, they do their expanding inside the battery. This causes them to project beyond the edges of the plates. The crowding to which they are subjected causes them to crack. Cracked separators permit "treeing" between plates, with a consequent short circuit.

2. Not Properly Treated. Separators which have not been given the proper chemical treatment are likely to develop Acetic acid after they are in the battery. Acetic acid dissolves the lead grids, the plate lugs, and the plate connecting straps rapidly. If the plate lugs are found broken, and crumble easily, acetic acid is very likely present, especially if an odor like that of vinegar is noticeable. Improperly treated separators will cause a battery to show low voltage at high rates of discharge, particularly in cold weather, and will also cause the negatives to give poor cadmium readings, which may lead the repairman to conclude that tile negatives are defective. The separators of batteries which have been shipped completely assembled without electrolyte and with moistened plates and separators will sometimes have the same effect.

3. Cracked. Separators should be carefully "candled" -- placed in front of a light and looked through. Cracks, resinous streaks, etc., mean that the separator should not be used, as it will breed trouble.

4. Rotted and Carbonized. This may be the result of old age, overheating, or high gravity electrolyte.

5. Pores Clogged. Impurities, dirt from impure water, and lead sulphate fill the pores of a separator and prevent the proper circulation of the electrolyte. The active material of frozen positives also fills up the pores of a separator.

6. Edges Chiseled Off. A buckling plate will cut through the lower edge of a separator and short circuit the cell. Holes will be cut through any part of a separator by a buckling plate, or a negative with bulged active material.

JAR TROUBLES

Battery jars are made of hard rubber, and are easily broken. They are not acted upon by the electrolyte, or any of the impurities which may be found in the jar. Their troubles are all mechanical, and consist of being cracked, or having small holes through the walls. Jars are softened by high temperatures, but this does no particular harm unless they are actually burned by an open flame or red hot metal. The causes of jar troubles are as follows:

1. Rough Handling. By far the most common cause of jar breakage is rough handling by careless or inexperienced persons. If one end of a battery rests on the floor, and the other is allowed to drop several inches, broken jars will probably result from the severe impact of the heavy lead plates. Storage batteries should be handled as if made of glass. When installed on a car, the springs protect the battery from shock to a considerable extent, but rough roads or exceptionally severe jolts may break jars.

2. Battery Not Properly Fastened. In this case a battery is bumped around inside the battery compartment, and damage is very likely to result.

3. Any Weight Placed on Top of the Battery is transmitted from the links to the plates, and by them to the bottom of the jars. Batteries should always be stored in racks, and not one on top of another. The practice of putting any weight whatever on top of a battery should be promptly discouraged.

4. Freezing. This condition has already been explained. It causes a great many broken jars every winter.

5. Groups Not Properly Trimmed. The outside negative plates in a cell come just inside the jar, and the strap ends must be carefully trimmed off flush with the plates, to prevent them from breaking the top of the jars. Jars have slightly rounded corners, and are somewhat narrower at the extreme ends than nearer the center. A group may therefore go into a jar quite readily when moved toward the other end of the jar to that into which the post strap must go when in proper position for the cover. When the group is forced back into its proper position the strap may break the jar. It is a good plan not only to trim the ends of the negative straps perfectly flush, but to round the strap corners where they go into the jar corners.

6. Defective Jars. (a) A jar not properly vulcanized may come apart at the scam. (b) A small impurity in the rubber may dissolve in the acid and leave a minute pinhole. All jars are carefully tested at the factory and the likelihood of trouble from defective jars is extremely small.

7. Explosion in Cell. (a) Hydrogen and oxygen gases evolved during charging make a very explosive mixture. An open flame brought near a battery on charge or freshly charged, will probably produce an explosion resulting in broken jars and jar covers. (b) An open circuit produced inside a cell on charge in the manner described on page 86 under the heading "Open Circuits," will cause a spark at the instant the circuit is broken, with the same result as bringing a flame near the battery. (c) The small holes in the vents must be kept free for the escape of the gases. These holes are usually sealed in batteries shipped with moistened plates and separators, to keep air out of the cells. The seals must be removed when the battery is prepared for service. If the vents remain plugged, the pressure of the gases formed during charge will finally burst the covers of jars.

BATTERY CASE TROUBLE

1. Ends Bulged Out. This may be due to a battery having been frozen or to hold-downs being screwed down too tight, or some similar cause. Whether the case can be repaired depends on the extent of the bulging. This can best be determined by the repairman.

2. Rotted. If the case is rotted around the top, it is evidence that: (a) Too much water was added, with subsequent overflowing when electrolyte warmed up during charge. (b) The tops were poorly sealed, resulting in leaks between the covers and the, jars. (c) Battery has not been fastened down properly, and acid has been thrown out of the jars by the jolting of the car on the road. (d) The vent plugs have not been turned down tightly. (e) Electrolyte has been spilled in measuring specific gravity.

If the case is rotted around the lower part it indicates that the jars are cracked or contain holes. Instructions for making repairs on battery cases are given on page 360.

TROUBLE WITH CONNECTORS AND TERMINALS

1. Corroded. This is a very common trouble, and one which should be guarded against very carefully. Corrosion is indicated by the presence of a grayish or greenish substance on the battery terminals, especially the positive. It is due to several causes:

(a) Too much water added to cells. The electrolyte expands on charge and flows out on the top of the battery.

(b) Battery not fastened firmly. The jolting caused by the motion of the car on the road will cause electrolyte to be thrown out of the vent caps.

(c) Battery poorly sealed. The electrolyte will be thrown out on the cover by the motion of the car through the leaks which result from poor sealing.

(d) Vent caps loose. This also allows electrolyte to be thrown out on the battery top.

(e) Electrolyte spilled on top of battery in measuring specific gravity.

(f) Battery cables damaged, or loose. The cables attached to the battery terminals are connected to lugs which are heavily coated with lead. The cables are insulated with rubber, upon which sulphuric acid has no effect. Care should be taken that the lead coating is not worn off, and that the rubber insulation is not broken or cut so as to allow electrolyte, which is spilled on the battery top as explained in (a), (b), (c), (d) and (e), to reach the bare copper conductors of the cable. The terminal parts are always so made that when the connections are kept tight no acid can come into contact with anything but lead and rubber, neither of which is attacked by sulphuric acid.

(g) Attaching wires directly to battery terminals. There should be no exposed metal except lead at the battery terminals. No wires of any other metal should be attached to the battery terminals. Such wires should be connected to the rubber covered cables which are attached to battery, and the connections should be made far enough away from the battery to prevent electrolyte from coming in contact with the wire. Car manufacturers generally observe this rule, but the car owner may, through ignorance, attach copper wires directly to the battery terminals. The positive terminal is especially subject to corrosion, and should be watched carefully. To avoid corrosion it is necessary simply to keep the top of the battery dry, keep the terminal connections tight, and coat the terminals with vaseline. The rule about connecting wires directly to the battery terminals must of course be observed also.

2. Loose. Loose terminal connections cause a loss of energy due to their resistance, and all such connections must be well made. If the inter-cell connectors are loose, it is due to a poor job of lead burning. This is also true of burned on terminals, and in either case, the connections should be drilled off, cleaned and re-burned.

Terminals sometimes become so badly corroded that it is impossible to disconnect the cables front the battery. Stitch terminals should be drilled off and soaked in boiling soda water.

ELECTROLYTE TROUBLES

(4) High Level. This condition is due to the addition of too much water. It leads to corrosion as already explained. It also causes a loss of acid. The Electrolyte which overflows is lost, this of course, causing a loss of acid. The condition of Low Gravity then arises, as described on page 321.

(6) Milky Electrolyte:

(a) Lead Sulphate in Battery Acid. It sometimes happens that sulphuric acid contains some lead sulphate in solution. This sulphate is precipitated when water is added to the acid in mixing electrolyte, and gives the electrolyte a milky appearance. This sulphate settles if the electrolyte is allowed to stand.

(b) Gassing. The most common cause of the **milky** appearance, however, is the presence of minute gas bubbles in large quantities. These may be the result of local action caused by the presence of metallic impurities in the battery. The local action will stop when the battery is put on charge, but will begin as soon as the battery is taken off charge. The impurities are gradually covered by lead or lead sulphate, and the local action is thus stopped.

Excessive gassing in a cell which contains no impurities may also cause the electrolyte to have a milky appearance. The gas bubbles are very numerous and make the electrolyte look milky white.

(c) Impurities in the electrolyte will also give it a milky appearance.

GENERAL TROUBLES

Open Circuits

1. Poor Burning of Connectors to Posts. Unless a good burned connection is made between each connector and post, the joint may melt under high discharge rates, or it may offer so much resistance to the passage of current that the starting motor cannot operate. Sometimes the post is not burned to the connector at all, although the latter is well finished off on top. Under such conditions the battery may operate for a time, due to frictional contact between the post and connector, but the parts may become oxidized or sulphated, or vibration may break the connection, preventing the flow of current. Frequently, however, the circuit is not completely open, and the poor connection acts simply as a high resistance. Under such a condition the constant current generator automatically increases its voltage, and forces charging current through the battery, although the latter, having only a low fixed voltage, cannot force out the heavy current required for starting the engine.

2. Terminals Broken Off. Inexperienced workmen frequently pound on the terminals to loosen the cable lugs, or pry on them sufficiently to break off the battery terminals. If the terminals and lugs are kept properly greased, they will come apart easily. A pair of terminal tongs is a very convenient tool. These exert a pressure between the terminal and the head of the terminal screw, which is first unscrewed a few turns.

3. Acid on Soldered Joints. Amateurs sometimes attempt to make connections by the use of a soldering iron and solder. Solder is readily dissolved by acid, not only spoiling the joint, but endangering the plates if any gets into the cells. Solder must never be used on a battery except for sweating the cables into the cable lugs, and the joint even here must be well protected by rubber tape.

4. Defective Posts. Posts withdrawn from the post mould before they are cool enough may develop cracks. Bubbles sometimes occur in the posts. Either trouble may reduce the current carrying capacity or mechanical strength of the post and result in a broken or burned-out spot.

5. Plates Improperly Burned. As previously explained, this is not likely to cause immediate trouble, but by imposing extra work on the balance of the plates, causes them to wear out quickly.

Dead Cells

1. Worn out Separators. The duties of separators are to prevent the plates from touching each other, and to prevent "treeing," or growth of active material from the negative to the positive plates. If they fail to perform these duties, the battery will become short-circuited internally. The separator troubles described on page 81 eventually lead to short-circuited cells.

2. Foreign Material. If a piece of lead falls between plates so as to later punch a hole through a separator, a short circuit will result. Great care should be taken in burning plates on the straps to prevent lead from running down between plates, as this lead will cause a short circuit by punching through the separator.

3. Accumulation of Sediment. The active material which drops from the plates accumulates in the "mud" space in the bottom of the jar. If this rises until it touches the bottom of the plates, a short-circuit results. Usually it is advisable to renew the positives in a battery which has become short-circuited by sediment, since the sediment comes largely from the positives, and if they have lost enough active material to completely fill the sediment space, they are no longer fit for use.

4. Badly sulphated plates and separators, impurities which attack the plates.

Loss of Capacity

A battery loses capacity due to a number of causes. Some of them have already been considered.

1. Impurities in the Electrolyte. These have already been discussed.

2. Sulphation. This also has been described.

3. Loose Active Material, as already described. The active materials which are not in contact with the grids cannot do their work.

4. Incorrect Proportions of Acid and Water in the Electrolyte. In order that all the active material in the plates may be utilized, there must be enough acid in the electrolyte, and also enough water. If there is not enough acid, the battery will lack capacity. If there is too much acid, the acid when the battery is fully charged will be strong enough to attack and seriously damage the plates and separators. Insufficient amount of acid may be due to replacing, with water, electrolyte which has been spilled or which has leaked out. Too much acid results from an incorrect proportion of acid and water in the electrolyte, or from adding acid instead of water to bring the electrolyte above the plate tops, and causes sulphation, corroded plates, and carbonized separators.

The remedy for incorrect proportions of acid and water in the electrolyte is to give the battery a full charge and adjust the gravity by drawing off some of the electrolyte and replacing it with water, or 1.400 specific gravity electrolyte, as the case may require.

5. Separators Clogged. The pores of the separators may become filled with sulphate or impurities, and thus prevent the proper circulation of the electrolyte. New separators must be put in.

6. Shedding. The capacity of a battery naturally decreases as the active material falls from the plates, since the amount of active material which can take part in the chemical actions that enable us to draw current from the battery decreases.

7. Low Level of Electrolyte. Aside from the loss of capacity which results from the sulphation caused by low electrolyte, there is a loss of capacity caused by the decrease in the useful plate area when the electrolyte is below the tops of the plates. Only that part of the plate surface which is below the electrolyte does any work, and the area of this part gradually decreases as the electrolyte falls.

8. Reversal of Plates. If one cell of a battery has an internal short circuit, or some other defect which causes it to lose its charge, the cell will be discharged before the others which are in series with it, and when this cell is completely discharged, the other cells will send a current through it in a discharge direction, and the negative plates will have a coating of lead peroxide formed on them, and will assume the characteristics of positive plates. The positives will be reversed also.

This reversal may also be the result of charging a battery in the wrong direction, on account of reversed charging connections. The remedy for reversed plates, provided they have not become disintegrated, is to give them a long charge in the right direction at a low rate.

9. Effect of Age. A battery gradually loses capacity due to its age. This effect is independent of the loss of capacity due to the other causes. In the negatives, the size of the grain increases its size, giving the plates a granulated appearance. Stitch plates are called "granulated" negatives. The spongy lead cements together and loses porosity.

Loss of Charge in An Idle Battery

It has been found that if a charged battery is allowed to stand idle, and is not charged, and no current is drawn from it, the battery will gradually become completely discharged and must be given an occasional "freshening" charge.

Now, as we have learned, when a battery discharges lead sulphate forms on each plate, and acid is taken from the electrolyte as the sulphate forms. In our idle battery, therefore, such actions must be taking place. The only difference in this case is that the sulphate forms without any current passing through the battery.

At the lead peroxide plate we have lead peroxide paste, lead grid, and sulphuric acid. These are all the element-, needed to produce a storage battery, and as the lead peroxide and the lead are touching each other, each lead peroxide plate really forms a short circuited cell. Why does this plate not discharge itself completely? A certain. amount of discharge does take place, and results in a layer of lead sulphate forming between the lead peroxide and the grid. The sulphate, having high resistance then protects the lead grid and prevents any further action. This discharge action therefore does not continue, but causes a loss of a certain part of the charge.

At the negative plate, we have pure spongy lead, and the grid. This grid is not composed entirely of lead, but contains a percentage of antimony, a metal which makes the grid harder and stronger. There is but very little difference of potential between the spongy lead and the grid. A small amount of lead sulphate does form, however, on the surface of the negative plate. This is due to the action between the spongy lead and the electrolyte.

Some of the lead combines with the acid to form lead sulphate, but after a small amount has been formed the action is stopped because a balanced chemical condition is soon obtained.

Thus only a small amount of lead sulphate is formed at each plate, and the cell thereby loses only a small part of its charge. In a perfectly constructed battery the discharge would then stop. The only further action which would take place would be the slow evaporation of the water of the electrolyte. The loss of charge which actually occurs in an idle charged battery is greater than that due to the formation of the small amounts of sulphate on the plates, and the evaporation of the water from the electrolyte.

Does an idle cell discharge itself by decomposing its electrolyte? We have a difference of potential of about two volts between the lead and lead peroxide plate. Why is the electrolyte not decomposed by this difference? At first it might seem that the water and acid should be separated into its parts, and hydrogen liberated at the negative plate. As a matter of fact, very little hydrogen gas is set free in an idle charged cell because to do so would require a voltage of about 2.5. At two volts, so little gas is formed that the loss of charge due to it may be neglected entirely.

The greatest loss of charge in an idle battery results from conditions arising from the processes of manufacture, internal troubles, and leakage between terminals. The grids of a cell are an alloy of lead and antimony. These are mixed while in a molten condition, and are then allowed to cool. If the cooling is not done properly, or if a poor grade of antimony is used, the resulting grid is not a uniform mixture of antimony and lead. There will be areas of pure lead, with an air hole here and there. The lack of uniformity in the grid material results in a local discharge in the grid. This causes some loss of charge.

If the active material completely fills the spaces between- the grids, the acid formed as the cell is charged may not be able to diffuse into the main body of the electrolyte, but forms a small pocket of acid in the plate. This acid will cause a discharge between paste and grid and a coating of lead sulphate forms on the arid, resulting in a certain loss of charge.

In general any metallic impurity in a cell will cause a loss at the lead plate. When a cell is charged, the current causes the metals to deposit on the lead plate. Local cells are formed by the metallic impurity, the lead plate, and the acid, and these tiny cells will discharge completely, causing a loss of charge. This has already been described on page 76.

Another cause of loss of charge in an idle cell is leakage of current between the terminals on the outside of the battery. During charge, the bubbles of gas which escape from the electrolyte carry with them minute quantities of acid which may deposit on the top of the battery and gradually form a thin conducting layer of electrolyte through which a current will flow from the positive to the negative terminals. This danger may be avoided by carefully wiping any moisture from the battery. Condensation of moisture from the air, on the top or sides and bottom of a battery will cause the same condition. This will be especially noticeable if a battery is kept in a damp place.

The tendency for crystals of lead to "tree" over from the negative to the positive plates is well known. An idle battery is one in which this action tends to take place. Treeing will occur through the pores of the separators and as there is no flow of electrolyte in or out of the plates, the lead "trees" are not disturbed in their growth. A freshening charge causes this flow to take place, and break up the "trees" which would otherwise gradually short circuit the cells.

CADMIUM TEST SET AND HOW TO MAKE THE TEST

As the cell voltage falls while the battery is on discharge, the voltage of the positive plates, and also the voltage of the negative plates falls. -When the battery is charged again the voltages of both positive and negative plates rise. If a battery gives its rated ampere-hour capacity on discharge, we do not care particularly how the voltages of the individual positive and negative groups change. If, however, the battery fails to give its rated capacity, the fault may be due to defective positives or defective negatives.

If the voltage of a battery fails to come up when the battery is put on charge, the trouble may be due to either the positives or negatives. Positives and negatives may not charge at the same rate, and one group may become fully charged before the other group. This may be the case in a cell which has had a new positive group put in with the old negatives. Cadmium tests made while the battery is on charge will tell how fully the individual groups are charged.

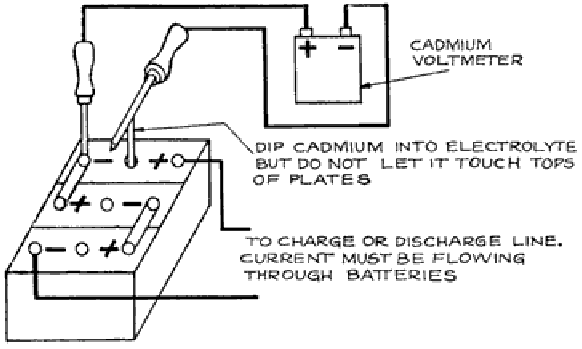
Since the voltages of the positives and negatives both fall as a battery is discharged, and rise as the battery is charged, if we measure the voltages of the positives and negatives separately, we can tell how far each group is charged or discharged. If the voltage of each cell of a battery drops to 1.7 before the battery has given its rated capacity, we can tell which set of plates has become discharged by measuring the voltages of positives and negatives separately. If the voltage of the positives show that they are discharged, then the Positives are not up to capacity. Similarly, negatives are not up to capacity if their voltage indicates that they are discharged before the battery has given its rated capacity.

Cadmium readings alone do not give any indication of the capacity of a battery, and the repairman must be careful in drawing conclusions from Cadmium tests.

In general it is not always safe to depend upon Cadmium tests on a battery which has not been opened, unless the battery is almost new. Plates having very little active material, due to shedding, or due to the active material being loosened from the grid, will often give good Cadmium readings, and yet a battery with such plates will have very little capacity. Such a condition would be disclosed by an actual examination of the plates, or by a capacity discharge test.

How Cadmium Tests Are Made

To measure the voltages of the positives and negatives separately, Cadmium is used. The Cadmium is dipped in the electrolyte, and a voltage reading is taken between the Cadmium and the plates which are to be tested. Thus, if we wish to test the negatives, we take a voltage reading between the Cadmium and the negatives, as shown in Fig. 119. Similarly, if we wish to test the positives, we take a voltage reading between the Cadmium and the positives, as shown in Fig. 120.



MAKING CADMIUM TEST ON NEGATIVE PLATES

Fig. 119

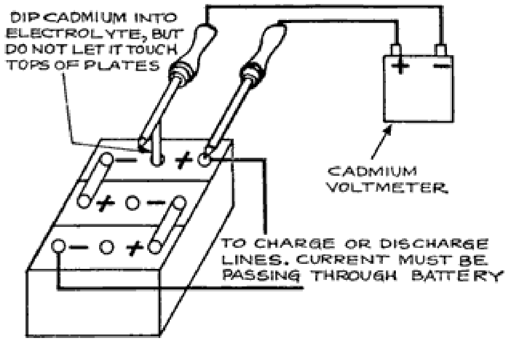


Fig. 120 MAKING CADMIUM TEST ON POSITIVE PLATES

In dipping the Cadmium into the electrolyte, we make two cells out of the battery cell. One of these consists of the Cadmium and the positives, while the other consists of the Cadmium and the negatives. If the battery is charged, the Cadmium forms the negative element in the Cadmium-Positives cell, and is the positive element in the Cadmium-Negatives cell. The voltage of the Cadmium does not change, and variations in the voltage readings obtained in making Cadmium tests are due to changes in the state of charge of the negative and positive plates which are being tested.

What Cadmium Is: Cadmium is a metal, just like iron, copper, or lead. It is one of the chemical elements; that is, it is a separate and distinct substance. It is not made by mixing two or more substances, as for instance, solder is made by mixing tin and lead, but is obtained by separating the cadmium from the compounds in which it is found in nature, just as iron is obtained by treatment of iron ore in the steel mill.

When Cadmium Readings Should Be Made

1. When the battery voltage drops to 1.7 per cell on discharge before the battery has delivered its rated ampere-hour capacity, at the 5-hour rate when a discharge test is made.

2. When a battery on charge will not "come up," that is, if its voltage will not come up to 2.5-2.7 per cell on charge, and its specific gravity will not come up to 1.280-1.300.

3. Whenever you charge a battery, at the end of the charge, when the voltage and specific gravity no longer rise, make Cadmium tests to be sure that both positives and negatives are fully charged.

4. When you put in a new group, charge the battery fully and make Cadmium tests to be sure that both the new and old groups are fully charged.

5. When a 20-minute high rate discharge test is made. See page 267.

That Cadmium Readings should be taken only while a battery is in action; that is, while it is on discharge, or while it is on charge.

Cadmium Readings taken on a battery which is on open circuit are not reliable.

When you are not using the Cadmium, it should be put in a vessel of water and kept there. Never let the Cadmium become dry, as it will then give unreliable readings.

Open Circuit Voltage Readings Worthless

Voltage readings of a battery taken while the battery is on open circuit; that is, when no current is passing through the battery, are not reliable. The voltage of a normal, fully charged cell on open circuit is slightly over 2 volts. If this cell is given a full normal discharge, so that the specific gravity of its electrolyte drops to 1.150, and is allowed to stand for several hours after the end of the discharge, the open circuit voltage will still be

2 volts. Open circuit voltage readings are therefore of little or no value, except when a cell is "dead," as a dead cell will give an open circuit voltage very much less than 2, and it may even give no voltage at all.

What the Cadmium Test Set Consists of

The Cadmium Tester consists of a voltmeter, Fig. 121, and two pointed brass prods which are fastened in wooden handles, as shown in Fig. 122. A length of flexible wire having a terminal at one end is soldered to each prod for attachment to the voltmeter. Fastened at right angles to one of the brass prods is a rod of pure cadmium.

Cadmium tests may be made with any accurate voltmeter which gives readings up to 2.5 volts in divisions of .05 volt.

The instructions given below apply especially to the special AMBU voltmeter but these instructions may also be used in making cadmium tests with any voltmeter that will give the correct reading.

Testing a Battery on Discharge

The battery should be discharging continuously, at a constant, fixed rate, see page 265.

Generally, on a starting ability test (see page 267), the positive Cadmium readings will start at about 2.05 volts for a hard or very new set of positives, and at 2.12 volts or even higher for a set of soft or somewhat developed positives, and will drop during the test, ending at 1.95 volts or less. The negative Cadmium readings will start at 0.23 volt or higher, up to 0.30, and will rise gradually, more suddenly toward the end if the plates are old, ending anywhere above 0.35 and up to 0.6 to 0.7 for poor negatives.

Short Circuited Cells: In cases of short circuited cells, the voltage of the cell will be almost down to zero. The Cadmium readings would therefore be nearly zero also for both positives and negatives. Such a battery should be opened for inspection and repairs.

Testing a Battery on Charge

The Battery should be charging at the finishing rate. (This i's usually stamped on the battery box.) Dip the cadmium in the electrolyte as before, and test the negatives by holding the plain prod on the negative post of the cell. See Fig. 119. Test the positives in a similar manner. See Fig. 120. The cell voltage should also be measured. If the positives are fully charged, the positive cadmium reading will be such that the pointer will move to the red line marked "Pos. Charged." See Fig. 125. If you are using an ordinary voltmeter, the meter will give a reading of from 2.35 to 2.42 volts. The negatives are then tested in a similar manner. The negative-cadmium reading on an ordinary voltmeter will be from .175 to .2 to the left of the "0" line; that is, the reading is a reversed one. If you are using the special ABM voltmeter, the pointer will move to the red line marked "Neg. Charged."

See Fig. 123. **The cell voltage should be the sum of the positive-cadmium and the negative cadmium readings.**

If the voltage of each cell will not come up to 2.5 to 2.7 volts on charge, or if the specific gravity will not rise to 1.280 or over, make the cadmium tests to determine whether both sets of plates, or one of them, give readings indicating that they are fully charged. If the positives will not give a reading of at least 2.35 volts, or if the negatives will not give a reversed reading of at least 0.1 volt, these plates lack capacity.

In case of a battery on charge, if the negatives do not give a minus Cadmium reading, they may be lacking in capacity, but, on the other hand, a minus negative Cadmium reading does not prove that the negatives are up to hill capacity. A starting ability discharge test (page 267) is the only means of telling whether a battery is up to capacity.

Improperly treated separators will cause poor negative-Cadmium readings to be obtained. The charging rate should be high enough to give cell voltages of 2.5-2.7 when testing negatives. Otherwise it may not be possible to get satisfactory negative-Cadmium reading. Separators which have been allowed to become partly dry at any time will also make it difficult to obtain satisfactory negative-Cadmium readings.

HIGH RATE DISCHARGE TESTERS

(See page 265 for directions for making tests.)

Figure 128 shows a high rate discharge cell tester. It consists of a handle carrying two heavy prongs which are bridged by a length of heavy nichrome wire. When the ends of the prongs are pressed down on the terminals of a cell, a current of 150 to 200 amperes is drawn from the cell. A voltage reading of the cell, taken while this discharge current is flowing is a means of determining the condition of the cell, since the heavy discharge current duplicates the heavy current drawn by the starting motor. Each prong carries a binding post, a low reading voltmeter being connected to these posts while the test is made. This form of discharge tester is riot suitable for making starting ability discharge tests, which are described on page 267.

Other forms of high rate discharge testers are made, but for the shop the type shown in Figure 128 is most convenient, since it is light and portable and has no moving parts, and because the test is made very quickly without making any connections to the battery. Furthermore, each cell is tested separately and thus six or twelve volt batteries may be tested without making any change in the tester.

For making starting ability discharge tests at high rates, a carbon plate or similar rheostat is most suitable, and such rheostats are on the market.

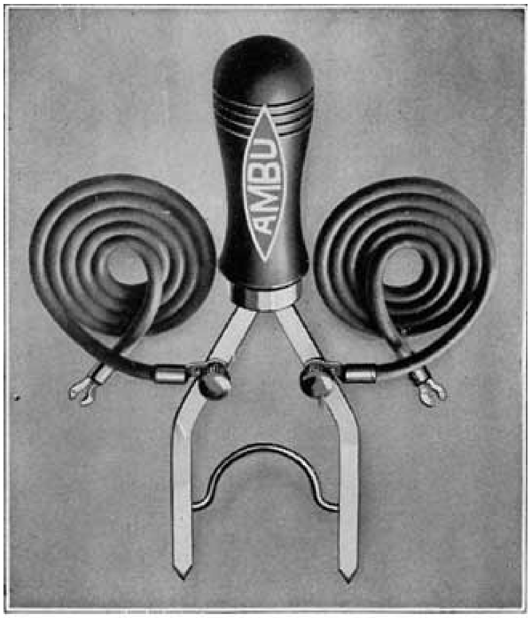


Fig. 128. High Rate Discharge Tester

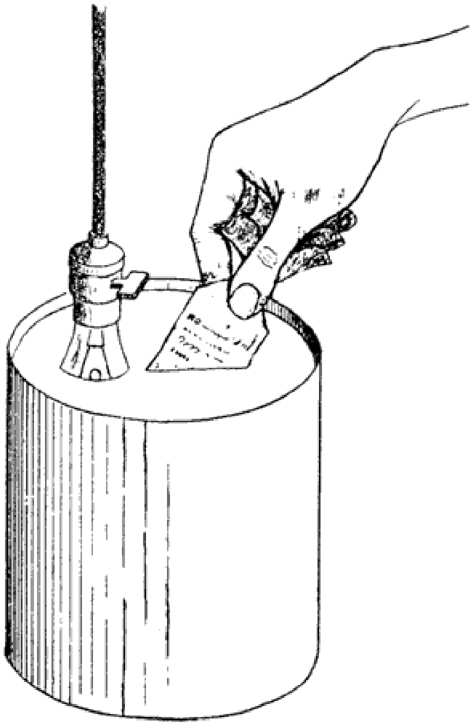


Fig. 129. Paraffine Dip Pot

PARAFFINE DIP POT

Paper tags are not acid proof, and if acid is spilled on tags tied to batteries which are being repaired, the writing on the tags is often obliterated so that it is practically impossible to identify the batteries. An excellent plan to overcome this trouble is to dip the tags in hot paraffine after they have been properly filled out. The writing on the tags can be read easily and since paraffine is acid proof, any acid which may be spilled on the paraffine coated tags will not damage the tags in any way.

Figure 129 shows a paraffine dip pot. A small earthenware jar is best for this purpose. Melt the paraffine slowly on a stove, pour it into the pot, and partly immerse a 60-watt carbon lamp in the paraffine as shown. The lamp will give enough heat to keep the paraffine melted, without causing it to smoke to any extent. After filling out a Battery Card, dip it into the Paraffine, and hold the card above the pot to let the excess paraffine run off. Let the paraffine dry before attaching the tag to the battery, otherwise the paraffine may be scratched off.

Battery Conditions

If a battery becomes very hot while on charge at a rate which is not normally too high for the battery, it indicates that the battery is badly sulphated, or has a partial short-circuit. Gassing generally goes with the high temperature.

If you can detect a vinegar-like odor rising from the vent holes, you may be absolutely sure that the separators used in that battery have developed acetic acid due to not having received the proper treatment necessary to prepare them for use in the battery. The electrolyte should be dumped from such a battery immediately and the battery should be filled and rinsed with water several times. Then the battery should be opened without loss of time, to see whether, by removing the separators and washing the plates thoroughly, the plates may be saved. If the acetic acid has been present for any length of time, however, the plates will have been ruined beyond repair, the lead parts being dissolved by the acid.

If the electrolyte of a battery on charge has a white, milky look, there may be impurities which cause numerous minute bubbles to form, such bubbles giving the electrolyte its milky appearance. The milky appearance may be due to the use of "hard" water in refilling, this water containing lime.

The electrolyte as seen with the acid of an electric lamp or flashlight should be perfectly clear and colorless. Any scum, particles of dirt, any color whatsoever shows that the electrolyte is impure. This calls for dumping out the electrolyte, filling and rinsing with pure water, refilling with new electrolyte and putting the battery back on the charging line. Of course, this may not cause the battery to charge satisfactorily, which may be due to the troubles already described.

Should it ever happen that it is impossible to send a current through a charging circuit go over all the connections to make sure that you have good contact at each battery terminal, and that there are no loose inter-cell connectors. If all connections to the batteries are -good, and there are no loose inter-cell connectors, cut out one battery at a time until you start the current flowing, when you cut out some particular battery. This battery should then be opened without further tests, as it is without a doubt in a bad condition.

The conditions which may exist when a battery will not charge, as shown especially by cadmium tests, are as follows:

(a) The battery may have been allowed to remain in a discharged condition, or the owner may have neglected to add water, with the result that the electrolyte did not cover the plates. In either case a considerable amount of crystallized sulphate will have formed in the plates. Plates in such a condition will require a charge of about a week at a low rate and will then have to be discharged and recharged again. Several such cycles of charge and discharge may be necessary. It may even be impossible to charge such a battery, no matter how many cycles of charge and discharge are given. If the owner admits that his battery has been neglected and allowed to stand idle for a considerable time, get his permission to open the battery.

(b) The battery may have been overheated by an excessive charging rate, or by putting it on a car in a sulphated condition. The normal charging rate of the generator on the car will over heat a sulphated battery. Overheated plates buckle their lower edges cut through the separators, causing a short-circuit between plates.

(c) The pockets in the bottoms of the jars may have become filled with sediment, and the sediment may be short-circuiting the plates.

(d) Impurities may have attacked the plates and changed the active materials to other substances which do not form a battery. Such plates may be so badly damaged that they are brittle and crumbled. Acetic acid from improperly treated separators will dissolve lead very quickly, and may even cause an open circuit in the cell.

(e) The conditions described in (a), (b), and (c) will permit a charging current to pass through the battery, but the plates will not become charged. It is possible, of course, but not probable, that a condition may exist in which all the plates of one or both groups of a cell may be broken from the connecting straps, or inter-cell connectors may be making no contact with the posts. In such a case, it would be impossible to send a charging current through the battery. Acetic acid from improperly treated separators, and organic matter introduced by the use of impure water in refilling will attack the lead of the plates, especially at the upper surface of the electrolyte, and may dissolve all the plate lugs from the connecting straps and cause an open-circuit.

(f) The separators may be soggy and somewhat charred and blackened, or they may be clogged up with sulphate, and the battery may need new separators.

(g) The spongy lead may be bulged, or the positives may be buckled. The active material is then not making good contact with the grids, and the charging current cannot get at all the sulphate and change it to active material. The remedy in such a case is to press the negatives so as to force the active material back into the grids, and to put in new positives if they are considerably buckled.

(h) One of the numerous "dope" electrolytes which are offered to the trustful car owner may have been put in the battery. Such "dopes" might cause very severe damage to the plates. Tell your customers to avoid using such "dope."

The conditions which may exist when the plates of a battery take a charge, as indicated by cadmium tests, but the gravity will not come up to 1.280 are as follows:

(a) There may be considerable sediment in the jars but not enough to short circuit the plates. If the battery has at some time been in a sulphated condition and has been charged At too high a rate, the gassing that resulted will have caused chips of the sulphate to drop to the bottom of the jars. When this sulphate was formed, some of the acid was taken from the electrolyte, and if the sulphate drops from the plates, this amount of acid cannot be recovered no matter how long the charge is continued. If the owner tells you that his battery has stood idle for several months at some time, this is a condition which may exist. The remedy is to wash and press the negatives, wash the positives, put in new separators, pour out the old electrolyte and wash out the jars, fill with 1.400 acid, and charge the battery.

(b) Impurities may have used up some of the acid which cannot be recovered by charging. If the plates are not much damaged the remedy is the same as for (a). Damaged plates may require renewal.

(c) Electrolyte may have been spilled accidentally and replaced by water.

(d) Too much water may have been added, with the result that the expansion of the electrolyte due to a rise in temperature on charge caused it to overflow. This, of course, resulted in a loss of some of the acid

The causes given in (c) and (d) may have resulted in the top of the battery case being acid-eaten or rotted. The remedy in these two instances is to draw off some of the electrolyte, add some 1.400 acid and continue the charge. If plates and separators look good and there is but little sediment, this is the thing to do.

If Battery will not hold a Charge. If a battery charges properly but loses its charge in a week or less, as indicated by specific gravity readings, the following troubles may exist:

(a) Impurities in the cells, due to the use of impure water in the electrolyte, or in the separators. Some impurities (see page 76) do not attack the plates, but merely cause self-discharge. The remedy is to dump out the old electrolyte, rinse the jars with pure water, fill with new electrolyte of the same gravity as the old and recharge. If this does not remove impurities, the battery should be opened, the plates washed, jars cleaned out, new separators put in, and battery reassembled and charged.

(b) There may be a slow short-circuit, due to defective separators or excessive amount of sediment. If preliminary treatment in (a) does not cause battery to hold charge, the opening of battery and subsequent treatment will remove the cause of the slow short-circuit.

Post Building

In drilling down through the inter-cell connectors to separate them from the posts in opening a battery, the posts may be drilled too short. In reassembling the battery it is then necessary to build the posts up to their original height. This is done with the aid of post-builders, shown in Figure 100.

Clean the stub of the post thoroughly and also clean the inside of the post builder. Then set the post builder carefully over the stub post, so that the upper surface of the post builder is parallel to the upper surface of the plate strap. The built up post will then be perpendicular to the surface of the strap, which is necessary, in order to have the covers and connectors fit properly.

With the post builder set properly adjust the burning torch to get a sharp, hissing flame. Bring the flame straight down on the center of the post stub. When the center of the post stub begins to melt, move the flame outward with a circular motion until the whole top of the stub begins to melt. Then run in lead from a burning lead strip, Figure 101, at the same time keeping the flame moving around on the top of the post to insure a good weld. In this way build up the post until the lead comes up to the top of the post builder. Then lift the flame straight up from the post. Allow the lead to set, and then remove the post builder, grasping it with a pair of gas or combination pliers and turn the post builder around to loosen it.

MOULDING LEAD PARTS

In using special moulds for casting inter-cell connectors, plate straps with posts, terminals, etc., follow the special instructions furnished by the manufacturers as to the manipulation of the special moulds made by them.

Aside from the special instructions for the use of moulds, there are general rules for the melting of lead and handling it after it is melted, which must be observed if good castings are to be made.

Raw Materials. In every battery repair shop a supply of old terminals, cell connectors, posts, and straps, will gradually accumulate. These should not be thrown away or sold as junk, but should be kept in a box or jar provided for that purpose. Old plates should not be saved, since the amount of lead in the grid is small and it is often covered with sulphate. The lugs connecting the plates to the straps may, however, be used. Before using the scrap lead as much dirt as possible should be brushed off, and all moisture must be dried off thoroughly. Scrap lead contains some antimony, which is metal used to give stiffness to tile parts. Using miscellaneous scrap sometimes gives castings which do not contain the proper percentage of antimony. If there is too much antimony present, cracked castings will be the result. To remedy this condition, bars of pure lead should be purchased from some lead manufacturing company. Adding pure lead will reduce the percentage of antimony. Bars of pure antimony should also be kept oil hand in case the castings are too soft.

Lead Melting Pots are standard articles which may be purchased from jobbers. A pot having a 25 pound capacity is suitable for small shops and for larger shops a 125-pound size is best. Before melting any lead in such pots, have them thoroughly free from dirt, grease, or moisture, not merely in order to get clean castings, but also to avoid melted lead being thrown out of the pot on account of the presence of moisture. Severe burns may be the result of carelessness in this respect.

In starting with an empty melting pot, turn oil the heat before putting in any lead, and let the pot become thoroughly heated in order to drive off any moisture. With the pot thoroughly hot, drop in the lead, which must also be dry. When the metal has become soft enough to stir with a clean pine stick, skim off the dirt and dross which collects on top and continue heating the lead until it is slightly yellow oil top. Dirt and lead do not mix, and the dirt rises to the top of the metal where it may readily be skimmed off.

With a paddle or ladle, drop in a cleaning compound of equal parts of powdered rosin, borax, and flower of sulphur. Use a teaspoonful of this compound for each ten pounds of metal, and be sure that the compound is absolutely dry. Stir the metal a little, and if it is at the proper temperature, there will be a flare, flash, or a little burning. A sort of tinfoil popcorn effect will be noticed oil top of the lead. Stir until this melts down.

Have the ladle with which you dip up the melted lead quite dry. When dipping up some of the lead, skim back the dark skin which forms oil top of the lead and dip up the clean bright lead for pouring.

In throwing additional lead into a pot which is partly filled with melted lead, be sure that the lead which is thrown in the pot is dry, or else hot lead may be spattered in your face.

Have the moulds clean and dry. The parts with which the lead comes into contact should be dusted with a mould compound which fills in the rough spots in the metal so that the flow of lead will not be obstructed, and the lead will fill the mould quickly. Dip tip enough lead to fill the part of the mould you use. When you once start pouring do not, under any circumstance, stop pouring until the lead has completely filled the mould. Lead cools very quickly after it is poured into the mould, and if you stop pouring even for all instant, you will have a worthless casting.

In a shop having an ordinary room temperature, it is generally unnecessary to heat the moulds before making up a number of castings. If it is found, however, that the first castings are defective due to the cold mould chilling the lead, the mould should be heated with a soft flame. After a few castings have been made, the mould will become hot enough so that there will be no danger of the castings becoming chilled.

When the castings have cooled sufficiently to be removed, strike the mould a few blows with a wooden mallet or a rawhide hammer to loosen, the castings before opening the mould. The castings may then be removed with a screwdriver.

Cracked castings indicate that the mould was opened before the castings had cooled sufficiently, or that there is too much antimony in the castings. The remedy is to let the castings cool for a longer time, or to add pure lead to the melting pot.

REINSULATION

Separators are the weakest part of a battery and wear out while the other parts of a battery are still in good condition. Good plates are often ruined by weakened separators causing short-circuits. Many batteries which have to be junked after being in service about a year would have given considerable service if they had been reinsulated.

Generally the separators of one cell wear out before those of the other cells. Do not, however, reinsulate that cell alone. The separators in the other cells are as old as those which have worn out, and are very near the breaking down point. If you reinsulate only one cell, the owner will naturally assume that the other cells are in good condition. What happens? A month or so later one of the other cells "goes dead." This does not have a very soothing effect on the owner, who will begin to lose confidence in you and begin to look around for another service station.

If you explain frankly that it is useless to reinsulate only one cell of a battery and that the other cells will break down in a short time, the customer will want you to reinsulate all the cells. A somewhat higher bill for reinsulating all the cells at once will be more agreeable than having the cells break down one at a time within a month or two.

In the case of the customers who come in regularly for testing and filling service, you will be able to tell when the separators are wearing out. When you find that a battery which has been in service about a year begins to run down frequently, and suceessive tests made in connection with testing and filling service show that the generator is not able to keep the battery charged, advise the owner to have the battery reinsulated. Do not wait for the battery to have a dead cell. Sell the owner on the idea that reinsulation will prevent the possibility of his battery breaking down when he may be out on a tour, and when it may be necessary to have his car towed in to a service station. If you allow the battery to remain on the car when it begins to lose its charge, the owner will not, of course, suspect that anything is wrong, and if his battery one day breaks down suddenly, lie will very likely lose confidence both in you and the battery, since he has been bringing in his car regularly in order to have his battery kept in good shape. The sudden failure of his battery will, therefore, make him believe that you do not know your business, or that the battery is a poor one.

New separators will give every battery which is a year old a new lease on life. If you explain to a customer that he will get a much longer period of service from his battery if he has it reinsulated when the battery is a year old, you should have no trouble in getting the job, and the subsequent performance of the battery will show that you knew what you were talking about.

SAFETY FIRST FOR THE BATTERY REPAIRMAN

1. Do not work on an empty stomach-you can then absorb lead easily.

2. Keep your fingers out of your mouth when at work.

3. Keep your finger nails short and clean.

4. Do not chew tobacco while at work. In handling tobacco, the lead oxides are carried to your mouth. Chewing tobacco does not prevent you from swallowing lead.

5. When you leave the shop at night, and before eating, wash your face, hands, and arms with soap, and clean your nose, mouth, and finger nails.

6. Do not eat in the repair shop.

7. Drink plenty of good milk. It prevents lead poisoning.

8. Use Epsom Salts when constipated. This is very important.

9. Bathe frequently to prevent lead poisoning.

10. Leave your working clothes in the shop.

11. It is better not to wear a beard or mustache. Keep your hair covered with a cap.

12. Before sweeping the shop dampen the floor to keep down the dust.

13. Do not drink beer or whisky, or any other alcoholic liquors. These weaken your system and make you more susceptible to lead poisoning.

14. In handling lead, wear gloves as much as possible, and -wash and dry the gloves every day that you wear them.

15. Wear goggles to keep lead and acid out of your eyes.

16. When melting lead in a hydrogen flame, as in burning on the top connectors, the fumes given off may be blown away by a stream of air. The air supply to the flame may be tapped for this purpose.

17. The symptoms of lead poisoning are: gums darken or become blue, indigestion, colic, constipation, loss of appetite, muscular pain. In the later stages there is muscular weakness and paralysis. The hands become limp and useless.

18. Wear rubber shoes or boots. Leather shoes should be painted with a hot mixture of equal parts of paraffine and beeswax.

19. Wear woolen clothes if possible. Cotton clothing should be dipped in a strong solution of baking soda and dried. Wear a flannel apron covered with sacking.

20. Keep a bottle of strong ammonia handy. If you should spill acid on your clothes, apply some of the ammonia immediately to neutralize the acid, which will otherwise burn a hole in your clothes.

21. Keep a stone, earthenware, or porcelain jar filled with a solution of washing soda or baking soda (bicarbonate of soda). Rinse your hands in this solution occasionally to prevent the acid from irritating them.

22. If you should splash acid in your eye, wash it out immediately with warm water, and drop olive oil on the eye. If you have no olive oil at hand, do not wait to get some, but use any, lubricating oil, or vaseline.

CHAPTER 15

REBUILDING THE BATTERY

How to Open a Battery

A battery is open when its plates have been drawn out of the hard rubber jars. All parts are then exposed, and accessible for inspection and repairs. In an assembled battery, the top of each cell is closed by a hard rubber cover. Leakproof joints are made between these covers and the rubber jars and the wooden case by means of sealing compound which is poured in place while in a molten condition, and joins the covers to the jars and which hardens as it cools. The joints between the covers and the posts which project through the covers are in many batteries made with sealing compound. The cells are then connected to each other by means of the cell connectors, also called "top-connectors," or simply "connectors." These connectors are joined to the lead posts, to which are connected the plate groups by fusing with a flame, and melting in additional lead to make a joint.

In opening a battery, we must first disconnect the cells from each other, and then open the joint made by the sealing compound between the covers and the jars and case. The plates may then be lifted out of the jars, and the battery is open. The steps necessary to open a battery follow, in the order in which they must be taken.

1. Clean the Battery. Set the battery on the tear down rack. See that the vent plugs are all tight in place. Then clean the outside of the battery. Remove the greater part of the dirt with a brush, old whisk-broom, or a putty knife. Then put the battery in the water, using a stiff bristled brush to remove whatever dirt was not removed in the first place. A four-inch paint brush is satisfactory for this work, and will last a year or more if taken care of. If water will not remove all the dirt, try a rag wet with gasoline.

2. Drilling Off the Connectors and Terminals. When you have cleaned the outside of the battery as thoroughly as possible, set the battery on the floor near your work bench. Make a sketch of the top of the battery, showing the exact arrangement of the terminals and connectors. This sketch should be made on the tag -which is tied to the battery. Tic this tag on the handle near the negative terminal of the battery or tack it to the ease. Then drill down over the Center of the posts. For this you will need a large brace with a heavy chuck, a drill the same size as the post (the part that goes down into the battery), a large screw driver, a center punch, and a hammer.

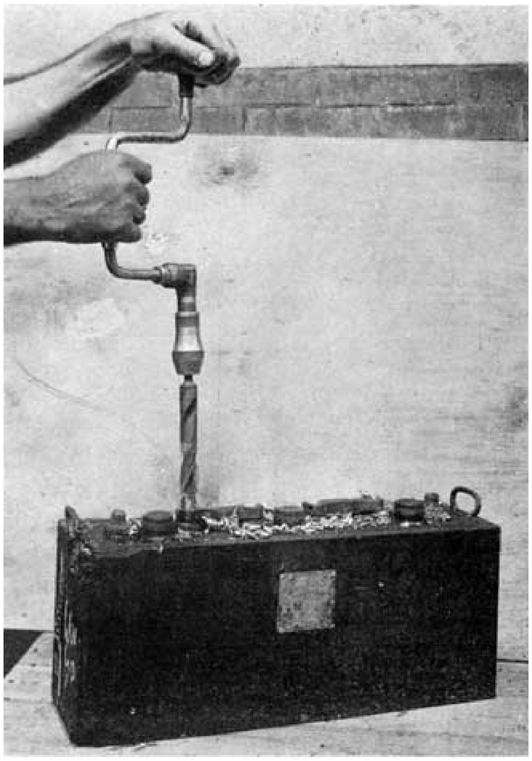


Fig. 191. Drilling Post and Cell Connector

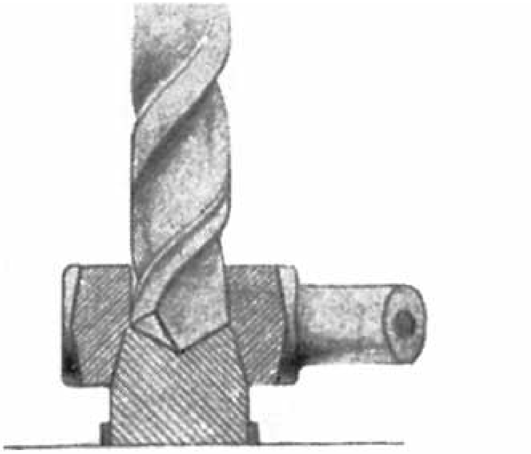


Fig. 192. Connector Drilled to Correct Depth

With the center punch, mark the exact centers of the tops of the posts and connectors. Then drill down about half way through the connectors and terminals until you cut through the part of the connector which is welded to the post. When you can see a seam between the post and connector you have drilled through the welded part. See Figs. 191 and 192.

Now pry off the connectors with the screw driver, as shown in Fig. 193. Lay a flat tool such as a chisel or file on the top edge of the ease to avoid damaging the ease when prying off the connectors.

If any connector is still tight, and you cannot pry it off with a reasonable effort, drill down a little deeper, and it -will come off easily, provided that the hole which you are drilling is exactly over the center of the post and as large as the post. There are five things to remember in drilling the connectors and posts:

(a) Be sure that the hole is exactly over the center of the post.

(b) Do not drill too deep. Make each hole just deep enough so that the connector will come off easily. Fig. 192 shows a cross section of a post and connector drilled to the proper depth. Notice that you need not drill down the whole depth of the connector, because the bottom part is not burned to the post.

(c) Be sure that the drill makes the right sized hole to permit the connectors and terminals to be removed easily when drilled half way through. An electric drill will do the work much faster than a hand brace.

(d) Protect the edge of the battery box when you pry up the connectors with a screw driver.

(e) Remove your drill after the hole is well started and see whether the hole is in the center of the post. Should you find that it is off center, tilt the drill, and with the end of the drill pointing the center of the post as you drill, gradually straighten the drill. This will bring the hole over the center of the post.

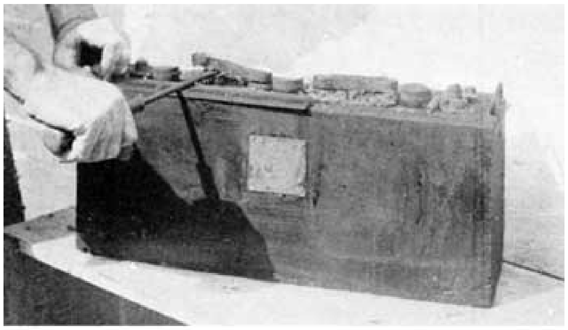


Fig. 193. Prying Off Cell Connector

Having removed the connectors, sweep all the lead drillings front the top of the battery into a box kept for lead drillings only. Fig. 194. When this box is full, melt the drillings and pour off in the burning lead mould.

Post Seal. If the post seal consists of a lead sealing nut, this may be removed now. With some types of batteries (Willard and U. S. L.), drilling the connectors also breaks the post seal. With other batteries, such as the Vesta, Westinghouse, Prest-0-Lite, Universal, it is more difficult to break the post seal. On these batteries, therefore, do not break this seal before drawing out the plates. You may find that it will not be necessary to separate the groups, and the post seal will not have to be broken at all, thereby saving yourself considerable time on the overhauling job.

3. Heating Up the Sealing Compound. Having disconnected the cells from each other by removing the cell connectors, the next step is to open the joint made by the sealing compound between the covers and jars. Fig. 195 shows the battery ready for this step. When cold, the compound is a tough substance that sticks to the cover and jar, and hence it must be heated until it is so soft that it is easily removed. There are several methods by means of which compound may be heated. These are as follows:

Steam. This is the most popular, and undoubtedly the best means of heating the compound, and in the following instructions it will be assumed that steam has been used. The battery is either placed in a special box in which steam is sent, or else steam is sent directly into each cell through the vent tube. In the first method the compound is heated from the outside, and in the second it is heated from the inside of the cell.

If the battery is placed in the steaming box, about ten minutes will be required for the steam to heat up the sealing compound. For batteries which use but very little compound, less time is required. if steam is sent directly into the cells through the vent tubes, five to seven minutes will generally be enough. The covers must be limp and the 1 compound must be soft before turning off the steam.

Hot Water. The electrolyte is poured out of the battery, which is then inverted in a vessel of hot water. This method is slower than the others, and is more expensive because it requires a larger volume of water to be heated.

Hot Putty Knife and Screwdriver. The compound may be dug out with a hot putty knife. This is a slow, unsatisfactory method in most instances, especially in those batteries which use a considerable amount of sealing compound. With some batteries using only a small quantity of compound, a heated putty knife may be run around the inside of the jar between the jar and the cover. This will break the joint between the cover and the jar, and allow the plates to be lifted out. The compound is then scraped from covers and inside of jars, heating the knife or screwdriver whenever it cools off.

Lead Burning Flame. Any soft lead burning flame may be used. Such a flame may be adjusted to any desired size. Where steam is available, a flame should, however, never be used. The temperature of the flame is very high, and the covers, jars, case, posts, and vent plugs may be burned and made worthless. Even for the expert repairman, a flame is not as satisfactory as steam.

The Gasoline Torch. This is the most unsatisfactory method, and should not be used if possible. The torch gives a hot, spreading flame and it is difficult to prevent the covers, jars, case, etc., from being burned. Do not use a gasoline torch if you can possibly avoid doing so. Alcohol torches are open to the same objections, and are not satisfactory, even in the hands of a highly skilled workman.

If a flame is used for heating the compound, be sure to blow out with a hand bellows or compressed air any gas that may have gathered above the plates, before you bring the flame near the battery.

Electric Heat. Special electric ovens for softening sealing compound are on the market. The heating element is brought close to the top of the battery. Where electric power is cheap, this method may be used. Otherwise it is rather expensive.

When the sealing compound has been softened, place the battery on the floor between your feet. Grasp the two posts of one cell with pliers, and pull straight up with an even, steady pull. If the battery has been steamed long enough, the plates will come up easily, carrying with them the cover (or covers, if the batter has upper and lower covers) to which the compound is sticking, as shown in Fig. 196. Do not remove the plates of the other cells until later.

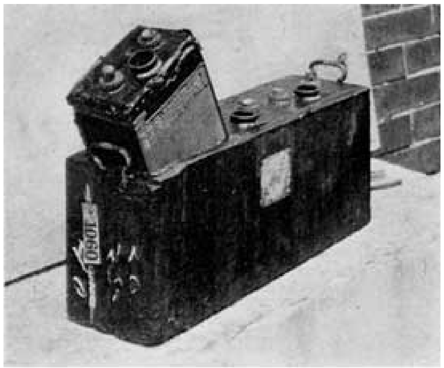


Fig. 197. Resting Element on Jar to Drain

Rest the plates on the top of the jar just long enough to allow most of the acid to drain from them, Fig. 197. If you have removed the post seal, or if the seal consists of compound (old Philadelphia batteries), pry off the covers now with a screw driver. Otherwise, leave the covers in place while cleaning off the compound.

While the plates are resting on the jars to drain, scrape the compound from the covers with a warm screw driver or putty knife, Fig. 198. Work quickly -while the compound is still hot and soft, and comes off easily. As the compound cools it hardens and sticks to the covers and is removed with difficulty. If the battery has sealing compound around the posts, this should also be removed thoroughly, both from the cover and from the post.

When you scrape the compound from the covers, do a good job. Do not scrape off most of it, and then leave pieces of it here and there. Remove every bit of compound, on the tops, edges, sides, and bottoms of the covers. If you need different sized putty knives or screw drivers to do this, use them. The time to remove all the compound is -while it is still hot, and not after it has become hard and cold. If the battery has single covers, the compound can be removed very quickly. If the battery is of the old double-cover type, the job will take more time, since all the compound should be scraped from both top and bottom covers, Fig. 199.

As soon as you have removed the compound from the covers of the first cell, scrape away the compound which may be sticking to the top and inside walls of the jar, Fig. 200. Here again you must do a good job, and remove all of this compound. If you do not do it now, you will have to do it when you try to put the plates back into the jar later on, as compound sticking to the inside walls of the jar will make it difficult, and even impossible to lower the plates into the jar.

Now draw up the plates of the next cell. Rest the plates on the top of the jar just long enough to drain, and then lift off the covers, and remove all of the compound, from cover, posts, and jar, just as you did in the first cell. The third cell, (and the others, if there are more than three cells) are handled just as you did the first one.

Remember that you should lose no time after you have steamed the battery. Hot compound is soft. and does not stick to the covers, jars, and posts and may therefore be removed quickly and easily. Cold compound is hard, and sticks to the covers. Draw out the plates of only one cell at a time, and clean the compound from the cover, posts and jar of that one cell before you draw out the plates of the other cells. In this way, the compound on the covers of the other cells will remain hotter than if all the plates of the battery were drawn out of the jars before any of the compound was removed from the covers. You should have all the plates drawn out, and all the compound removed within five minutes after you draw up the plates,

Throw away the old compound. If is very likely acid-soaked and not fit for further use.

What Must Be Done with the Battery?

The battery is now open, and in a condition to be examined and judgment pronounced upon it. The question now arises, "What must be done with it!" In deciding upon this, be honest with your customer, put yourself in his place, and do just what you would like to have him do if he were the repairman and you the car owner. The best battery men occasionally make mistakes in their diagnosis of the battery's condition, and the repairs necessary. Experience is the best teacher in this respect, and you will in time learn to analyze the condition of a battery quickly.

Handle every cell of a battery that comes in for repairs in the same way, even though only one dead cell is found, and the others are apparently in good condition. Each cell must be overhauled, for all cells are of the same age, and the active materials are in about the same condition in all the cells, and one cell just happened to give out before the others. If you overhaul only the dead cell, the others cells are quite likely to give out soon after the battery is put into service again.

1. Examine plates to determine whether they can be used again Rules for determining when to discard or use old plates follow.

2. If all plates of both positive and negative groups are to be discarded, use new groups.

The question as to whether the old negatives should be used with new positives has caused considerable discussion. If the negatives are old and granulated, they should of course be discarded. Remember that the capacity of negatives decreases steadily after they are put into service, while the capacity of positives increases. Putting new positives against negatives which are rapidly losing capacity is not advisable. However, trouble often arises in a battery whose negatives still have considerable capacity, and such negatives may safely be used with new positives.

If you feel that a battery will not give at least six months' more service after rebuilding with the old negatives, put in all new plates, or sell the owner a new battery, allowing him some money on the old battery. But if you really believe that the negatives still have considerable capacity, put in new positives if required. If all new plates are used, proceed as directed in this chapter, beginning at page 348.

3. If you find that only some of the plates are to be discarded, or if you are not certain as to the condition of the plates, eliminate any short circuits which may exist, and give the battery a preliminary charge, as described later, before you do any work on the plates. Plates that are fully charged are in the best possible condition for handling, and you should make it an ironclad rule that **if some of the plates can be used again always to charge a battery before you work on the plates, no matter what is to be done to them.** If both positives and negatives are to be discarded, the preliminary charge should not, of course, be given, but if only the negatives, or the negatives and some or all of the positives are to be used again, give this preliminary charge. Very few batteries will come to your shop in a charged condition, and an exhausted battery is not in a good condition to be worked on. Charge the whole battery even though only one cell is in a very bad condition. **This is a method that has been tried out thoroughly in practice, not in one or two cases, but in thousands.** Batteries in all sorts of conditions have been rebuilt by this method, and have always given first class service, a service which was frequently as good, if not better than that given by new batteries.

Examining the Plates

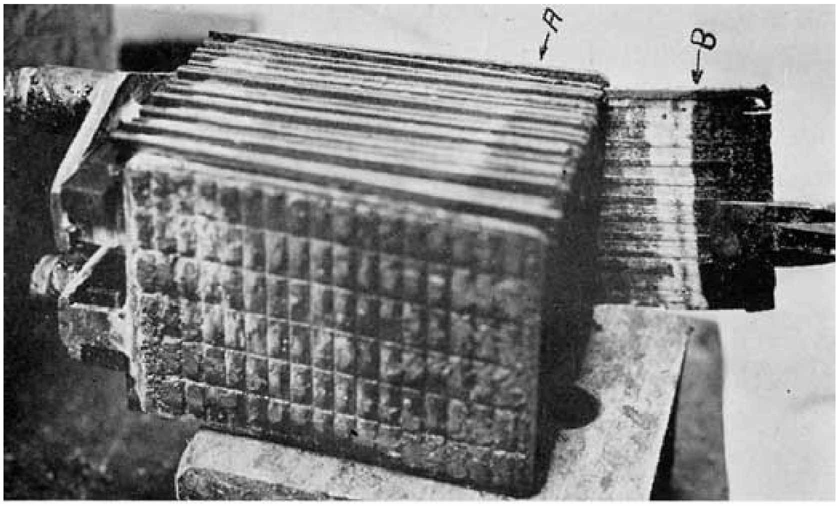


Fig. 201. Element on Block for Examination

Place an element on a block of wood as shown in Fig. 201. Carefully pry the plates apart so that you can look down between them and make a fair preliminary examination. Whenever possible, make your examination of the plates without separating the groups or removing the old separators. This should be done because:

(a) Very often the active material is bulged or swollen, and if you pull out the old separators and put in new ones before charging, the element spreads out so at the bottom that it cannot be put back into the jars without first pressing in a plate press. **Pressing a complete element with the separators in place should never be done** if it can possibly be avoided. If it is done the separators should be thrown. away after you have charged the battery, washed and pressed the negatives, and washed the positive.

(b) If you put in new separators before giving the battery the preliminary charge, the new separators may pick up any impurities which may be on the plates, and will probably be cracked by forcing them- between the bulged and sulphated plates. If, however, the old separators are covered with sulphate, it is best to throw them away and put in new separators before giving the battery its preliminary charge, because such separators will greatly hinder the flow of the charging current. In batteries using rubber sheets in addition to the wooden separators, remove all the wooden separators and leave the rubber sheets in place between the plates. Where only wooden separators are used in a battery, these may be thrown away and perforated rubber separators used for the preliminary charge. Rubber separators may be used again. See (a) above about precautions against pressing a complete element.

If you are not absolutely certain as to the condition of the plates, draw out a few separators. If separators stick to the plates, loosen them by inserting a putty knife blade between them and the plates. Removing a few separators will permit you to separate the groups before removing the rest of the separators. To separate the groups, grasp a post in each hand, as, in Fig. 202, and work them back and forth, being careful not to injure the posts, or break off any plates. With the groups separated, the remaining separators will either fall out or may be easily pushed out with a putty knife. Ordinarily, the groups may be separated in this way if the elements have thirteen plates or less.

The natural thing to do at this point is to decide what must be done to the plates, and we therefore give a number of rules to help you determine which are to be junked, and which are to be used again. Study these rules carefully, and have them fixed firmly in your mind so that you can tell instantly what must be done with the plates.

When to Put In New Plates

1. If one or more jars are cracked and leak, and positive plates have been ruined by freezing, as shown in Fig. 203, and if upon drawing out the separators, and separating the positive and negative groups the active material drops out of the grids, the only way to put the battery in a good condition is to put in 'new positives, and new jars and case if necessary.

2. If the battery is more than two years old, and the active material on the negative plates is granulated (grainy appearance), Figs. 204 and 205, and somewhat disintegrated; if the plates are weak and brittle around the edges, and several grids are cracked, Fig. 206, and the plates have lost a considerable amount of active material; and if the case has been rotted by the acid, the battery should be junked.

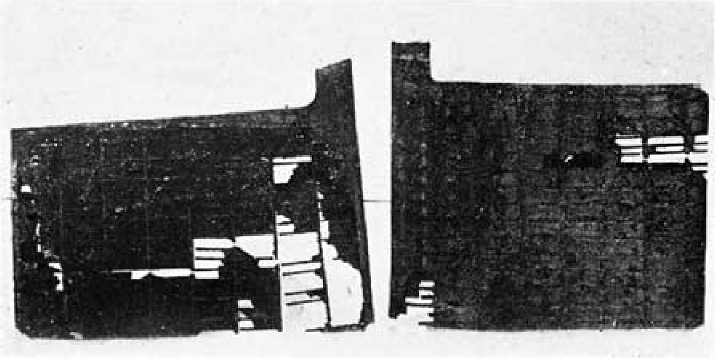


Fig. 206. Weak and Cracked Positives

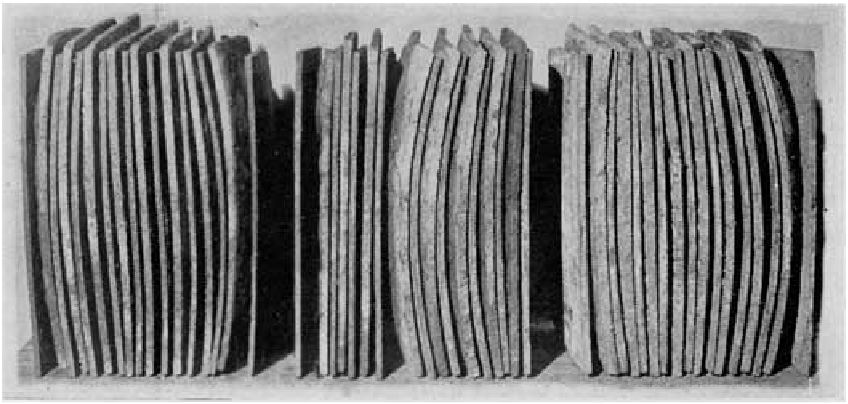


Fig. 208. An Unusually Bad Case of Buckling

3. If the positive plates are badly distorted from buckling, as in Figs. 207 and 208 discard them, for they will cut through new separators, if put into commission again, ill from two to six months.

4. A battery which has has been dry and badly sulphated at some past period of its life will have tile dry portion.", covered with a white sulphate, tile acid line being clearly distinguishable by this white color, as shown at A and B in Fig. 201. If the plates are otherwise ill good shape and you wish to use them, give them the "water cure" described on page 349.

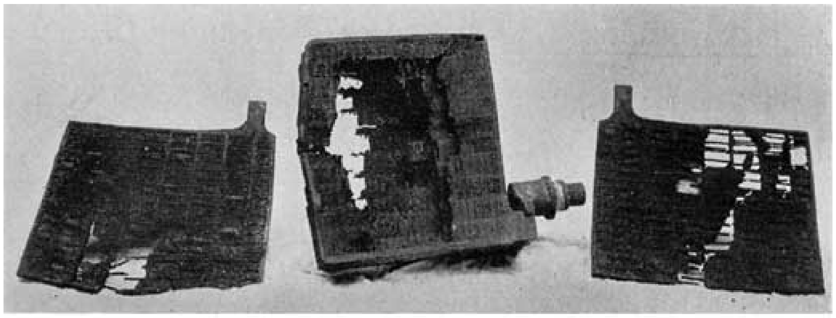


Fig. 210. Disintegrated Positives

5. Rotten and disintegrated positive plates, Figs. 209 and 210, must be replaced with new plates. The plates have fallen to pieces or break at the slightest pressure. Disintegrated plates are an indication of impurities or overcharging, providing the battery is not old enough to cause disintegration normally,--say about two years. The lead grid is converted into peroxide of lead and becomes soft. As a result, there is nothing to support the paste, and it falls out. Better put in new negatives also.

6. Batteries with high gravity or hot electrolyte have burned and carbonized separators, turning them black and rotting them, the negative paste becomes granulated and is kept in a soft condition, and gradually drops from the grids on account of the jolting of the car on the road. Fig. 211 shows such a battery.

7. Dry, hard, and white, long discharged, and badly sulphated plates, Figs. 201 and 209, are practically ruined, though if the trouble is not of long standing, the plates may be revived somewhat by a long charge at a very low rate, using distilled water in place of the electrolyte, and then discharging at a current equal to about one-eight to one-tenth of the ampere hour capacity of the battery at the discharge board. Charge and discharge a battery a number or times, and you may be able to put a little "pep" into it. In charging sulphated plates, use a low charging rate, and do not allow gassing before the end of the charge, or a temperature of the electrolyte above 110°F.

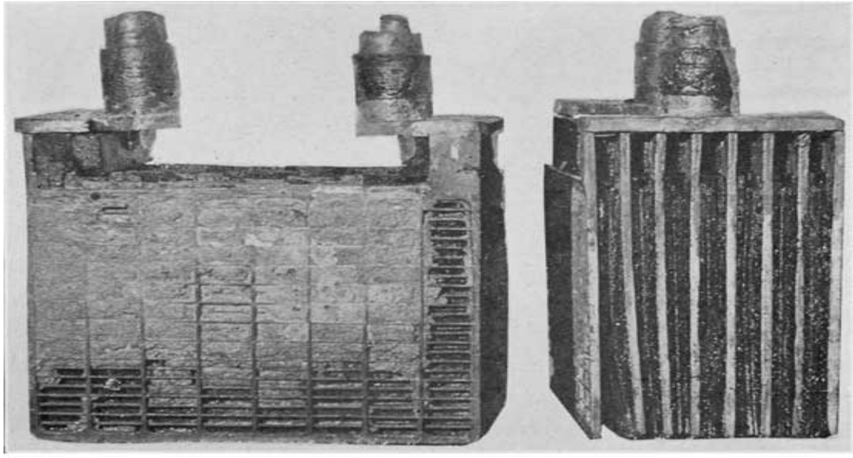


Fig. 211. Side and End View of Element
from Traveling Salesman's Battery

8. If a battery case is not held down firmly, or if the elements are loose in the jars, the plates will jump around when the car is in motion. This will break the sealing compound on top of the battery, and cause the battery to be a slopper. The active materials will be shaken out of the grids, as shown in Fig. 212, and the plates will wear through the separators. New plates are required.

9. If Battery Has Been Reversed. Often the plates of such 'a battery disintegrate and crumble under the slightest pressure. If the reversal is not too far advanced, the plates may be restored (See page 81), but otherwise they should be discarded. This condition is recognized by the original negatives being brown, and the original positives gray.

From. the foregoing explanations, you see that most of the trouble is with the positives:

(a) Because the positive active material does not stick together well, but drops off, or sheds easily.

(b) Because the positives warp or buckle, this causing most of the battery troubles.

(c) Because the positive plate is weaker and is ruined by freezing.

When the Old Plates May be Used Again

1. If one or more plates are broken from the plate connecting straps, or the joint between any strap and the plate is poorly made. If plates are in good condition, reburn the plate lugs to the straps.

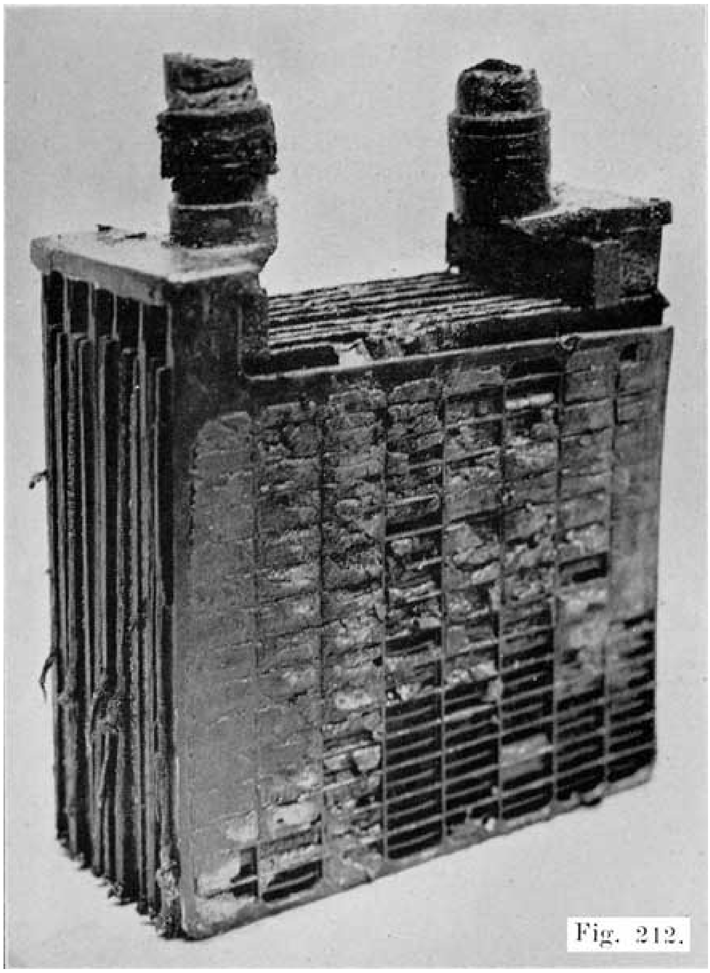


Fig. 212.

Fig. 212. Element from a "Slopper." Element was Loose in Jar. and Jolting of Car Caused Paste to Fall Out

2. Straight Rebuild. If the general condition of the battery is good, i.e., the plates straight or only slightly buckled. only a slight amount of shedding of active material, no white sulphate oil either plate, the grids not brittle. active material adhering to and firmly touching the grids. the positive active material of a dark chocolate brown color and fairly hard (as determined by scratching with blade of a pocket knife), tile negative active Material dark gray in color and not blistered or granulated, and tile plates not too thin, make a straight rebuild. To do this, charge the battery. remove any sediment from the bottom of the jar, wash and press the negatives, wash the positives, clean the parts, insert new separators, and reassemble as directed later. The only trouble may be cracked sealing compound, or a broken jar. Broken jars should, of course, be replaced.

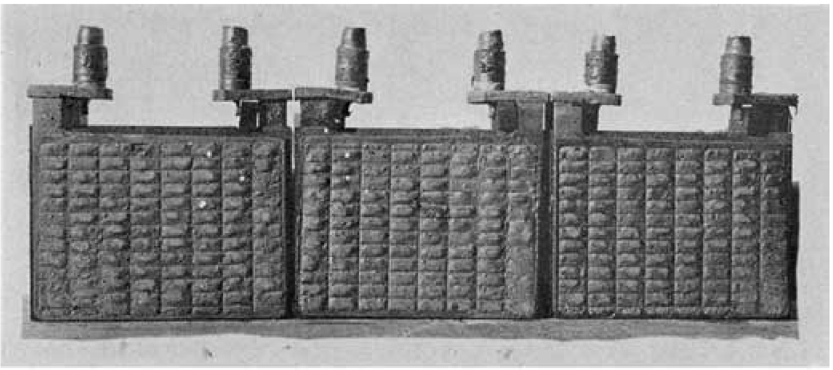


Fig. 213. Badly Bulged Negatives.
Such Plates Must Be Pressed

3. "**Badly bulged negative plates,** Fig. 213, cause lack of capacity because the active material is loose, and does not make good contact with the grids. If the active material is not badly granulated (having a grainy appearance) the plates call be used again. Sulphated negatives have very hard active material, and will feel as bard as stone when scratched with a knife. Hard negatives from Which active material has been falling ill lumps Oil account of being overdischarged after having been in in undercharged condition may be nursed back to life, if too much of the active material has not been lost.

4. The formation of an excessive amount of sulphate may result in cracking the grids, and the active materials falls out in lumps. Such plates may be put in a serviceable condition by a long charge and several cycles of charge and discharge if there is not too much cracking or too much loss of active material.

5. Positives which are only slightly warped or buckled may be used again.

6. When the only trouble found is a slight amount of shedding. Positive active material must be of a dark chocolate brown color and fairly hard. Negatives must be a dark gray.

7. When the plates are in a good condition, but one or more separators have been worn or out through, or a jar is cracked.

If the battery is one which will not hold its charge, and plates seem to be in a good condition, the trouble is very likely caused by the separators approaching the breaking down point, and the repair job consists of putting in new separators or "reinsulating" the battery.

What To Do With the Separators

It is the safest plan to put in new separators whenever a battery is opened, and the groups separated. Separators are the weakest part of the battery, and it is absolutely essential that all their pores be fully opened so as to allow free passing of electrolyte through them. Some of the conditions requiring new separators are:

1. Whenever the pores are closed by any foreign matter whatsoever. Put in new separators whether you can figure out the cause of the trouble or not. The separator shown in Fig. 201 is sulphated clear through above the line B, and is worthless. The separator shown in Fig. 203 should not be used again.

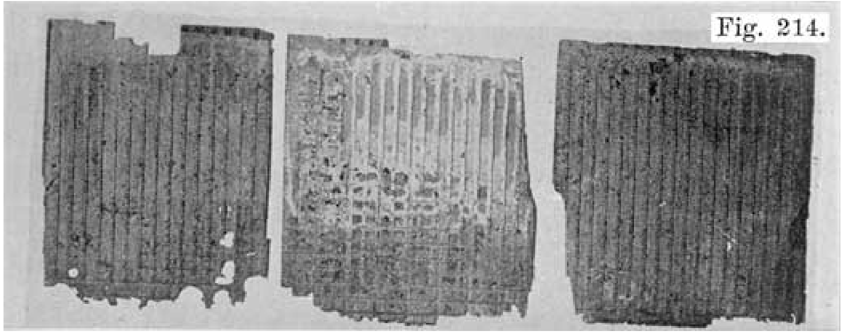


Fig. 214.

Fig. 214. Separators Worn Thin and Cut Through on Edges by Buckled Plates. Holes Worn Trhough by Bulged Active Material, Center One Shows Cell Was Dry Two Thirds of the Way Down.

2. When the separators have been cut or "chiseled off" by the edge of a buckled plate, Fig. 214.

3. When a buckling plate or plate with bulged active material breaks through the separator, Fig. 214.

4. When a battery has been used while the level of the Fig. 214. Separators Worn Thin and Cut Through on Edges by Buckled Plates. Holes Worn Through by Bulged Active Material. Center One Shows Cell Was Dry Two Thirds of the Way Down electrolyte has been below the tops of the plates, or the battery has been used in a discharged condition, and lead sulphate has deposited on the separators, Fig. 201.

5. When a battery has been over-heated by overcharging or other causes, and the hot acid has rotted, burned and carbonized the separators, Fig. 215.

6. When a battery has been damaged by the addition of acid and the separators have been rotted, Fig. 215.

7. Separators which are more than a year old should be replaced by new ones, whether plates are defective or not.

When you have put in new separators, and put the battery on charge, the specific gravity of the electrolyte may go down at first, instead of rising. This is because the separators may absorb some of the acid. If the battery was discharged when you put in the new separators, the lowering of the specific gravity might not take place, but in most cases the specific gravity will go down, or not change at all.

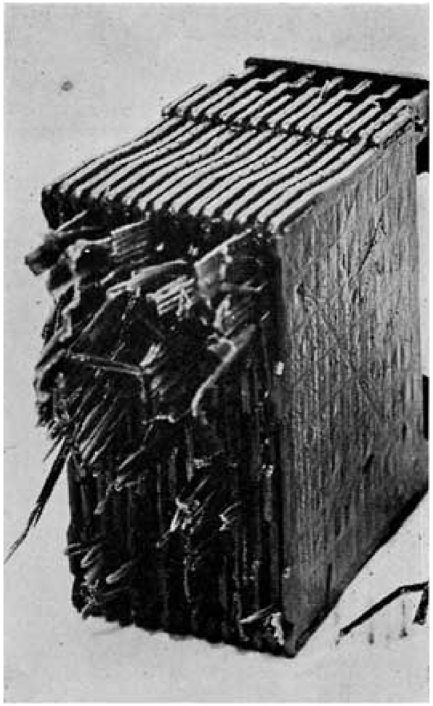


Fig. 215. Rotted Separators

Find the Cause of Every Trouble

The foregoing rules **must** be studied carefully and be clearly tabulated in your mind to be able to tell what to put into commission again and what to discard as junk. It will take time to learn how to discriminate, but keep at it persistently and persevere, and as you pass judgment on this battery and that battery, ask yourself such questions as: What put this battery in this condition? Why are the negative plates granulated? Why are the positive plates buckled? What caused the positive plates to disintegrate? Why are the separators black? Why is the case rotten when less than a year old? Why did the sealing compound crack on top and cause the electrolyte to slop? Why did one of the terminal connectors get loose and make a slopper? Who is to blame for it, the car manufacturer, the manufacturer of the battery, or the owner of the car? Why did this battery have to be taken off the car, opened up and rebuilt at 5 months old, when the battery taken off a car just the day before had been on for 30 months and never had been charged off the car but once? There is a reason; **find** it. Locate the **cause** of the **trouble** if possible, **remove** the **cause**; your customer will appreciate it and tell his friends about it, and this will mean more business for you.

Eliminating "Shorts"

If you have decided that some or all of the plates may be used again, the next thing to do is to separate any plates that are touching, and put the battery on charge. It may be necessary to put in new separators in place of the defective ones. Examine the separators carefully. Whenever you find the pores of the separators stopped up from any cause whatsoever, put in new separators before charging.

1. Sometimes the negative plates are bulged or blistered badly and have worn clear through the separators, Fig. 214, and touch the positives. In cases of this kind, to save time and trouble, separate the groups, press the negatives lightly, as described later, assemble the element with new separators, and it is ready for charging.

2. There is another case where the groups must be separated and new separators inserted before they will take charge, and that is where the battery has suffered from lack of water and has sulphated clear through the separators, Fig. 201. The separators will be covered with white sulphate. Chemical action is very sluggish in such cases.

If you find. that the separator pores are still open, leave the separators in place and proceed to separate the plates that are touching. How? That depends on what insulating material you have available that is thin enough. If nothing else is available, take a piece of new dry separator about 3/8 inch to 1/2 inch square, or a piece of pasteboard the same size. Use a screw driver or putty knife to separate the plates far enough to insert the little piece of insulation as in Fig. 216. Free all the shorts in this way, unless you have some old rubber insulators. In this case, break off some narrow strips 3/4 inch wide or less, put two together and repeat the operation as above, using the rubber strips instead of the pieces of separator. Insert down 1/2 inch or so and bend over and break off. Occasionally the Lipper edges of the plates are shorted, in which case they must be treated the same way.

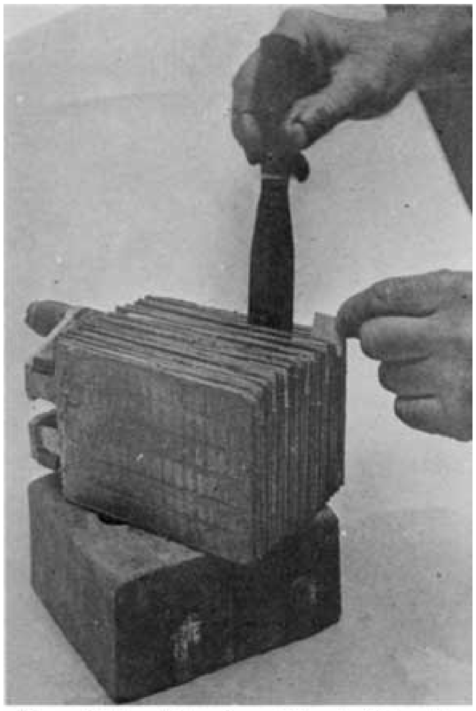


Fig. 216. Clearing Short Circuits

Charging

When you have in this way cleared all the "shorts" in the elements place the elements back in the jars in the same position as they were when you opened the battery, and add enough distilled water to the electrolyte to cover the plates to a depth of one-half inch.

If the negatives are badly sulphated (active material very hard), they will charge more quickly if all the old electrolyte is dumped out and the cells filled with distilled water before putting the battery on charge. This "water cure" is the best for sulphated negatives and will save many plates that could otherwise not be used again. Make it a rule to replace the old electrolyte with distilled water if negatives are sulphated.

The next operation is to put the battery on charge. Grasp each post in the jaws of a pair of gas pliers and work the pliers back and forth, Fig. 217, so as to remove the scale and allow the connecting straps to make good contact. Now take a knife and cut off the rough edges left in the connecting straps by the drill. Taper the edge, if necessary to go on post. Turn the connectors upside down and pound gently in position, Fig. 218, to make a good connection. Temporary charging connections may also be made by burning lead strips on the posts. This being properly done, the battery is ready for charging. Check up the connections to be sure they are correct.

Now put the battery on charge, and charge at a low rate. Do not allow the temperature of any cell to rise above 110°F. Continue the charge until the electrolyte clears up, and its specific gravity stops rising and the plates have a normal color' over their entire surface. Fully charged positive plates have a chocolate brown color, and fully charged negative plates have a dark gray color. By holding an electric light directly over a cell, and looking down, the color of both negatives and positives may be determined. Do not take the battery off charge until you have obtained these results, although it may be necessary to continue the charge for two, three, four, or five days. In this preliminary charge it is not necessary to bring the gravity up to 1.280, because the electrolyte is not to be used again, and the plates will become charged completely, regardless of what the gravity is. The essential thing is to charge until the electrolyte becomes perfectly clear, the gravity stops rising, and the plates have the right color. The Cadmium test may be used here to determine when the plates are charged. If the gravity rises above 1.280 during the preliminary charge, adjust it to 1.280 by drawing out some of the electrolyte and adding distilled water. **The battery must stay on charge** until you have the desired conditions. If one cell does not charge,--that is, if its specific gravity does not rise,--you have probably not freed all the shorts, and must take the element out of the jar again and carefully inspect it for more shorts.

Right here is where one of the most important questions may be asked about rebuilding batteries. Why must you free the shorts and put the battery on charge? Why not save time by putting in all new separators, sealing the battery, burning on the cell connectors, and then putting it on charge? If you have ever treated a battery in this way, what results did you get? Why did you have a badly unbalanced gravity of electrolyte? How could you know what specific gravity electrolyte to put in each cell? Perhaps one was charged, one only half charged, and the other dead. Suppose the dead cell had impurities in it. How could you get rid of them? Suppose the battery showed poor capacity on test, what would you do?

Washing and Pressing the Negatives

To continue the actual work on the battery. The battery being fully charged,--the electrolyte clear, the plates of normal color, the specific gravity no longer rising,--remove it from the charging bench and put it on the work bench. Draw each element and let drain as in Fig. 197.

Here again the labeled boxes described on page 183 come in handy. Separate one group, remove the separators, and put one group in each end of box to keep clean. Separate another group, And nest the plates, Fig. 219, the negative with the negative, and positive with positive. Separate the third element and put groups in the boxes. Pour the old electrolyte out of the jars, and wash out the jars as described on page 360. You now have the plates in the best possible shape for handling. 'Fake the boxes containing the plates to the sink. Have the plate press and the plate press boards ready for use.

If, for any reason, you are called away from your work at this point to be gone for five minutes, do not leave the fully charged negatives exposed to the air, as they will become very hot. Cover them with water. A one-gallon stone or earthenware jar will hold the negative plates of a 100 ampere hour battery if you nest two of the groups. You may also put negatives back in jars from which they were taken, and fill with water.

Now hold a negative group under the faucet, and let a strong stream of water run down over each plate so as to wash it thoroughly, and to remove any foreign matter from the plate surfaces. All negative groups must be handled in exactly the same way so as to get the same results in each case.

After you have washed the first group, place it on edge on a clean board with the post down and pointing away from you, and the bottom of the group toward you. Now insert plate press boards which are slightly larger than the plates, and of the exact thickness required to fill the spaces between plates, Fig. 113. For the standard 1/8 inch plates, a 5-16 inch board, or two 1/8 inch boards should be placed between plates.

The 1/8 inch boards are actually more than 1/8 inch thick, and will give the proper spacing. For thin plates, use 1/4 inch boards. Do not push the plate press boards more than 1/8 inch above the tops of the plates, and be sure that the boards cover the entire plates. Put a board on the outside of each end plate of the group. In this way insert the plate press boards in each of the three negative groups.

Then place each negative group on the lower jaw of the plate press with the post of each group pointing toward you. Three groups may be pressed at one time. Bring the top edges of the transite boards flush with the front edge of the lower jaw of the press, so that no pressure will be applied to the plate lugs. See Fig. 114. Pressure applied to the plate lugs will break them off.

Now screw down the upper jaw of the press as tightly as you can with the handwheel, so as to put as much pressure on the plates as possible. Leave the plates in the press for about five minutes. Then remove them from the press, take out the boards, and replace the plates in the battery jar from which they were removed, and cover with water. They may also be placed in a stone or earthernware jar and covered with water, especially if there is any work to be done on the jars or case of the battery. If the spongy lead of the negatives is firm, they may be reassembled in the battery as soon as they have been pressed. If, however, the spongy lead is soft and mushy, keep the negatives covered with water for 12 to 24 hours. This will make them hard and firm. Then remove them from the water and dry them in the air. In drying, the plates will become heated and will steam. As soon as you notice any steaming, dip the plates in water until they are cool. Then remove them from the water and continue the drying process. Each time the negatives begin to steam as they dry in the air, dip them in the water until they are cool.

When the negatives are dry, they are ready to be reassembled in the battery and prepared for service. Negatives treated in this way will give good service for a much longer time than they would if not treated in this way. The spongy lead has been made firm and elastic. If you have other negatives in your shop which are not in use, treat them in the same way and put them away for future use, to use as rental batteries. Always put them through the same process:

1. Charge them fully.

2. Press them in the plate press to force the spongy lead back into the grids.

3. Soak them in water, if the spongy lead is soft and mushy, for 12 to 24 hours, or even longer until the spongy lead is firm. Dry them in the air, dipping them in water whenever they begin to steam and become heated. This -will give you negatives that will give excellent service and have a long life. Many negatives treated in this way will be good for fifteen months to two years of additional service. The rental batteries should be assembled in the same way as those you are rebuilding for the owners.

The importance of pressing negatives cannot be exaggerated. Always press the negatives of the batteries which you rebuild. Do not do it to half, or three-fourths of the negatives, but to all of them. The work takes but a few minutes, and the time could not be put to better advantage. The spongy lead of the negatives swells and bulges out and makes very poor contact with the grids as a battery become,, discharged. This results in a loss of capacity, gradual sulphation of the loose active material, corrosion of the grids, failure of the gravity to rise high enough on charge, overheating of the battery on charge, gassing before the sulphate is reduced to active material with breaking off and roughening of the active material, and makes the battery lazy and sluggish in action. The spongy lead must make good contact with the grids if the battery is to have a long life and give good service.

No amount of charging will cure a negative with bulged, swollen active material. Once this material becomes bulged nothing but pressing will put it back where it belongs, and until it is pressed back into the grids the plates are in a poor condition for service. Even if the bulging is but very slight, the plates must be pressed.

Washing Positives

If you intend to use some of the positives, they should now be washed. If you intend to use all new positives, throw away the old ones, of course. The positives should not be held under the faucet as the negatives were, because the stream of water will wash out much of the positive active material. Rinse the positives a number of times in a jar of clean water by moving them up and down in the water. This will remove impurities from the surfaces of the plates and wash off any foreign or loose materials. After rinsing each positive group, replace it in the box.

Never attempt to straighten badly buckled positives, as the bending cannot be done successfully, and the active material will not have good contact with the grids. Positives cannot be pressed as negatives can, because the positive active material lacks the elasticity and toughness of the negative spongy lead. Slightly buckled positives may sometimes be straightened by bending them lightly all around the edges with a pair of thin, wide nosed pliers. This should be (lone very carefully, however, and the straightening done. gradually. If the plates cannot be straightened in this way and the separators do not lie perfectly flat against them without pinching at the corners, the plates should be discarded, and new ones used in their place.

Burning on Plates

When you put new plates into a battery, or find some of the plates broken from the connecting strap, it will be necessary to burn the plates to the strap. Frequently you will find plates which are otherwise in a good condition broken from the connecting straps. This is most likely to happen when the plates have been cast on to the connecting strap instead of being burned on. These plates must be burned on.

New plates are frequently necessary. From pages 339 to 346 you see that new plates are required under the following conditions:

(a) Positives. Ruined by freezing; weak and brittle from age, large part of active material shed; badly buckled; rotten and disintegrated by impurities; reversed. Positives in a reasonably good mechanical condition can be restored to a good electrical condition by charging.

(b) Negatives. Active material granulated, bulged and disintegrated; charged while dry; positives disintegrated by impurities; ruined by overcharging; badly sulphated because allowed to stand idle, or used while discharged; much active material lost, and that which is left soft and mushy; negatives reversed by charging battery backwards.

When making plate renewals, never install plates of different design in the same group. Always use plates of the type intended for the battery. The battery should first be fully charged, as already explained. If all the plates in a group are to be discarded, clamp the post in a vise, being careful not to crack the hard rubber shell if one is on it, or to damage the threads on Posts such as the Exide or to draw up the vise so tightly as to crush the post. Then saw off all the old plates with a new coarse toothed hacksaw, a sharp key hole saw, or any good saw which has a wide set, close to the post. This separates the entire group of plates from the post in one short operation. This method is much better than the one of sawing the plates off below the connecting strap, and sawing or punching the old plate ends out of the strap.

Work on the Jars

The work on the jars consists of removing any sediment which may have collected, washing out all dirt, and replacing leaky jars. The removal of sediment and washing should be done after the preliminary charge has been given and the old electrolyte poured out unless the preliminary charge was given with distilled water in the jars. The old electrolyte need not be poured down the sewer, but may be kept in stone or earthenware jars and used later in making electrical tests to locate leaky jars.

Testing Jars

Remove all sealing compound from the jar by means of a hot putty knife, finishing by wiping with a gasoline soaked rag. Inspect each jar carefully under a strong light for cracks and leaks. If you know which jar is leaky by having filled each cell with water up to the correct level, when you made the first examination of the battery, and then having it allowed to stand over night to see if the electrolyte in any cell has dropped below the tops of the plates, no tests are necessary, but if you are in doubt as to which jar, if any, is leaky, you must make tests to determine which jar is leaky. If you know that there is no leaky jar, because of the bottom of the case not being acid eaten and rotted, it is, of course, not necessary to test the jars.

Removing Defective Jars

The method of removing the jars from the case depends on the battery. In some batteries the jars are set in sealing compound. To remove a jar from such a battery, put the steam hose from your steamer outfit into the jar, cover up the top of the jar with rags, and steam the jar for about five minutes. Another way is to fill the jar with boiling hot water and let it stand for fully five minutes. Either of these methods will soften the sealing compound around the jar so that the jar may be pulled out. To remove the jar, grasp two sides of the jar with two pairs of long, flat nosed pliers and pull straight up with an even, steady pull.

Some batteries do not use sealing compound around the jars, but simply use thin wooden wedges to hold the jars in place, or have bolts running through opposite faces of the case by means of which the sides are pressed against the jars to hold them in place. The jars of such batteries may be removed without heating, by removing the wedges or loosening the bolts, as the case may be, and lifting out the jars with pliers, as before. New jars should be steamed for several minutes before being put in the case. When you put jars into such batteries, do not apply too much pressure to them, as they may be cracked by the pressure, or the jar may be squeezed out of shape, and the assembling process made difficult.

Repairing the Case

If the case is rotten at top, patch it with good wood. If the top and bottom are so rotten that considerable time will be required to repair it, advise the owner to buy a new case. Sometimes the top of the case can be greatly improved by straightening the side edges with a small smoothing plane, and' sometimes a 1/2 inch strip or more fitted all along the edge is necessary for a good job. Handles that have been pulled, rotted, or corroded off make disagreeable repair jobs, but a satisfactory job can be done unless the end of the case has been pulled off' or rotted. Sometimes the handle will hold in place until the battery is worn out by old age if three or four extra holes are bored and countersunk in the handle where the wood is solid, and common wood screws, size 12, 1/2 or 5/8 inch long used to fasten the handle in place. Sometimes it will be necessary to put in one half of a new end, the handle being fastened to the new piece with brass bolts and nuts before it is put into place. Sometimes you can do a good job by using a plate of sheet iron 1-16 inch thick, and 4 inches wide, and as long as the end of the case is wide. Rivet the handle to this plate with stovepipe, or copper rivets, and then fasten the plate to the case with No. 12 wood screws, 1/2 inch long.

If the old case is good enough to use again, soak it for several hours in a solution of baking soda in water to neutralize any acid which may have been spilled on it, or which may be spilled on it later. After soaking the case, rinse it in water, and allow it to dry thoroughly. Then paint the case carefully with asphaltum paint.

REASSEMBLING THE BATTERY

Reassembling the Elements

Take a negative group and put it on edge on a board, with post away from you, and lower edge toward you. Mesh a positive in the negative group. The groups are now ready for the separators. Take six moist separators from your stock. Slip one into position from the bottom in the middle of the group, with the grooved side toward the positive plate, spreading the plates slightly if necessary. Take another separator, slip it into position on the opposite side of the positive against which your first separator was placed. In this way, put in the six separators, with the grooved side toward the positives, working outward in both directions from the center, Fig. 225. The grooves must, of course, extend from the top to the bottom of the plate. Now grasp the element in both hands, and set it right side up on the block, giving it a slight jar to bring the bottoms of the plates and separators on a level.

Fig. 225. Inserting Separators

Now grasp the element in both hands, and set it right side up on the block, giving it a slight jar to bring the bottoms of the plates and separators on a level.

Next take a cover, and try it on the posts, Fig. 226. Pull the groups apart slightly, if necessary, before inserting any more separators, so that the cover fits exactly over the posts, Fig. 227. See that the separators extend the same distance beyond each side of the plates. You may take a stick, about 10 inches long, 1 1/2 inches wide, and 7/8 inch thick, and tap the separators gently to even them up. A small wood plane may be used to even up the side edges of wood separators. If you put in too many separators before trying on the cover, the plates may become so tight that you may not be able to shift them to make the cover fit the posts or you may not be able to shift the separators to their proper positions. It is therefore best to Put in only enough separators to hold the groups together and so they can be handled and yet remain in their proper position when set up on the block. Without separators, the posts will not remain in position.

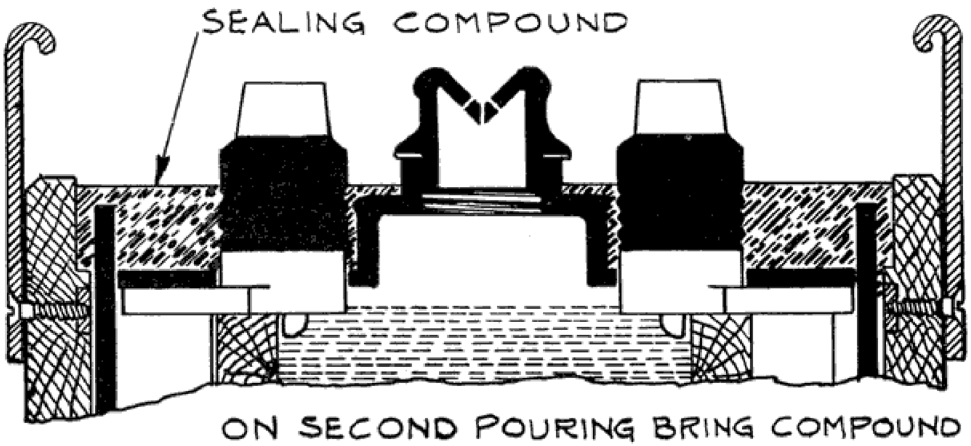
With the element reassembled, and the remaining separators in their proper positions, see that all the plates are level on bottom, and no foreign matter sticking to them. Place the element in box shown in Fig. 219 to keep clean. Reassemble the other elements in exactly the same way, and put them in the box. The elements are now ready to be put in the jars.

Use 1.400 Acid

If you have followed the directions carefully, and have therefore freed all the shorts, have thoroughly charged the plates, have washed and pressed the negative groups, have washed the positives, have then added any new plates which were needed, and have put in new separators, use 1.400 specific gravity electrolyte. This is necessary because washing the plates removed some of the acid, and the new separators will absorb enough acid so that the specific gravity after charging will be about 1.280.

The final specific gravity must be between 1.280 and 1.300. In measuring the specific gravity the temperature must be about 70°F., or else corrections must be made. For every three degrees above 70°, add one point (.001) to the reading you obtain on the hydrometer. For every three degrees under 70°, subtract one point (.001) from the reading you obtain on the hydrometer. For instance, if you read a specific gravity of 1.275 and find that the temperature of the electrolyte is 82°F., add ((82-70)/3 = 4) four points (1.275 + .004), which gives 1.279, which is what the specific gravity of the electrolyte would be if its temperature were lowered to 70°. The reason this is done is that when Ave speak of an electrolyte of a certain specific gravity, say 1.280, we mean that this is its specific gravity when its temperature is 70°F. We must therefore make the temperature correction if the temperature of the electrolyte is much higher or lower than 70°F.

Sealing compound



ON SECOND POURING BRING COMPOUND WITH 1/16 INCH OF TOP OF CASE.

Fig. 232

Fill the pouring ladle with compound, which is thinner than that used in the first pouring, and pour within 1/16 inch of the top of the case, being careful to get in just enough, so that-after it has cooled, the covers will press down exactly even with the top of the case, Fig. 232. It will require some experience to do this, but you will soon learn just how much to use.

As soon as you have finished pouring, run the flame all around the edges of the case and around the post, being very careful not to injure any of the vent tubes. A small, hot-pointed flame should be used. Now turn on the fan again to cool the compound.

While the compound is cooling, get the cell connectors and terminal connectors, put them in a two-quart granite stew pan, just barely cover with water, and sprinkle a tablespoon of baking soda over them. Set the stew pan over the fire and bring water to boiling point. Then pour the water on some spot on a bench or floor where the acid has been spilled. This helps to neutralize the acid and keep it from injuring the wood or cement. Rinse off the connectors and wipe them dry with a cloth, or heat them to dry them.

Now take the top covers, which must be absolutely clean and dry, and spread a thin coat of vaseline over the top only, wiping off any vaseline from the beveled edges. Place these covers right side up on a clean board and heat perfectly limp with a large, spreading blow torch flame. Never apply this flame to the under side of the top covers. The purpose is to get the covers on top of the battery absolutely level, and exactly even with the top of the case all around it, and to have them sticking firmly to the compound. There is not an operation in repairing and rebuilding batteries that requires greater care than this one, that will show as clearly just what kind of a workman you are, or will count as much in appearance for a finished job. If you are careless with any of the detail, if just one bump appears on top, if one top is warped, if one cover sticks above top of case, try as you may, you never can cover it up, and show you are a first-class workman. See that you have these four conditions, and you should not have any difficulty after a little experience:

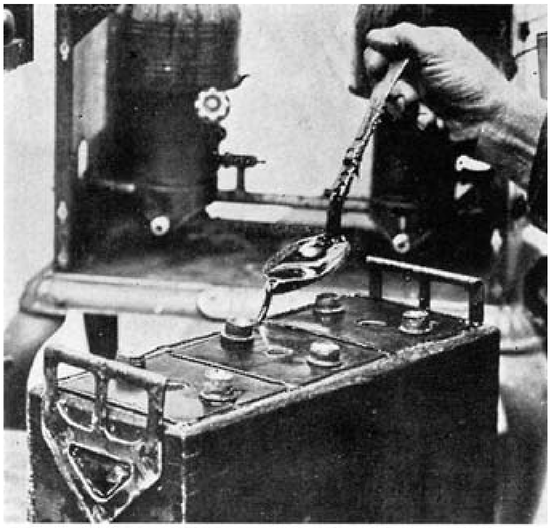


Fig. 236. Filling Cracks Around Covers With Sealing Compound

When you have removed the excess compound from the cracks around the edges of the covers with the screwdriver, take a large iron spoon which has the end bent into a pouring lip, and dip up from 1/2 to 2/3 of a spoonful of melted compound (not too hot). Wipe off the bottom of the spoon, Fig. 235, and pour a small stream of compound evenly in all the cracks around the edges of the covers until they are full, as in Fig. 236. Do not hold the spoon too high, and do not smear or drop any compound on top of battery or on the posts. No harm is done if a little runs over the outside of the case, except that it requires a little time to clean it off. A small teapot may be used instead of the spoon. If you have the compound at the right temperature, and do not put in too much at a time, you will obtain good results, but you should take care not to spill the compound over covers or case. Some workmen pour hot compound clear to the top of the case and then hurry to put on a cold, dirty top. What happens? The underside of the cover, coming in contact with the hot compound, expands and lengthens out, curling the top surface beyond redemption. As you push down one corner, another goes up, and it is impossible to make the covers level.

Burning-on the Cell Connectors

With the covers in place, the next operation is to burn in the cell connectors. Directions for doing this are given on page 213. If you did not fill the jars with electrolyte before sealing the covers, do so. now. See page 364.

Marking the Battery

You should have a set of stencil letters and mark every battery you rebuild or repair. Stamp "POS," "P," or "+" on positive terminal and "NEG," "N," or on negative terminal.

To go one step farther, keep a record of condition of plates, and number of new plates, if you have used any. Grade the plates in three divisions, good, medium and doubtful. The "doubtful" division will grow smaller as you become experienced and learn by their appearance the ones to be discarded and not used in a rebuilt battery.

Cleaning and Painting the Case

The next operation is to thoroughly clean the case; scrape off all compound that has been spilled on it, and also any grease or dirt. If any grease is on the case, wipe off with rag soaked in gasoline. Unless the case is clean, the paint will not dry. Brush the sides and end with a wire brush; also brighten the name plate. Then coat the case with good asphaltum paint. Any good turpentine asphaltum is excellent for this purpose. If it is too thick, thin it with turpentine, but be sure to mix well before using, as it does not mix readily. Paint will soak in around the edge on top of an old case more easily than on the body of the case as it is more porous.

Charging the Rebuilt Battery

With the battery completely assembled, the next step is to charge it at about one-third of the starting or normal charge rate. For batteries having a capacity of 80 ampere hours or more, use a current of 5 amperes. Do not start the charge until at least 12 hours after filling with electrolyte. This allows the electrolyte to cool. Then add water to bring electrolyte up to correct level if necessary. The specific gravity will probably at first drop to 1.220-1.240, and will then begin to rise.

Continue the charge until the specific gravity and voltage do not rise during the last 5 hours of the charge. The cell voltage at the end of the charge should be 2.5 to 2.7, measured while the battery is still on charge. Make Cadmium tests on both positive and negatives. The positives should give a Cadmium reading of 2.4 or more. The negatives should give a reversed reading of 0.175. The tests should be made near the end of the charge, with the cell voltages at about 2.7. The Cadmium readings will tell the condition of the plates better than specific gravity readings. The Cadmium readings are especially valuable when new plates have been installed, to determine whether the new plates are, fully charged. When Cadmium readings indicate that the plates are fully charged, and specific gravity readings have not changed for five hours, the battery is fully charged. If you have put in new plates, charge for at least 96 hours.

Measure the temperature of the electrolyte occasionally, and if it should go above 110°F., either cut down the charging current, or take the battery off charge long enough to allow the electrolyte to cool below 90°F.

Adjusting the Electrolyte

If the specific gravity of the electrolyte is 1.280 to 1.300 at the end of the charge, the battery is ready for testing. If the specific gravity is below or above these figures, draw off as much electrolyte as you can with the hydrometer. If the specific gravity is below 1.280, add enough 1.400 specific gravity electrolyte with the hydrometer to bring the level up to the correct height (about 1/2 inch above tops of plates). If the specific gravity is above 1.300, add a-similar amount of distilled water instead of electrolyte. If the specific gravity is not more than 15 points (.015) too low or too high, adjust as directed above. If the variation is greater than this, pour out all the electrolyte and add fresh 1.280 specific gravity electrolyte.

After adjusting the electrolyte, continue the charge until the gravity of all cells is 1.280-1.300, and there is no further change in gravity for at least two hours. Then take the battery off charge and make a final measurement of the specific gravity. Measure the temperature at the same time, and if it varies more than 10° above or below 70°, correct the hydrometer readings by adding one point (.001 sp. gr.) for each 3 degrees above 70°, and subtracting one point (.001 sp. gr.) for each 3 degrees below 70°. Be sure to wipe off any electrolyte which you spilled on the battery in adjusting the electrolyte or measuring the specific gravity. Use a rag dipped in ammonia, or baking soda solution.

High Rate Discharge Test

Whenever you have time to do so, make a 20-minute high rate discharge test on the rebuilt battery, as described on page 266. This test will show up any defect in the battery, such as a poorly burned joint, or a missing separator, and will show if battery is low in capacity. If the test gives satisfactory results, the battery is in good condition, and ready to be put into service, after being charged again to replace the energy used by the test.

Chousing a battery for Storage and Survival

In general battery types run (from cheapest to most expensive): generic golf car (such as those sold at Sam's Club or Costco), "regular" deep cycle, such as the Trojan's, heavy duty or premium deep cycle, such as the Rolls-Surrette, and then the sealed AGM by Concorde and the industrial batteries, such as the Crown forklift batteries.

Generic golf car batteries can be expected to last 3 to 5 years, Trojan and similar types around 4 to 6 years, Surrette (depending on type) 8 to 20 years, and industrial 15 to 25 years. AGM's will generally go for 5 to 8 years. There are pro's and con's to both sides - if you are only going to survive the long term then get the 20 year batteries.

11-Lead-Acid Batteries

(11/3/2008)

The best and/or cheapest battery in the world is not much good if it so heavy that you cannot move it. While the industrial batteries, such as the Crown are the heaviest duty batteries, they are also the heaviest - some can weigh as much as 2,000 pounds for a 12-volt pack. On the other hand you don't want to end up with 50 or 60 small batteries that are a nightmare to wire up and keep maintained. A good rule is to try to use a total number of batteries between no more than 8 to 12 at a time. If you need more capacity, get bigger batteries, not more small ones. Keep backups in storage checking the voltage regularly.

Sealed batteries, such as the Concorde, make sense in some applications - but not all. Sealed (AGM) batteries are generally 2 to 3 times as expensive as flooded, and the cycle lifetime is usually similar.

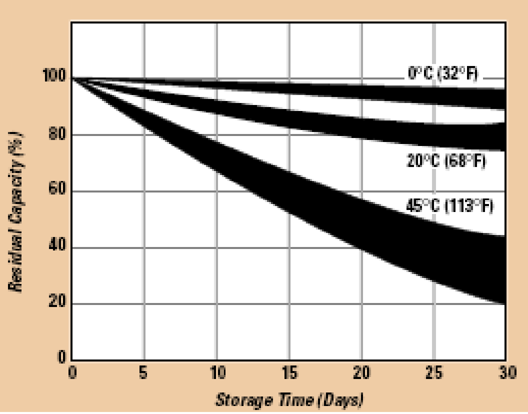
A rough rule often quoted, the total battery capacity (in amp-hours) should be three to five times your daily usage. 3 days is usually sufficient in most of the sunbelt states, 4 in most of the Midwest, in the East and Northwest, 4 to 5 days is better.

In a survival situation it’s the energy you can produce to charge the batteries that determines size. Don’t get batteries bigger than you can charge in one to two weeks of non-use. You can always use more power than you can charge.

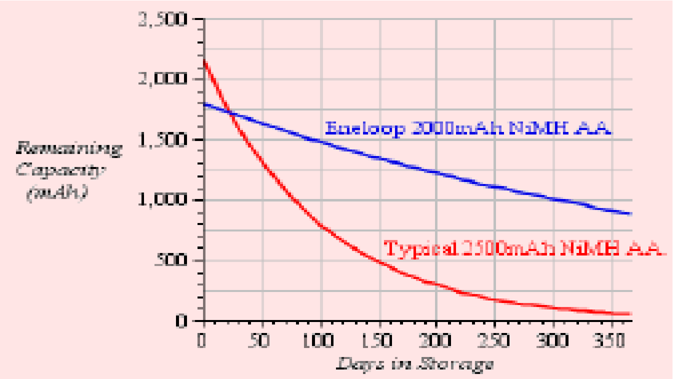
*www.krnida.biz/acs/word_files/Choosing_a_Deep_Cycle_**Battery**.doc*

Appendix

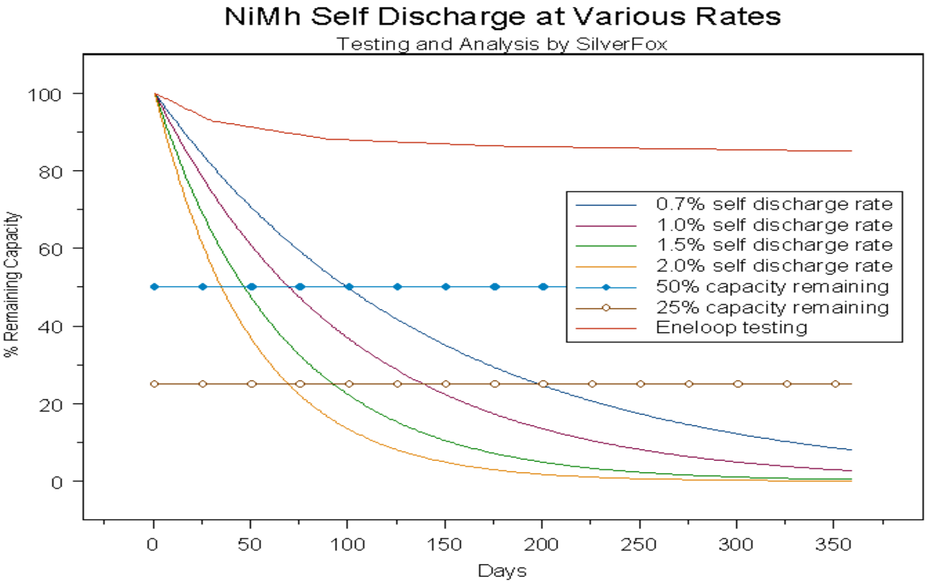
NiMH batteries Temperature and Capacity in Storage.



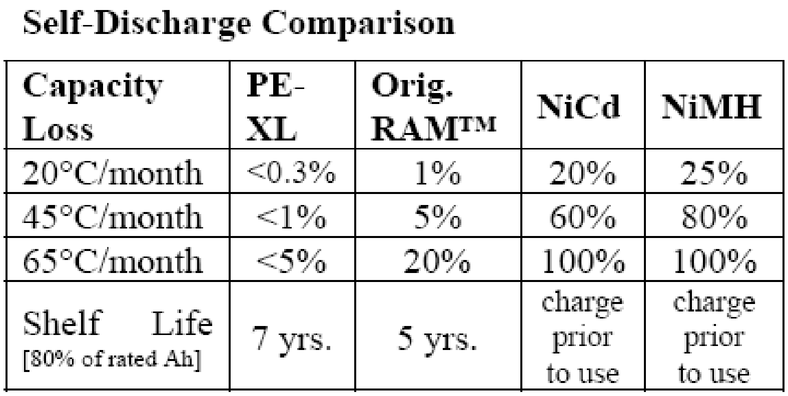
NiMH Low Self-Discharge batteries are worth the price over older types.



Although these cells start out with about 20% more capacity than the Eneloops, they lose their capacity more quickly. After only three weeks of storage, the Eneloops have more capacity remaining. After about 3½ months, the Eneloops will have twice the capacity of the traditional cells.



Appendix



Self-Discharge Comparison

Capacity Loss	PE-XL	Orig. RAM™	NiCd	NiMH
20°C/month	<0.3%	1%	20%	25%
45°C/month	<1%	5%	60%	80%
65°C/month	<5%	20%	100%	100%
Shelf Life [80% of rated Ah]	7 yrs.	5 yrs.	charge prior to use	charge prior to use

Recharging				
Type	Cycles (to 80%)	Charge time	Discharge per month	Cost per kWh
Alkaline	50 (50%)	3-10h	0.30%	$95.00
NiCd	1500	1h	20%	$7.50
NiMH	300-500	2-4h	30%	$18.50
Li-ion	500-1000	2-4h	10%	$24.00
Polymer	300-500	2-4h	10%	
Lead acid	200-2000	8-16h	5%	$8.50

Battery History

1800	Voltaic pile: silver zinc
1836	Daniell cell: copper zinc
1859	Planté: rechargeable lead-acid cell
1868	Leclanché: carbon zinc wet cell
1888	Gassner: carbon zinc dry cell
1898	Commercial flashlight, D cell
1899	Junger: nickel cadmium cell
1946	Neumann: sealed NiCd
1960s	Alkaline, rechargeable NiCd
1970s	Lithium, sealed lead acid
1990	Nickel metal hydride (NiMH)
1991	Lithium ion
1992	Rechargeable alkaline (RAM)
1999	Lithium ion polymer
2005	Low Self-Discharge (NiMH)

Appendix

Use this table to help build Home Made batteries. The difference between the voltages for two chosen electrodes will give the expected voltage of the battery under ideal conditions.

Metals and Soils

Potential Differences of metals
(Soil Galvanic series)

Metal ...	Potential V Cu/CuSO4 electrode
Magnesium (pure)	-1.75
Magnesium (alloy)	-1.60
Zinc	-1.10
Aluminum (alloy)	-1.05
Aluminum (pure)	-0.8
Steel (clean)	-0.50 to -0.80
Steel (rusted)	-0.20 to -0.50
Cast Iron	-0.50
Lead	-0.50
Steel (concrete)	-0.20
Copper	-0.20
Brass	-0.20
Bronze	-0.20
Steel (mill scale)	-0.20
Cast iron (high silicon)	-0.20
Carbon	+0.30
Graphite	+0.30
Coke	+0.30

Notes: Non-uniform conditions at node surface results in different voltages

Ref.: Engineering Tutorials: Potential of Metals in Soils

The following table gives the results of three different ways of comparing manufactures of NiMH batteries.

Appendix

Sorted by Brand Name				Sorted by highest measured mAh				Sorted by % off from printed mAh			
Brand Name	Printed on the cell mAh	Measured mAh	% off	Brand Name	Printed on the cell mAh	Measured mAh	% off	Brand Name	Printed on the cell mAh	Measured mAh	% off
AccuPower	2600	2316	10.92	Sanyo	2700	2569	4.85	Ray O Vac IC3	1800	1807	-0.39
AccuPower	2900	2413	16.79	Duracell	2650	2440	7.92	Titanium	2000	2002	-0.10
Ansmann	2300	2188	4.87	AccuPower	2900	2413	16.79	Titanium Power Max	1800	1797	0.17
Brody Energizer	2300	2159	6.13	Sanyo Industrial	2500	2350	6.00	CBP	1650	1630	1.21
CBP	1650	1630	1.21	Titanium	2700	2328	13.78	Radio Shack	1500	1459	2.73
DigitalConcepts	2500	1878	24.88	Powerex	2500	2316	7.36	GP	1800	1747	2.94
Duracell	2300	2000	13.04	Titanium	2600	2313	11.04	Sanyo	2700	2569	4.85
Duracell	2400	2169	9.63	AccuPower	2600	2316	10.92	Ansmann	2300	2188	4.87
Duracell	2650	2440	7.92	Jet Cell	2400	2283	4.88	Jet Cell	2400	2283	4.88
Energizer	2100	1994	5.05	Energizer	2500	2230	10.80	Energizer	2100	1994	5.05
Energizer	2300	1990	13.48	Duracell	2400	2169	9.63	Sanyo Industrial	2500	2350	6.00
Energizer	2500	2230	10.80	Ansmann	2300	2188	4.87	Sanyo	2300	2159	6.13
GP	1800	1747	2.94	Titanium	2400	2125	11.46	Brody Energizer	2300	2159	6.13
Green Sleeve	1400	1289	7.93	Sanyo	2300	2159	6.13	Sanyo Eneloop	2000	1871	6.45
Jet Cell	2400	2283	4.88	SupremePower	2300	2132	7.30	Kodak	1700	1585	6.76
Kodak	1700	1585	6.76	Vapextech	2500	2195	12.20	SupremePower	2300	2132	7.30
La Crosse	2000	1561	21.95	Brody Energizer	2300	2159	6.13	Powerex	2500	2316	7.36
Powerex	2300	1616	29.74	Sony	2300	2068	10.09	Ray O Vac IC3	2000	1842	7.90
Powerex	2500	2316	7.36	Titanium	2000	2002	-0.10	Duracell	2650	2440	7.92
Quest	2300	1566	31.91	X1	2400	2013	16.13	Green Sleeve	1400	1289	7.93
Radio Shack	1500	1459	2.73	Duracell	2300	2000	13.04	Duracell	2400	2169	9.63
Ray O Vac IC3	1800	1807	-0.39	Energizer	2100	1994	5.05	Sony	2300	2068	10.09
Ray O Vac IC3	2000	1842	7.90	Sanyo Eneloop	2000	1871	6.45	Energizer	2500	2230	10.80
Sanyo	2300	2159	6.13	Ray O Vac IC3	2000	1842	7.90	AccuPower	2600	2316	10.92
Sanyo	2700	2569	4.85	Energizer	2300	1990	13.48	Titanium	2600	2313	11.04
Sanyo Eneloop	2000	1871	6.45	Titanium Power Max	1800	1797	0.17	Titanium	2400	2125	11.46
Sanyo Industrial	2500	2350	6.00	Ray O Vac IC3	1800	1807	-0.39	Vapextech	2500	2195	12.20
Sony	2300	2068	10.09	DigitalConcepts	2500	1878	24.88	Duracell	2300	2000	13.04
Sunpack	2300	1271	44.74	GP	1800	1747	2.94	Energizer	2300	1990	13.48
SupremePower	1800	1359	24.50	CBP	1650	1630	1.21	Titanium	2700	2328	13.78
SupremePower	2300	2132	7.30	Powerex	2300	1616	29.74	X1	2400	2013	16.13
Titanium	2000	2002	-0.10	Quest	2300	1566	31.91	AccuPower	2900	2413	16.79
Titanium	2400	2125	11.46	Kodak	1700	1585	6.76	La Crosse	2000	1561	21.95
Titanium	2600	2313	11.04	La Crosse	2000	1561	21.95	SupremePower	1800	1359	24.50
Titanium	2700	2328	13.78	SupremePower	1800	1359	24.50	DigitalConcepts	2500	1878	24.88
Titanium Power Max	1800	1797	0.17	Radio Shack	1500	1459	2.73	Powerex	2300	1616	29.74
Vapextech	2500	2195	12.20	Sunpack	2300	1271	44.74	Quest	2300	1566	31.91
X1	2400	2013	16.13	Green Sleeve	1400	1289	7.93	Sunpack	2300	1271	44.74
average =	2232	1974	11.14	average =	2232	1974	11.14	average =	2232	1974	11.14

Appendix

Household Battery Types Compared

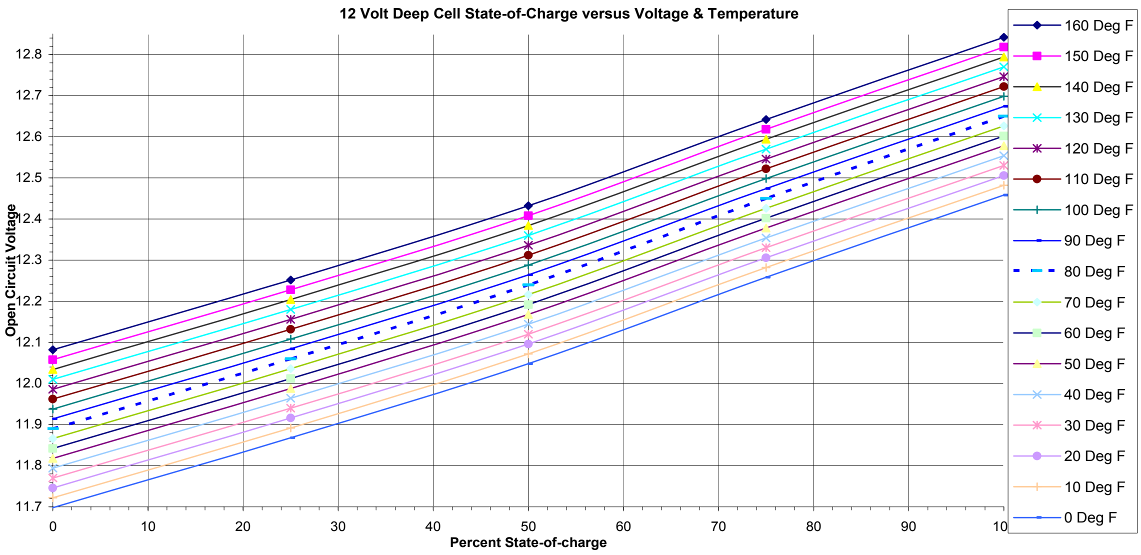
	Alkaline	Rechargeable Alkaline	Nickel-Metal Hydride (NiMH)	Nickel-Cadmium (NiCd)	Lithium	Carbon Zinc (General Purpose) Zinc Chloride (Heavy Duty)
Volts	1.5	1.5	1.2	1.2	1.75	1.5
Capacity	**High**	**High at first, but diminishes w/use**	**High**	Low	**High**	Low
Capacity in mAh (AA)	2400	2000 at first	1300-2500 depends on brand	600-1000 depends on brand	2100	500-1000
Capacity in mAh (D)	12,000	8000 at first	2200-11000 depends on brand	1800-4500 depends on brand	not available in this size	3000
Performance in hi-drain devices (e.g., digital cameras)	Standard: Poor Special: Good	Poor	**Good**	**Good**	**Good**	Poor
Rechargeable?	Not really	**Sort of***	**Yes** (but see note about C & D sizes)	**Yes** (but see note about C & D sizes)	No	No
Recharge cycles	??? I'm guessing <10	50-500 Accucell	100's of times	100's to 1000's of times	N/A	??? I'm guessing <10
Special Disposal Needs	**No**	**No**	**No**	Yes	Yes	**No**
Self-discharge rate	**Slow / up to 5 yrs. shelf**	**Slow**	Fast (30%/mo.)	Fast (10% in 1st 24hrs, then 10%/mo.)	**Very slow**	**Slow**
Memory effect	No	No	Sometimes	Sometimes	N/A	No

Key Voltage Ranges for six-cell lead-acid batteries

All voltages are at 20C, and must be adjusted for temperature changes. Float voltage recommendations vary, according to the manufacturers' recommendation. Precise (+/-0.05V) float voltage is critical to longevity; too low (sulfation) is almost as bad as too high (corrosion & electrolyte loss). Typically new lead-acid cells Low self-discharge at about 40% in one year. They have no memory effect. Should not be overheating during charging.

- Open-circuit (no load for 12 hours) at full charge: 12.6 - 12.8 V
- Open-circuit at full discharge: 11.8 - 12.0 V
- Loaded at full discharge: 10.5 V. (about 1.75 volts/cell)
- Continuous-preservation (float) charging: 13.8V for gelled electrolyte; 13.5V for AGM (Absorbed Glass Mat) and 13.4V for flooded.
- Typical (daily) charging: 14.2 - 14.5 V (depending on manufacturer's recommendation).
- Equalization charging (for flooded lead acids): 15 - 16 V
- Gassing threshold: 14.4 V
- After full charge the terminal voltage will drop quickly to 13.2 V and then slowly to 12.6 V.

Appendix


12 Volt Deep Cell State-of-Charge versus Voltage & Temperature
Open Circuit Voltage
Percent State-of-charge
11.7
11.8
11.9
12.0
12.1
12.2
12.3
12.4
12.5
12.6
12.7
12.8
0
10
20
30
40
50
60
70
80
90
10
160 Deg F
150 Deg F
140 Deg F
130 Deg F
120 Deg F
110 Deg F
100 Deg F
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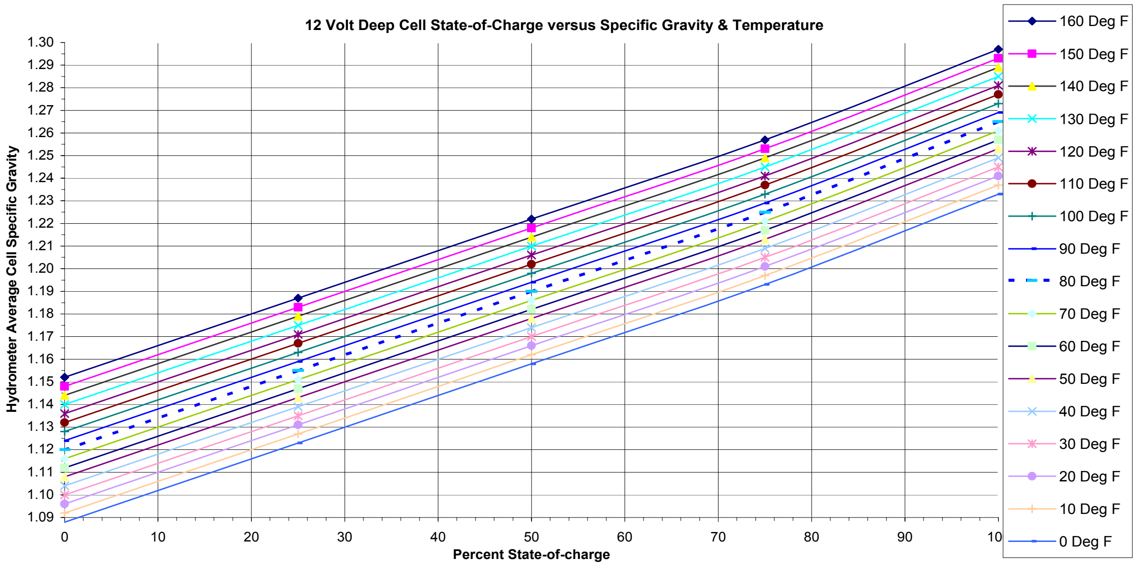
80 Deg F
70 Deg F
60 Deg F
50 Deg F
40 Deg F
30 Deg F
20 Deg F
10 Deg F
0 Deg F


12 Volt Deep Cell State-of-Charge versus Specific Gravity & Temperature
Hydrometer Average Cell Specific Gravity
Percent State-of-charge
1.09
1.10
1.11
1.12
1.13
1.14
1.15
1.16
1.17
1.18
1.19
1.20
1.21
1.22
1.23
1.24
1.25
1.26
1.27
1.28
1.29
1.30
0
10
20
30
40
50
60
70
80
90
10
160 Deg F
150 Deg F
140 Deg F
130 Deg F
120 Deg F
110 Deg F
100 Deg F
90 Deg F
80 Deg F
70 Deg F
60 Deg F
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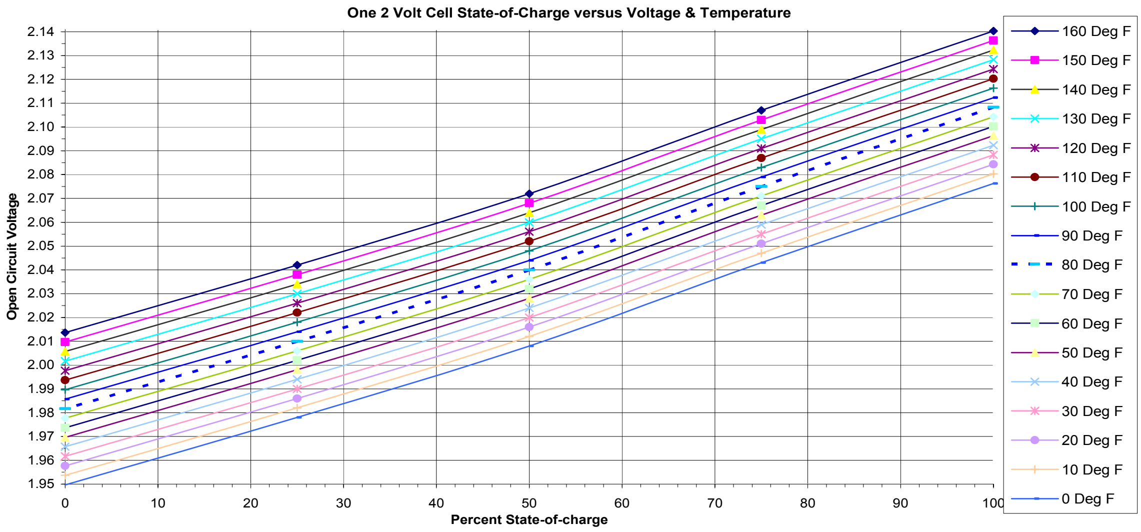
30 Deg F
20 Deg F
10 Deg F
0 Deg F


One 2 Volt Cell State-of-Charge versus Voltage & Temperature
Open Circuit Voltage
Percent State-of-charge
1.95
1.96
1.97
1.98
1.99
2.00
2.01
2.02
2.03
2.04
2.05
2.06
2.07
2.08
2.09
2.10
2.11
2.12
2.13
2.14
0
10
20
30
40
50
60
70
80
90
100
160 Deg F
150 Deg F
140 Deg F
130 Deg F
120 Deg F
110 Deg F
100 Deg F
90 Deg F
80 Deg F
70 Deg F
60 Deg F
50 Deg F
40 Deg F
30 Deg F
20 Deg F
10 Deg F
0 Deg F

Appendix

Measured voltages across a load "R" to determine State-of-Charge for Lead-Acid batteries

Lead Acid Gell Cell Discharge Voltages					
	75 deg F	Lead Acid 2.8 ah	Lead Acid 2.8 ah	Lead Acid 6V 2.8ah	Lead Acid 12V 2.8ah
No of Cells		1	1	3	6
R ohms/bat =		14.3	40	120	240
Discharge Hrs =		21.0	62.0	62.0	62.0
mAh =		2955	3137	3137	3137
ma avg =		140	51	51	51
Avg Volts =		2.019	2.031	6.092	12.185
Watt-hr =		5.97	6.37	19.11	38.22
Rechargeable times		650	650	650	650
Energy Cost Factor					
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	2.253	2.253	6.760	13.520
5	95	2.137	2.157	6.470	12.940
10	90	2.123	2.143	6.429	12.858
15	85	2.112	2.133	6.399	12.798
20	80	2.102	2.123	6.370	12.740
25	75	2.090	2.110	6.330	12.660
30	70	2.078	2.097	6.290	12.580
35	65	2.066	2.083	6.250	12.500
40	60	2.053	2.070	6.210	12.420
45	55	2.041	2.053	6.160	12.320
50	50	2.027	2.040	6.120	12.240
55	45	2.013	2.023	6.070	12.140
60	40	1.999	2.010	6.030	12.060
65	35	1.983	1.993	5.980	11.960
70	30	1.968	1.977	5.930	11.860
75	25	1.952	1.960	5.880	11.760
80	20	1.935	1.940	5.820	11.640
85	15	1.913	1.920	5.760	11.520
90	10	1.890	1.897	5.690	11.380
95	5	1.857	1.863	5.590	11.180
100	0	1.800	1.800	5.400	10.800

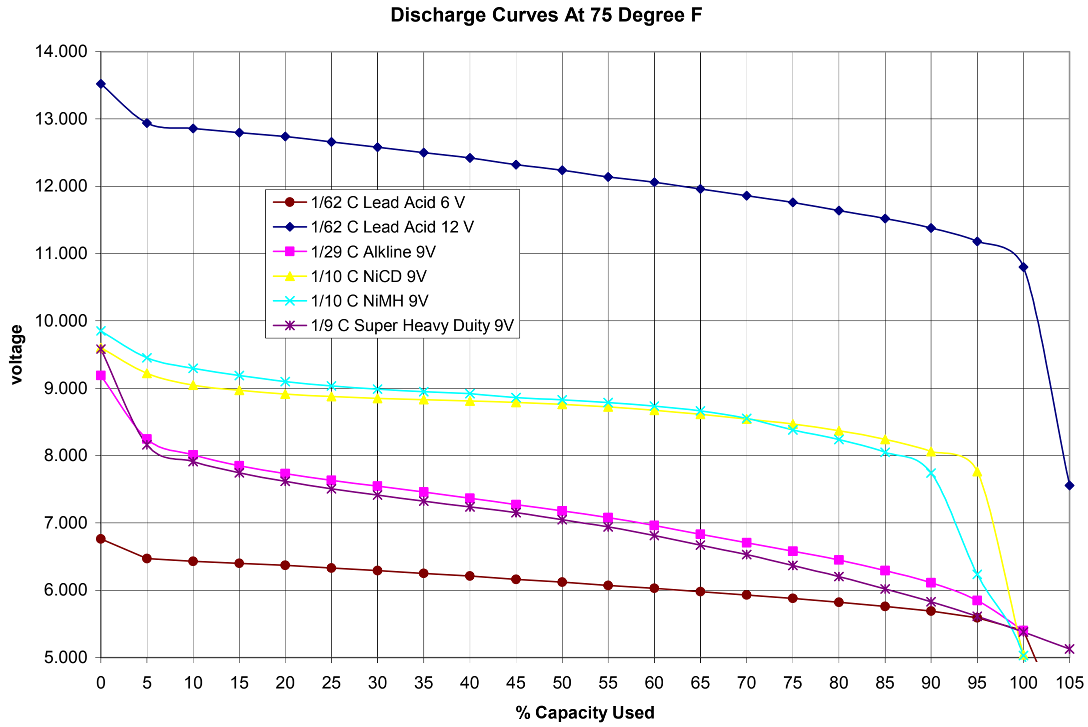
State-Charge measurements for 9 Volt Batteries

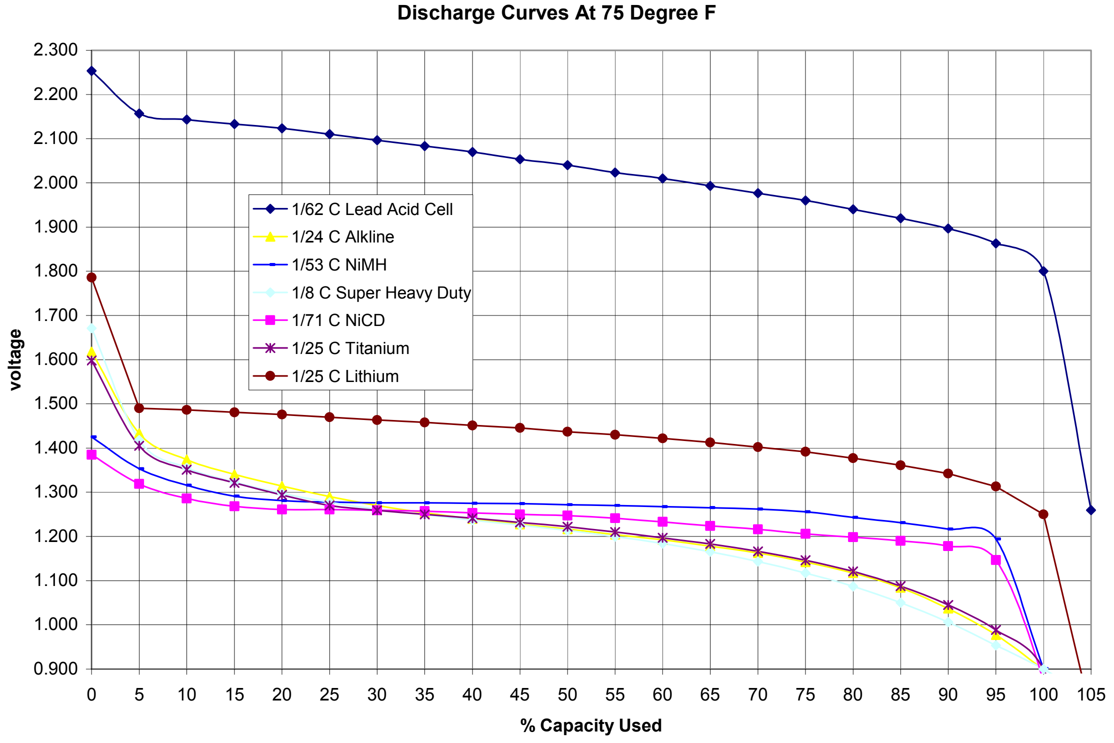
9 Volt Battery Discharge Voltages						
	75 deg F	NiCD 9V 100mah	NiMH 9V 180mah	Super Heavy Duty 9V	Alkaline 9V	Alkaline 9V
No of Cells		6	6	6	6	6

Appendix

R ohms/bat =		979	666	300	300	666
Discharge Hrs =		10.0	10.0	8.8	18.9	28.6
mAh =		88	133	203	465	302
ma avg =		9	13	23	25	11
Avg Volts =		8.531	8.518	7.002	7.434	7.130
Watt-hr =		0.75	1.13	1.42	3.46	2.15
Rechargeable times		2000	750	1	6	6
Energy Cost Factor		0.0115	0.0202	12.0862	0.8291	1.3310
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	9.600	9.850	9.580	9.370	9.190
5	95	9.221	9.450	8.160	8.465	8.246
10	90	9.046	9.295	7.912	8.202	8.010
15	85	8.971	9.189	7.742	8.029	7.850
20	80	8.914	9.100	7.617	7.887	7.730
25	75	8.878	9.034	7.506	7.769	7.631
30	70	8.850	8.986	7.414	7.670	7.545
35	65	8.830	8.950	7.321	7.587	7.457
40	60	8.810	8.920	7.238	7.517	7.366
45	55	8.790	8.860	7.153	7.455	7.271
50	50	8.760	8.827	7.047	7.395	7.180
55	45	8.721	8.787	6.939	7.328	7.080
60	40	8.672	8.735	6.812	7.260	6.960
65	35	8.613	8.663	6.671	7.195	6.832
70	30	8.542	8.551	6.528	7.115	6.704
75	25	8.470	8.380	6.367	7.030	6.580
80	20	8.369	8.237	6.204	6.930	6.450
85	15	8.241	8.049	6.017	6.830	6.290
90	10	8.059	7.742	5.828	6.696	6.110
95	5	7.763	6.236	5.612	6.533	5.846
100	0	5.040	5.030	5.380	5.845	5.400

Appendix





State-Charge measurements for AAA Size Batteries

AAA Size Cell Discharge Voltages

Appendix

	75 deg F	AAA-NiMH 750mah	AAA-NiMH 900mah	AAA-NiMH 900mah	AAA-Super Heavy Duty	AAA-Alkaline	AAA-Alkaline
No of Cells		1	1	1	1	1	1
R ohms/bat =		12	12	118	12	12	12
Discharge Hrs =		5.0	5.8	53.3	2.8	7.8	5.1
mAh =		505	593	561	263	759	477
ma avg =		102	103	11	95	97	94
Avg Volts =		1.220	1.225	1.258	1.159	1.184	1.142
Watt-hr =		0.62	0.73	0.71	0.30	0.90	0.54
Rechargeable times		750	750	750	1	6	6
Energy Cost Factor		0.0373	0.0316	0.0325	56.5128	3.1911	5.2634
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	1.341	1.359	1.425	1.639	1.516	1.460
5	95	1.280	1.292	1.353	1.367	1.352	1.321
10	90	1.262	1.268	1.316	1.299	1.310	1.285
15	85	1.254	1.257	1.291	1.275	1.281	1.258
20	80	1.250	1.252	1.281	1.248	1.259	1.221
25	75	1.247	1.250	1.278	1.231	1.240	1.201
30	70	1.246	1.249	1.276	1.212	1.226	1.183
35	65	1.244	1.248	1.276	1.201	1.213	1.169
40	60	1.243	1.246	1.275	1.187	1.202	1.156
45	55	1.241	1.245	1.274	1.174	1.191	1.145
50	50	1.239	1.243	1.272	1.163	1.181	1.133
55	45	1.236	1.241	1.270	1.148	1.170	1.122
60	40	1.234	1.239	1.267	1.126	1.159	1.110
65	35	1.231	1.236	1.265	1.105	1.148	1.098
70	30	1.227	1.232	1.262	1.081	1.136	1.085
75	25	1.221	1.227	1.256	1.060	1.123	1.070
80	20	1.214	1.221	1.243	1.030	1.105	1.055
85	15	1.205	1.212	1.231	0.995	1.085	1.036
90	10	1.189	1.202	1.217	0.964	1.058	1.014
95	5	1.115	1.188	1.194	0.936	1.015	0.979
100	0	0.894	0.811	0.901	0.900	0.899	0.887

State-Charge measurements for AA Size Rechargeable Batteries

AA Size Rechargeable Cell Discharge Voltages						
	75 deg F	AA-NiCD 700mah	AA-NiCD 700mah	AA-NiMH 2300mah	AA-NiMH-Hybrio-2100mah	AA-NiMH-Eneloop-2000mah
No of Cells		1	1	1	1	1
R ohms/bat =		43	118	12	118	118
Discharge Hrs =		22.8	71.0	16.6	184.9	182.5
mAh =		658	741	1734	1959	1946
ma avg =		29	10	104	11	11

Appendix

Avg Volts =		1.218	1.226	1.241	1.248	1.254
Watt-hr =		0.80	0.91	2.15	2.44	2.44
Rechargeable times		2000	2000	750	750	750
Energy Cost Factor		0.0107	0.0095	0.0107	0.0094	0.0094
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	1.343	1.385	1.362	1.446	1.461
5	95	1.286	1.319	1.301	1.351	1.364
10	90	1.265	1.286	1.284	1.293	1.316
15	85	1.254	1.268	1.276	1.277	1.299
20	80	1.250	1.261	1.273	1.272	1.286
25	75	1.250	1.261	1.270	1.271	1.275
30	70	1.249	1.259	1.269	1.269	1.269
35	65	1.247	1.257	1.267	1.267	1.267
40	60	1.245	1.253	1.265	1.266	1.266
45	55	1.242	1.250	1.263	1.264	1.264
50	50	1.239	1.247	1.261	1.262	1.263
55	45	1.235	1.241	1.258	1.259	1.261
60	40	1.229	1.233	1.255	1.256	1.258
65	35	1.223	1.224	1.251	1.252	1.255
70	30	1.215	1.216	1.246	1.246	1.250
75	25	1.207	1.206	1.239	1.238	1.243
80	20	1.199	1.198	1.231	1.229	1.235
85	15	1.192	1.190	1.220	1.216	1.223
90	10	1.183	1.178	1.205	1.199	1.208
95	5	1.167	1.147	1.181	1.166	1.180
100	0	0.854	0.871	0.878	0.899	0.898

State-Charge measurements for AA Size Non-Rechargeable Batteries

AA Size Non-Rechargeable Cell Discharge Voltages					
	75 deg F	AA- Super Heavy Duty	AA- Alkaline	AA- Titanium Energizer	AA- Lithium Energizer
No of Cells		1	1	1	1
R ohms/bat =		12	12	12	12
Discharge Hrs =		7.9	23.5	25.4	24.8
mAh =		776	2354	2535	2944
ma avg =		99	100	100	119
Avg Volts =		1.206	1.218	1.214	1.436
Watt-hr =		0.94	2.87	3.08	4.23
Rechargeable times		1	6	6	1
Energy Cost Factor		18.3667	1.0000	0.9319	4.0705
Capacity, % Used	Capacity, % Left	R1 Voltage	R1 Voltage	R1 Voltage	R1 Voltage
0	100	1.671	1.618	1.598	1.786
5	95	1.418	1.433	1.405	1.490

Appendix

10	90	1.356	1.374	1.351	1.486
15	85	1.323	1.340	1.321	1.481
20	80	1.298	1.314	1.294	1.476
25	75	1.277	1.290	1.270	1.470
30	70	1.261	1.270	1.259	1.464
35	65	1.249	1.253	1.250	1.458
40	60	1.237	1.240	1.241	1.451
45	55	1.225	1.228	1.232	1.446
50	50	1.214	1.216	1.222	1.437
55	45	1.200	1.204	1.210	1.430
60	40	1.184	1.192	1.197	1.422
65	35	1.165	1.178	1.183	1.413
70	30	1.143	1.162	1.166	1.402
75	25	1.117	1.142	1.146	1.392
80	20	1.087	1.117	1.121	1.377
85	15	1.050	1.084	1.088	1.361
90	10	1.006	1.037	1.045	1.342
95	5	0.953	0.977	0.988	1.313
100	0	0.900	0.899	0.899	1.250

State-Charge measurements for NiMH Rechargeable Batteries

NiMH discharging at .1 of max capacity					
% Charged	% Dis-charged	Voltage (Volts)	% Charged	% Dis-charged	Voltage (Volts)
100	0	1.400	33	67	1.255
99	1	1.390	28	72	1.250
98	2	1.380	23	77	1.240
97	3	1.370	20	80	1.230
95	5	1.360	17	83	1.220
94	6	1.350	15	85	1.210
92	8	1.340	13	87	1.200
91	9	1.330	11	89	1.190
89	11	1.320	10	90	1.180
87	13	1.310	9	91	1.170
83	17	1.300	8	92	1.150
79	22	1.295	7	93	1.140
74	26	1.290	6	94	1.130
69	32	1.285	5	95	1.110
63	37	1.280	4	96	1.090
57	44	1.275	3	97	1.070
50	50	1.270	2	98	1.050
44	56	1.265	1	99	1.030
38	62	1.260	0	100	1.000

Wire Gauge-size and maximum Amp flow Table

Appendix

AWG gauge	Diameter Inches	Diameter mm	Ohms per 1000 ft	Ohms per km	Maximum amps for chassis wiring	Maximum amps for power transmission	Shunt length in Inches for 1 mv = 1 amp	Shunt length in CM for 1 mv = 1 amp
OOOO	0.4600	11.6840	0.0490	0.1607	380	302	244.898	622.200
OOO	0.4096	10.4038	0.0618	0.2027	328	239	194.175	493.330
OO	0.3648	9.2659	0.0779	0.2555	283	190	154.044	391.371
0	0.3249	8.2525	0.0983	0.3224	245	150	122.075	310.151
1	0.2893	7.3482	0.1239	0.4064	211	119	96.852	246.068
2	0.2576	6.5430	0.1563	0.5127	181	94	76.775	195.060
3	0.2294	5.8268	0.1970	0.6462	158	75	60.914	154.760
4	0.2043	5.1892	0.2485	0.8151	135	60	48.290	122.687
5	0.1819	4.6203	0.3133	1.0276	118	47	38.302	97.312
6	0.1620	4.1148	0.3951	1.2959	101	37	30.372	77.165
7	0.1443	3.6652	0.4982	1.6341	89	30	24.087	61.196
8	0.1285	3.2639	0.6282	2.0605	73	24	19.102	48.532
9	0.1144	2.9058	0.7921	2.5981	64	19	15.150	38.490
10	0.1019	2.5883	0.9989	3.2764	55	15	12.013	30.521
11	0.0907	2.3038	1.2600	4.1328	47	12	9.524	24.197
12	0.0808	2.0523	1.5880	5.2086	41	9.3	7.557	19.199
13	0.0720	1.8288	2.0030	6.5698	35	7.4	5.991	15.221
14	0.0641	1.6281	2.525	8.282	32	5.9	4.752	12.074
15	0.0571	1.4503	3.184	10.444	28	4.7	3.769	9.575
16	0.0508	1.2903	4.016	13.172	22	3.7	2.988	7.592
17	0.0453	1.1506	5.064	16.610	19	2.9	2.370	6.020
18	0.0403	1.0236	6.385	20.943	16	2.3	1.879	4.775
19	0.0359	0.9119	8.051	26.407	14	1.8	1.490	3.787
20	0.0320	0.8128	10.150	33.292	11	1.5	1.182	3.004
21	0.0285	0.7239	12.800	41.984	9	1.2	0.938	2.382
22	0.0254	0.6452	16.140	52.939	7	0.92	0.743	1.889
23	0.0226	0.5740	20.360	66.781	4.7	0.729	0.589	1.497
24	0.0201	0.5105	25.670	84.198	3.5	0.577	0.467	1.188
25	0.0179	0.4547	32.37	106.17	2.7	0.457	0.371	0.942
26	0.0159	0.4039	40.81	133.86	2.2	0.361	0.294	0.747
27	0.0142	0.3607	51.47	168.82	1.7	0.288	0.233	0.592
28	0.0126	0.3200	64.90	212.87	1.4	0.226	0.185	0.470
29	0.0113	0.2870	81.83	268.40	1.2	0.182	0.147	0.373
30	0.0100	0.2540	103.20	338.50	0.86	0.142	0.116	0.295
31	0.0089	0.2261	130.10	426.73	0.7	0.113	0.092	0.234
32	0.0080	0.2032	164.10	538.25	0.53	0.091	0.073	0.186
Metric 2.0	0.0079	0.2000	169.39	555.61	0.51	0.088	0.071	0.180
33	0.0071	0.1803	206.90	678.63	0.43	0.072	0.058	0.147
Metric 1.8	0.0071	0.1800	207.50	680.55	0.43	0.072	0.058	0.147
34	0.0063	0.1600	260.90	855.75	0.33	0.056	0.046	0.117
Metric 1.6	0.0063	0.1600	260.90	855.75	0.33	0.056	0.046	0.117
35	0.0056	0.1422	329.0	1079.1	0.27	0.044	0.036	0.093
Metric 1.4	0.0055	0.1400	339.0	1114.0	0.26	0.043	0.035	0.090
36	0.0050	0.1270	414.8	1360.0	0.21	0.035	0.029	0.074

Appendix

Metric1.25	0.0049	0.1250	428.2	1404.0	0.2	0.034	0.028	0.071
37	0.0045	0.1143	523.1	1715.0	0.17	0.0289	0.023	0.058
Metric1.12	0.0044	0.1120	533.8	1750.0	0.163	0.0277	0.022	0.057
38	0.0040	0.1016	659.6	2163.0	0.13	0.0228	0.018	0.046
Metric 1	0.0039	0.1000	670.2	2198.0	0.126	0.0225	0.018	0.045
39	0.0035	0.0889	831.8	2728.0	0.11	0.0175	0.014	0.037
40	0.0031	0.0787	1049.0	3440.0	0.09	0.0137	0.011	0.029

The “Shunt Length” column in the above table can be used to determine the length of cable to be used to make a heavy duty DC amp meter. One measures the voltage drop across a given length of the cable that is currently in use supplying the power from the battery. This voltage drop is measure ideally by use of a digital meter; however an analog meter can also be used. One mili-volt measured is equal to one amp of current. If this meter is used on the 200 mv scale then one can read in tenths of an amp up to 200 amps. For small wire sizes if one uses 10 times the length as shown in the table above then the readings will be down to one hundredth of an amp. One simply clips, solders, or clamps the volt meter leads onto the proper length of existing volt source supply cable.

Battery Glossary of Terms and Definitions

(11/3/2008)

Absorbed Electrolyte - The electrolyte in a battery is absorbed in an Absorbent Glass Mat between the plates to ensure that there is no free liquid electrolyte to spill or leak from the cell. The battery using this technology is typically referred to as an AGM battery.

Absorbent Glass Mat (AGM) - A separator technology used in some sealed lead-acid batteries in which the glass-mat separator absorbs 100% of the electrolyte. Because of the immobilized electrolyte, an AGM battery will not leak or spill and does not require water addition. This battery is used in deep-cycle and specialty applications such as telecommunications, wheelchairs and security alarm systems, as well as in automotive starting applications.

Absorption - The taking up or retention of one material by another by chemical or molecular action.

AC (Alternating Current) - An electrical current that continually reverses direction.

Acceptance Test - A controlled discharge of a new battery at either a constant current (expressed in amperes) or constant power (expressed in watts) rate to determine its actual capability as compared to the user's specification or manufacturer's ratings.

Accumulator - A rechargeable battery or cell (see also Secondary battery).

Acid - As used in Lead-Acid batteries refers to sulphuric acid (H_2SO_4), the active component of the electrolyte, or a mixture of sulphuric acid and water.

Active Material - Electrode materials in a battery which cause an electrochemical reaction to generate electricity. The chemical paste that adheres to the positive (+) and negative (-) electrodes in a battery and reacts with the sulfuric acid Alkaline Battery - A non rechargeable, dry-cell battery — such as a AA, AAA, C, D or 9-volt battery — that uses alkaline aqueous solution for its electrolyte. It has a greater capacity than some other types of dry-cell batteries.The material in a lead acid battery involved in the electrochemical reaction to produce a current. Materials include the lead dioxide (PbO2) of the positive plate, sulfuric acid (H2SO4) in the electrolyte and sponge lead (Pb) of the negative plate. The active portion of the battery plates; peroxide of lead on the positives and spongy metallic lead on the negatives.

Actual Capacity or Available Capacity - The total battery capacity, usually expressed in ampere-hours or milliampere-hours, available to perform work. The actual capacity of a particular battery is determined by a number of factors, including the cut-off voltage, discharge rate, temperature, method of charge and the age and life history of the battery.

Aging - A finished or semi-finished battery is store under specified conditions for a specified period.

AGM - Commonly referred to as Absorbed Glass Mat battery. The electrolyte solution is absorbed into the separators. This keeps the batteries from ever leaking fluid if broken.

AH - amp-hour.

Alkaline - A primary battery (non-rechargeable) often used in electronics applications requiring heavy currents for long periods of time (i.e.: cd players, radios, etc.). Alkaline batteries can deliver 50-100% more total energy than conventional Carbon/Zinc batteries of the same size, hence their popularity in consumer applications.

Alloy - A mixture of different types of metals or a mixture of a metal and a nonmetal. As used in Lead-Acid battery practice, a homogeneous combination of lead and antimony.

Alternating Current (AC) - An electric current that varies periodically in magnitude and direction. A battery does not deliver alternating current. This periodic variation is counted in hertz. Electric current which does not flow in one direction only, like direct current, but rapidly reverses its direction or "alternates" in polarity so that it will not charge a battery.

Alternator - An alternating-current generator that produces and rectifies current so that it can be used in an automobile.

Ambient Temperature - The average temperature of the surroundings.

American National Standards Institute - An organization, sponsored by the National Electric Manufacturers Association (NEMA), that establishes policy and standards regarding cell sizes, terminals and testing procedures.

Ammeter - An instrument that measures the flow of current in amps. Ammeters can be made to read DC (Direct Current) and AC (Alternating Current.)

Amperage or Ampere or Amp (I) - The unit of measure of the rate of flow of electric current. One amp is the amount of current produced by an electromotive force of one volt acting through the resistance of one ohm. Named for the French physicist Andre Marie Ampere. The abbreviation for Amp is A but its mathematical symbol is "I". Small currents are measured in milli-Amps or thousandths of an Amp. The flow of 1 X 10 to 26 power of electrons per second in a conductor. Amperes are measured by an ammeter. The fundamental unit of electric current, named for the French physicist Andr-Marie Ampre (1775-1836), one of the pioneers in studying electricity. The official definition of the ampere goes like this: suppose we have two parallel conductors, infinitely long and having negligible cross section. Place these conductors one meter apart in a perfect vacuum. One ampere is the current which, if it's flowing in these conductors, creates between them a force of 0.2 micronewtons per meter of length. (You're welcome to object that no one can make an infinitely long conductor, nor a perfect vacuum. But scientists can use the idealized definition to construct appropriate real-world equipment in their laboratories.) The other electrical units are all defined in terms of the ampere. For example, one ampere represents a current flow of one coulomb of charge per second. One ampere of current results from a potential distribution of one volt per ohm of resistance, or from a power production rate of one watt per volt of potential.

Ampere Hour or Amp Hour (AH) - The unit of electrical capacity - this tells you how much power the battery will store. Current multiplied by time in hours equals ampere-hours. A current of one amp for one hour would be one amp-hour; Also, 1 amp hour is equal to 1,000 mAh; a current of 3 amps for 5 hours would be 15 AH. Similar to the "gallons per day" measure of water. Amp-hour ratings will vary with temperature, and with the rate of discharge. For example, a battery rated at 100 AH at the 6-hour rate would be rated at about 135 AH at the 48-hour rate. Ampere-hours (AH) designates the storage capacity of the battery. SLI batteries are not rated in AH, but in "CCA", or cold-cranking amps (marine batteries are often rated in "marine cranking amps").. Terms such as "6 hour rate" or "20 hour rate" indicate that the battery is discharged steadily over 6 or 20 hours, and the Amp-hour capacity is measured by how much it puts out before reaching 100% DOD, or 1.75 volts per cell. Example: A battery delivering 10 amps for 20 hours = 10 amps x 20 hours = 200 AH. The ampere-hour capacity of a battery on discharge is determined by a number of factors, of which the following are the most important: final limiting voltage; quantity of electrolyte; discharge rate; density of electrolyte; design of separators; temperature, age, and life history of the battery; and number, design, and dimensions of electrodes.

Anode - During discharge, the negative electrode of the cell is the anode. During charge, that reverses and the positive electrode of the cell is the anode. The anode gives up electrons to the load circuit and dissolves into the electrolyte. In a primary or secondary cell, the metal electrode that gives up electrons to the load circuit and dissolves into the electrolyte. The electrode in an electrochemical cell where oxidation takes place. During discharge, the negative electrode of the cell is the anode. During charge, the positive electrode is the anode.

ANSI - American National Standards Institute.

Antimony (Sb) - A metal alloyed with lead to improve the strength and castability of the grids. Antimony is normally used only in lead acid batteries in cycle service, and where make-up water may be added. It is not normally used in VRLA batteries due to its relatively high gassing rate.

Application - The vehicle or equipment in which a battery is used.

Aqueous Batteries - Batteries with water-based electrolytes. The electrolyte may not appear to be liquid since it can be absorbed by the battery’s separator.

Autonomy - The time during which the battery must supply power to the load.

Available Capacity - The total battery capacity, usually expressed in ampere-hours or milliampere-hours that are available to perform work. This depends on factors such as the endpoint voltage, quantity and density of electrolyte, temperature, discharge rate, age, and the life history of the battery.

Average Drain - The average current withdrawn — i.e., the drain — from a cell or battery during discharge, usually approximated by calculating the current at 50% depth of discharge.

Average Voltage - The average of the battery terminal voltage during a discharge. Battery terminal voltage will actually decline during discharge from the open circuit voltage to the end point voltage.

Bandwith - A range of frequencies over which a certain phenomenon is to be considered.

Battery - A device that produces and stores electrical energy as a result of a chemical reaction. A 12-volt battery has six individual 2-volt cells that contain positive (+) plates and negative (-) plates that create electrical current. A fully charged 12-volt battery produces at least 12.66 volts. A battery is a device that transforms chemical energy into electric energy. The term is usually applied to a group of two or more electric cells connected together electrically. In common usage, the term “battery” is also applied to a single cell, such as a AA battery.

Battery Capacity - The electric output of a cell or battery on a service test delivered before the cell reaches a specified final electrical condition and may be expressed in ampere-hours, watt- hours, or similar units. The capacity in watt-hours is equal to the capacity in ampere-hours multiplied by the battery voltage.

Battery Charge - See State of Charge.

Battery Charger - A device capable of supplying electrical energy to a battery.

Battery Council International (BCI) - An association of battery industry companies whose members establish policy and standards for the industry.

Battery Group Size - See Group Size.

Battery Pack - Two or more electrochemical cells electrically interconnected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels. Under common usage, the term "battery" is often also applied to a single cell.

Battery Rack - A stand on which individual batteries are installed. Racks are typically rated for their seismic capabilities and act to support the batteries.

Battery Terminals -Devices attached to the positive post of one end cell and the negative of the other, by means of which the battery is connected to the car circuit.

Battery Types - There are, in general, two type of batteries: primary batteries, and secondary storage or accumulator batteries. Primary types, although sometimes consisting of the same active materials as secondary types, are constructed so that only one continuous or intermittent discharge can be obtained. Secondary types are constructed so that they may be recharged, following a partial or complete discharge, by the flow of direct current through them in a direction opposite to the current flow on discharge. By recharging after discharge, a higher state of oxidation is created at the positive plate or electrode and a lower state at the negative plate, returning the plates to approximately their original charged condition.

Battery Voltage, final - The prescribed lower-limit voltage at which battery discharge is considered complete. The cutoff or final voltage is usually chosen so that the useful capacity of the battery is realized. The cutoff voltage varies with the type of battery, the rate of discharge, the temperature, and the kind of service in which the battery is used. The term "cutoff voltage" is applied more particularly to primary batteries, and "final voltage" to storage batteries. Synonym: Voltage, cutoff.

Battery-Charging Rate - The current expressed in amperes (A) or milli amps (mA) at which a battery is charged.

BCI - The acronym for Battery Council International, consisting of a group of Starting, Lighting and Ignition (SLI) battery manufacturers who issue standards related to SLI batteries and establish standard dimensions (group sizes) for batteries used in automotive applications.

Blackout - A total loss of electrical power.

Boost Charging - Charging at an extremely high rate of 50-300 amps, this method is primarily used to rapidly charge a battery in order to start a vehicle in a matter of a few seconds to five minutes.

Bridge (Rib) (Lead-Acid).Wedge-shaped vertical projection from bottom of rubber jar on which plates rest and by which they are supported.

Bridge Converter - A DC to DC converter topology (configuration) employing four active switching components in a bridge configuration across a power transformer.

British thermal unit (Btu) - A unit of heat energy defined as the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. In America the British thermal unit is sometimes called the heat unit. In defining the Btu, it is necessary to specify the temperature of the water; thus there have been several definitions over the years. However, one Btu is equal to about 251.996 (small) calories, or 0.251 996 of the (kilo-)calories counted by dieters. Using the current definition of the calorie (the IT calorie), one Btu equals approximately 778.169 foot pounds, 1.055 056 kilojoules or 0.293 071 watt hour.

Brownout - A reduction of the AC mains' distribution voltage, usually caused deliberately by the utility company to reduce power consumption when demand exceeds generation or distribution capacity. It can also happen when a generator producing power runs too slow.

Buckling - Warping or bending of the battery plates.

Bunsen Valve - A type of pressure relief valve based on a rubber cap or ring, which, under normal conditions, closes an opening in a cell and temporarily deflects to provide pressure relief upon the buildup of excessive cell pressure within the cell. Bunsen valves are typically used in Valve Regulated Lead Acid (VRLA) batteries.

Burn-in - Operating a newly manufactured power supply, usually at rated load, for a period of time in order to force component infant mortality failures or other latent defects before the unit is delivered to a customer.

Burning - A term used to describe the operation of joining two pieces of lead by melting them at practically the same instant so they may run together as one continuous piece. Usually done with mixture of oxygen and hydrogen or acetylene gases, hydrogen and compressed air, or oxygen and illuminating gas.

Burning Strip - A convenient form of lead, in strips, for filling up the joint in making burned connections.

C - The rated capacity, in ampere-hours, for a specific, constant discharge current (where I is the number of hours the cell can deliver this current). For example, the C5 capacity is the ampere-hours that can be delivered by a cell at constant current in 5 hours. As a cell's capacity is not the same at all rates, C5 is usually less than C20 for the same cell. C is used to signify a charge or discharge rate equal to the capacity of a battery divided by 1 hour. Thus C for a 1600 mAh battery would be 1.6 A, C/5 for the same battery would be 320 mA and C/10 would be 160 mA. Because C is dependent on the capacity of a battery the C rate for batteries of different capacities must also be different.

C/10 - rate = 500 Ah / 10 h = 50 A.

CA - Cranking Amps (Lead-Acid) - A rather optimistic market driven rating, especially for "economy" or "value priced" batteries. The same as CCA, but at at 32 degrees F (0 C) temperature. The standard BCI rating is CCA, at 0 degrees F (about -18 C). The MCA, or Marine Cranking Amps is basically the same as CA. CCA is about 20% less than CA or MCA.

Cabinet Battery System - An enclosed metal case containing a complete battery system of individual series connected batteries. It may or may not include required fuses or circuit breakers for protection of the connecting cable.

Cable - An insulated group of flexible twisted wires, usually copper, used to interconnect individual or groups of batteries. Examples include: inter-unit cable connectors, inter-tier cable connectors and inter-rack cable connectors.

Cadmium - (Lead-Acid).A metal used in about the shape of a pencil for obtaining voltage of positive or negative plates. It is dipped in the electrolyte but not allowed to come in contact with plates. It is also alloyed with lead to improve the strength and cast-ability of the lead grid. Normally used with maintenance free and VRLA batteries due to its minimal impact on the battery gassing rate.

Capacitive Coupling - Coupling of a signal between tow circuits, due to discrete or parasitic capacitance between the circuits.

Capacitor - A device that can store a charge on conducting plates, it is most frequently called a condenser, as in "points and condenser," in an automobile. It is an electrical component capable of storing and releasing a charge via the action of an electrostatic field between two parallel metal plates. Typically used in filter networks, along with inductors or chokes, to smooth the AC ripple voltage which may appear at the output of a DC power source.

Capacity - The capacity of a battery is a measure of the amount of energy that it can deliver in a single discharge. The ability of a fully charged battery to deliver a specified quantity of electricity (AH) at a given rate (amps) over a definite period of time (hours). The ampere-hour or watt-hour rating of a cell. Lead acid batteries are typically rated in ampere-hours at either a 5, 8, 10 or 20 hour discharge rate. For example, a battery that could produce five amperes of current for 20 hours to a minimum voltage of 1.75 volts per cell would be rated as a 100 ampere hour battery at the 20 hour rate (C2O = 100 Ah). Battery capacity is normally listed as amp-hours (or milli amp-hours) or as watt-hours. The energy is referenced to the discharge current for a measured period of time until it reaches a cut-off voltage.

Capacity Offset - A correction factor applied to the rating of a battery if discharged under different C-rates from the one rated.

Capacity Retention - (or Charge Retention)

Capacity Test - A constant current or constant power load is applied to a battery under standard temperature conditions to determine its actual ampere-hour or watt-hour capacity at the particular discharge rate.

Carbon/Zinc - A primary battery (non-rechargeable) commonly used in low drain consumer applications (i.e.: clocks, calculators, garage door openers, etc.). Available in the same sizes as the Alkaline and Manganese Dioxide. The Carbon/Zinc is one of the most widely used dry primary batteries because of its low cost and reliable performance. It is a general-purpose battery, made of a carbon-zinc alloy, such as a AA, AAA, C, D or 9-volt battery. It typically has a lower capacity than alkaline batteries but is used in the same applications, e.g., flashlights.

Case - The containing box which holds the battery cells.

Cathode - (1) The negative (-) terminal of an electrolyte battery. (2) The positive (+) terminal of a primary cell battery.

Cathode - In a primary or secondary cell, the electrode that, in effect, oxidizes the anode or absorbs the electrons. During discharge, the positive electrode of a voltaic cell is the cathode. When charging, that reverses and the negative electrode of the cell is the cathode. The cathode is the electrode in an electrochemical cell where reduction takes place. During discharge, the positive electrode of the cell is the cathode. During charge in a rechargeable battery, the negative electrode is the cathode.

CCA or Cold Cranking Amps - The maximum amperes that can be continuously removed from a battery for 30 seconds at zero degrees F before it's voltage drops too low to use (1.2 volts per cell, or 7.2 volts). This term is used only for engine starting batteries, and has little to do with the amp-hour capacity or deep cycle batteries. This rating will also appear on many deep cycle marine batteries. See also CA and MCA.

CCV - Closed-circuit voltage.

Cell - The basic electrochemical unit used to generate or store electrical energy. It is an electrochemical device, composed of positive and negative plates and electrolyte, which is capable of storing electrical energy. It is the basic “building block” of a battery. A cell is an individual electrochemical device composed of two electrodes of dissimilar metals (active materials) and an electrolyte. When the electrodes are immersed in an electrolyte, the cell will produce a voltage differential between electrodes. When connected to electrodes, the cell will produce a current through an external circuit. In the lead acid battery, the electrodes are lead dioxide (PbO2) and sponge lead (Pb). The electrolyte is a solution of sulfuric acid (H2SO4) and water (H2O). The lead acid battery has a nominal voltage of two volts per cell.

Cell (Dry) - The basic unit that converts chemical energy directly into electric energy. Typically consists of two electrodes of dissimilar material isolated from one another electronically in immobilized electrolyte. See also Dry-Cell Battery.

Cell (Flooded) - The basic unit that converts chemical energy directly into electric energy. Typically consists of a set of positive (+) plates, negative (-) plates, liquid electrolyte, separators and casing. A 12-volt battery has six cells.

Cell Mismatch - The condition of a battery pack that contains cells with significant variations in voltage or capacity. In a liquid-electrolyte battery, cell mismatch may be determined using a hydrometer.Cell Reversal - See Reversed Polarity.

Cell Reversal - The stronger cells of a battery (several cells connected in series) impose a voltage of reverse polarity across a weaker cell during a deep discharge. This is when the normal positive (+) to negative (-) polarity of a cell is reversed due either to incorrect connection of the charger or the discharge of the lowest capacity cell in a series-connected group of cells beyond the recommended end point voltage.

CEMF - counter electromotive force.

Charge - Passing direct current through a battery in the direction opposite to that of discharge, in order to put back the energy used on discharge. To charge is the operation during which a reverse reaction of discharge occurs when electrical energy is received from an external source.

Charge Control - Technique for effectively terminating the charging of a rechargeable battery.

Charge Controller - An electronic regulator that controls the amount of voltage and/or current going from the charging source into the batteries. Regulators come in three general types: on-off, single stage, and 3-stage. Regulators may control the current with a relay or transistor (usually a FET). The simplest type, the on-off, applies full array power to the battery up to a certain voltage, and then cuts off. On-off regulators are not recommended, although there are still quite a few out there on older systems. Single stage regulators work similar to the on-off type, but generally also do some regulation of the current going to the battery. For many years, single stage regulators were the standard, but in the past few years several excellent 3-stage PWM regulators have become available at reasonable prices. 3-stage regulators are becoming the standard for most systems.

Charge Efficiency - The ratio of the ampere-hours removed during discharge to ampere-hours recharge required to restore 100% state of charge multiplied by 100%.

Charge Rate - The proper rate of current to use in charging a battery from an outside source. It is expressed in amperes and varies for different sized cells. The amount of current applied to battery during the charging process. This rate is commonly expressed as a fraction of the capacity of the battery. For example, the C/2 or C/5 amps.

Charge Retention - The capacity retained following specific storage conditions and a specified period of time. See Self Discharge, Shelf Life, and Local Action.

Charge, state of - Condition of a cell in terms of the capacity remaining in the cell.

Charger - A Direct Current (DC) power supply used to supply current to a battery to restore the ampere-hours capacity removed during the discharge. It is the process of restoring the ampere-hours removed from a battery during discharge. Approximately 108% to 115% of the ampere-hours discharged must be restored to attain a full state of charge. The process of supplying electrical energy for conversion to stored chemical energy.

Charging - The process of supplying electrical energy to a discharged battery for conversion to stored chemical energy.

Charging Voltage - The voltage used to overcome a battery's internal resistance and to recharge the battery.

Choke (L) - See Inductor.

Circuit - A closed path that can conduct an electric current. The path followed by a current. See also Open Circuit, Parallel Circuit and Series Circuit.

Circuit Breaker (CB) - A switch that turns off a circuit if the current flow becomes grater than a given amount, that the barker is designed for. It basically is a resetable fuse.

Cladded Battery Rack - An open battery stand to which metal or plastic sides have been added to prevent access by unauthorized personnel. These provide easy removal of the sides for maintenance.

Closed Circuit - A completed circuit through which current can flow when a switch in the circuit is either "On" or "Closed."

Closed circuit voltage (CCV) - Voltage across the terminals of a battery when it is on discharge. As a battery has an internal resistance, CCV is lower than OCV and CCV becomes lower with a range of current. The potential or voltage of a battery when it is discharging or charging.

Cold-Cranking Amps (CCA) - A rating that is used to define the battery's ability to start an engine under low-temperature conditions. BCI defines it as "the number of amps a lead-acid battery at 0ºF (-17.8ºC) can deliver for 30 seconds and maintain at least 1.2 volts per cell (7.2 volts for a 12-volt lead-acid battery). See also CA and HCA. The discharge load in amperes which a new, fully charged battery at 0 degrees F (-17.8C) can continuously deliver for 30 seconds and maintain a terminal voltage equal to or greater than 1.2 volts per cell

Condition - A process that utilizes a series of heavy discharges and recharges on a battery to assure optimum performance.

Conditioning - The process of preparing a lead-acid battery for a set of standard electrical tests by a precise charge regime.

Conductance (Mho) - A measure of a material's ability to conduct current. It is the reciprocal of resistance.

Conductance Meter - A test instrument that applies an AC voltage across the electrodes of a battery and measures the resulting AC current flow to determine the conductance of a battery.

Conductor - A material that allows the movement of electrons (current), such as the metals used for wire and contacts. The best conductors are gold, silver and copper, followed by lead, aluminum and steel.

Constant Current - Charging or discharging method in which current does not change appreciably in magnitude regardless of battery voltage or temperature. An electron flow through a conductor (a current) that does not vary significantly from a present value. During discharge, a constant current drain can be maintained by reducing the resistive load as the battery voltage normally declines. To recharge a battery at a constant current level, the charging voltage must increase as the battery cell voltages increase.

Constant Power - A battery discharge regime whereby the current during the discharge increases as the battery voltage decreases. DC power in watts is equal to the product of voltage multiplied by current in amperes. A constant power discharge occurs when the load current is increased during the discharge by an amount proportional to the normal decline in battery voltage.

Constant Resistance - A battery discharge regime whereby the resistance of the equipment load remains constant throughout discharge.

Constant Voltage - A voltage that does not vary significantly from a preset value. When recharging a battery at constant voltage, the current acceptance will decline as the battery cell voltage rises. The battery cannot be discharged at a constant voltage. The battery voltage normally declines during the discharge.

Constant-Current Battery Charger - A battery charger with output current that stays relatively constant as the battery state of charge increases.

Constant-Current Charge - A charging process in which the current of a storage battery is maintained at a constant value. For some types of lead-acid batteries this may involve two rates called the starting and finishing rates.

Constant-Current Discharge - A discharge in which the current drawn from the battery remains constant.

Constant-Voltage Battery Charger - A voltage-regulated battery charger that allows a decrease in charging current as the battery state of charge increases.

Constant-Voltage Charge - A charging process in which the voltage of a storage battery at the terminals of the battery is held at a constant value.

Container - See Jar.

Continuity - The indication that a circuit is complete between two points; continuity does not exist in an open circuit.

Continuous Test - A battery test in which the battery is continuously discharged until it reaches a predetermined voltage.

Converter - An electrical circuit which accepts a DC input and generates a DC output of a different voltage, usually achieved by high frequency switching action employing inductive and capacitive filter elements.

Corrosion - A destructive chemical reaction with a reactive metal that forms a new compound. Saltwater or dilute sulfuric acid on steel, for example, forms the corrosion compound, rust. Battery terminals can be subject to corrosion. It usually is the attack of metal parts by acid from the electrolyte; it is the result of lack of cleanliness.

Coulomb - One coulomb is the amount of charge accumulated in one second by a current of one ampere. Electricity is actually a flow of particles called electrons, and one coulomb represents the charge on approximately 6.241506 x 10 to the18 power of electrons. The coulomb is named for a French physicist, Charles-Augustin de Coulomb (1736-1806), who was the first to measure accurately the forces exerted between electric charges.

Counter Electromotive Force (CEMF) - The battery voltage plus and voltage drop occurring due to the battery's internal resistance and current flow in the battery.

Cover - The rubber cover which closes each individual cell; it is flanged for I sealing compound to insure an effective sea].

Cranking Amps (CA) - A rating that is used to define the battery's ability to start an engine in moderate temperature conditions. BCI defines it as "the discharge load in amps that a new, fully-charged battery at 32ºF (0ºC) can continuously deliver for 30 seconds while maintaining a terminal voltage equal to or higher than 1.20 volts per cell." This artificially high rating should not be confused with CCA, which is conducted at 0ºF (-17.8ºC.) Cranking Amps is the discharge load in amperes which a new, fully charged battery at 32 degrees F(0c) can continuously deliver for 30 seconds and maintain a terminal voltage equal to or greater than 1.2 volts per cell.

Cranking Battery - An SLI battery.

C-Rate - (also see Hourly Rate)

Crest Factor - In an AC circuit, Crest Factor is the mathematical ratio of the peak to RMS values of a waveform. Crest factor is sometimes used for describing the current stress in AC mains supply wires, since for a given amount of power transferred, the RMS value, and hence the losses, become greater with increasing peak values. Crest Factor gives essentially the same information as Power Factor, and is being replaced by Power Factor in power supply technology.

Critical Load - The equipment to which the battery supplies power during a commercial power failure.

Current (I) - The rate that electricity flows through a conductor, such as the wire in a battery cable. Current is measured in amps. See also Alternating Current and Direct Current. Current refers to the quantity or intensity of electricity flow, whereas voltage refers to the pressure or force causing the electrical flow.

Current Collector - An inert structure of high electrical conductivity used to conduct current from or to an electrode during discharge or charge.

Current Density - The current per unit active area of the surface of an electrode.

Current Drain - The current withdrawn from a battery during discharge. See Drain.

Current Limiting Chargers - A charger that keeps the charge current constant during the charge process but allows the voltage to Fluctuate (typically used on NiCd and NiMh chargers).

Current Monitor - An analog power supply signal which is linearly proportional to output current flow. Usually only feasible for single output power supplies.

Cutoff Voltage - The battery voltage at which the discharge is terminated. The cutoff voltage is specified by the battery manufacturer and is generally a function of discharge rate. When battery voltage is below this level, the connected equipment will not operate and operation is not recommended.

Cutoff Voltage, final - The prescribed lower-limit voltage at which battery discharge is considered complete. The cutoff or final voltage is usually chosen so that the maximum useful capacity of the battery is realized. The cutoff voltage varies with the type of battery and the kind of service in which the battery is used. When testing the capacity of a NiMH or NiCD battery a cutoff voltage of 1.0 V is normally used. 0.9V is normally used as the cutoff voltage of an alkaline cell. A device that is designed with too high a cutoff voltage may stop operating while the battery still has significant capacity remaining.

Cycle - One charge and discharge. A "cycle" is a somewhat arbitrary term used to describe the process of discharging a fully charged battery down to a particular state of discharge. The term "deep cycle" refers to batteries in which the cycle is from full charge to 80% discharge. A cycle for an automotive battery is about 5%, and for telephone batteries is usually 10%. One sequence of charge and discharge. Deep cycling requires that all the energy to an end voltage established for each system be drained from the cell or battery on each discharge. In shallow cycling, the energy is partially drained on each discharge; i.e., the energy may be any value up to 50%.

Cycle Life - How many times a battery can be cycled before it reaches the point where it can only be charged up to (usually) 80% of it's original capacity. This depends on how deep the battery is cycled. Cycle life ratings are not commonly published - especially for the lower quality batteries, and in many cases may not have been done, as it can be quite time consuming. A battery with a cycle life of 900 would take 3 years just to test (although accelerated testing is commonly done). NiMH batteries typically have a cycle life of 500 cycles, NiCd batteries can have a cycle life of over 1,000 cycles. The cycle of a battery is greatly influenced by the type depth of the cycle (deep or shallow) and the method of recharging. Improper charge cycle cutoff can greatly reduce the cycle life of a battery. Some definitions of cycle life say it is the number of cycles a battery can provide before it is no longer usable (a battery is considered non-usable if its nominal capacity falls below 60-80%)

Cycle Service - An application where the battery is the primary source of power, such as in portable instruments, wheelchairs and golf carts. The life of batteries in cycle service is usually defined in terms of the number of deep cycles to be delivered.

Cycling - The repeated charge/discharge cycle of a battery. Some batteries are rated according to their ability to cycle.

Cylindrical Battery - (1) A battery that has a height greater than its diameter. (2) A battery made up of cylindrical cells.

Cylindrical Cell - A battery cell design in which the positive (+) plates and negative (-) plates are rolled up and placed into a cylindrical-shaped container.

DC - Direct current. Electrical current which flows in one direction.

Deep Cycle - A battery discharge consuming more than 80% of the battery's rated capacity. Deep cycling typically occurs in recreational vehicle, wheel chair and golf cart applications. See Cycle. A cycle in which the discharge is continued until the battery reaches it's cut-off voltage, usually 80% of discharge.

Deep Cycling - The process of drawing a high percentage of a battery's capacity (deep discharging) and recharging it to full capacity.

Deep Discharge - The discharge of the battery to below the specified cutoff voltage before the battery is replaced or recharged.

Deep-Cycle Battery - A battery that is designed to withstand repetitive discharges to a 20% depth of discharge or more and to continue providing its rated capacity after hundreds of cycles. Deep-cycle batteries are often used in marine/RV and industrial applications.

Density – for Lead-Acid batteries it is the Specific gravity.

Depth of Discharge (DOD) - The percent of rated capacity to which a cell or battery is discharged. It is the reciprocal of a battery's state of charge. Example: a battery that has a depth of discharge of 45% has a state of charge of 55%. The amount of energy that has been removed from a battery (or battery pack). Usually expressed as a percentage of the total capacity of the battery. For example, 50% depth of discharge means that half of the energy in the battery has been used. 80% DOD means that eighty percent of the energy has been discharged, so the battery now holds only 20% of its full charge.

Derating - A reduction in an operating specification to improve reliability. For power supplies it is usually a specified reduction in output power to facilitate operation at higher temperatures.

Design Life - The expected lifetime of a power supply during which it will operate to its published specifications.

Desorption - The opposite of absorption, whereby the material retained by a medium or another material is released.

Developing - (Lead-Acid).The first cycle or cycles of a new or rebuilt battery to bring about proper electrochemical conditions to give rated capacity.

Differential Mode Noise - Noise that is measured between two lines with respect to a common reference point excluding common-mode noise. The resultant measurement is the difference of the noise components of the two lines. The noise between the DC output and DC return is usually measured in power supplies.

Diffusion - (Lead-Acid).Pertaining to movement of acid within the pores of plates. (See Equalization.)

Digital Voltmeter (DVM) - See voltmeter.

Diode - A semiconductor device that acts like a one-way valve for current. Today's alternators use diodes to rectify current. A semi-conducting crystal that restricts the flow of current to just one direction. It is commonly used to convert AC current to DC current.

Dip - A short term voltage decrease. EMI - Electro-Magnetic Interference

Direct Current - DC - An electron flow through a conductor that travels in only one direction. A battery produces a DC voltage and current. Electrical current that flows in one direction only. Batteries produce direct current as the current flows from a negative to a positive source. Most home systems and some RV and boats use an inverter to convert the DC into 117 volts alternating current (AC), which is the standard household power.

Discharge - The conversion of the chemical energy of a battery into electrical energy, and the withdrawal of the electrical energy into a load. The operational state during which the battery is delivering current to a load. The rate of discharge is the number of amperes being delivered. Discharge or charge current, in amperes, expressed in multiples of the rated capacity. For example, C/10 discharge current for a battery rated at 1.5 Ah is: 1.5 AH/I 0 = 150 mA (A cell's capacity is not the same at all discharge rates and usually increases with decreasing rate.) Discharge is the flow of current from a battery through a circuit, opposite of "charge." Operation during which a battery delivers current to an external circuit.

Discharge and over discharge - Discharging is the process of using power from the battery. As power is drawn from the battery, chemical changes take place between the Lead, the acid, and the Lead Sulfate. Charging reverses this chemical change. Next to overcharging, the worst thing for a battery is to remain fully or partly discharged for long periods of time. This causes Sulfation, which is a hard Lead Sulfate coating on the plates. Sulfation can reduce battery capacity dramatically.

Discharge characteristics (Discharge curve) - Change of a battery voltage with discharge current and time.

Discharge Rate - The rate at which current is drawn from a battery, usually expressed in amps.

Discharge, deep - Withdrawal of all electrical energy to the end-point voltage before the cell or battery is recharged.

Discharge, high-rate - Withdrawal of large currents for short intervals of time, usually at a rate that would completely discharge a cell or battery in less than one hour.

Discharge, low-rate - Withdrawal of small currents for long periods of time, usually longer than one hour.

Discharged - The state of a battery when it has less than a 100% state of charge. Levels of discharge are shown in the Open-Circuit-Voltage Chart.

Discharging - The withdrawal of electrical energy from a cell or battery, usually to operate connected equipment. A battery is discharging when it delivers current.

DOD - Depth of discharge. How much of the available charge has been used compared to 100%. SOC (state of charge is similar - it is how much is left). Most deep cycle batteries are considered to be at 0% SOC, or 100% DOD, when cell voltage is 1.75 volts, or 10.5 volts for a 12 volt battery.

Drain - Withdrawal of current from a cell or battery. Often referred to as discharging. See also Average Drain and Initial Drain.Dry Battery - A battery in which the electrolyte is immobilized, being either in the form of a paste or absorbed into the separator material.

Drift - The change in an output voltage, after a warm-up period, as a function of time when all other variables such a line, load, and operating temperature are held constant.

Dropout - The lower limit of the AC input voltage where the power supply just begins to experience insufficient input to maintain regulation. The dropout voltage for linears is quite load dependent. For most switchers it is largely design dependent, and to a smaller degree load dependent.

Dry Cell - A cell with immobilized electrolyte. A primary cell in which the electrolyte is absorbed in a porous medium, or is otherwise restrained from flowing. Common practice limits the term “dry cell” to the Leclanche, cell, which is the common commercial type. Dry cells are completely sealed, maintenance-free, spill-proof, leak-proof, vibration-resistant, recombinant batteries that do not emit carbon dioxide or hydrogen gasses. Available in various voltages and performance ratings, these environmentally friendly batteries are safe and reliable.

Dry Out - Resulting from significant overcharging, dry-out refers to the total loss of electrolyte due to gassing.

Dry-Charged - An individually formed plate or a completed lead acid battery drained of all electrolyte that has undergone a special drying process. The plate or battery can than be stored for indefinite periods of time with only minor degradation due to sulfation. At a later date, the plate or battery is activated by the addition of the electrolyte and application of a special charging regimen.

Dual Rate Charger - A charger with two output voltages used to charge batteries. One is usually at the lower recommended float voltage, while the other is usually at the higher recommended equalization voltage.

Dual-Alloy Battery - See Low-Maintenance Battery.

Dual-Terminal Battery (DT) - An automotive battery with top terminals and side terminals.

Dumb Battery - Straight battery pack without internal circuits enabling communication between the battery and the user.

Duration time - (Duration period): Time until a battery voltage exceeds the end-point voltage during discharge.

Duty Cycle - The time duration and use frequency during which a battery is drained. It is affected by such factors as charge and discharge rates, depth of discharge, length of cycle, and length of time in standby mode. The operating regime of a battery including factors such as charge and discharge rates, depth of discharge, cycle duration, and length of time in the standby mode.

DVM - Digital voltmeter. See voltmeter.

E - volt.

Effective Internal Resistance - The apparent opposition to current within a battery that manifests itself as a drop in battery voltage proportional to the discharge current. Its value is dependent upon battery design, state-of-charge, temperature, degree of sulfation, and age.

Efficiency - The ratio of output power of a device to the power applied. Efficiency = power out/power in. The ratio of total output power to input power expressed as a percentage. Normally specified at full load and nominal input voltage.

Electric Circuit - A conductive path through which current can flow. A copper wire can form an electric circuit. The movement of electrons along a conductor.

Electricity - The flow of electrons through a conductive medium, such as a copper wire.

Electrochemical Couple - The system of active materials within a cell that provides electrical energy storage through an electrochemical reaction.

Electrochemical Equivalent - Weight of a substance that is deposited at an electrode when the quantity of electricity which is passed is one coulomb

Electrode - An electrical conductor through which an electric current enters or leaves a conducting medium, whether it be an electrolytic solution, solid, molten mass, gas, or vacuum. For electrolytic solutions, many solids, and molten masses, an electrode is an electrical conductor at the surface of which a change occurs from conduction by electrons to conduction by ions. For gases and vacuum, the electrodes merely serve to conduct electricity to and from the medium. The positive or negative plate of a lead acid battery. The site, area or location at which electrochemical processes take place.

Electrolysis - The chemical process that breaks down the water in the electrolyte, releasing hydrogen from the cathode and oxygen from the anode.

Electrolyte - Medium in a battery which causes ions to move to create an electrochemical reaction. A chemical compound which, when fused or dissolved in certain solvents, usually water, will conduct an electric current. All electrolytes in the fused state or in solution give rise to ions which conduct the electric current. It is any acidic, basic, or salt solution capable of conducting current. In a lead acid battery, the electrolyte is a dilute solution of sulfuric acid (H2SO4) in water (H2O). The dilute solution of approximately 25% sulfuric acid (H2SO4) and 75% water by volume in a lead-acid battery, it conducts electricity required for the battery to supply energy. A lead-acid battery may have a liquid, gelled or immobilized electrolyte. The conductive chemical (such as acid), usually fluid or gel, in which the flow of electricity takes place within the battery, and which supports the chemical reactions required. The electrolyte is the medium which provides the ion transport mechanism between the positive and negative electrodes of a cell.

Electrolyte Reserve - When a battery has more electrolyte acid available than that required to fully react the active materials of the plates. When fully discharged, there will still be sufficient conductive acid available in the electrolyte to carry significant recharge current.

Electrolyte Starved - When a battery has insufficient electrolyte acid available to fully react to all the active material of the plates. When fully discharged, the acid is almost fully consumed from the electrolyte, and initial recharge current acceptance may be reduced. This is typical of SLI and VRLA batteries.

Electromechanical - Of, relating to, or being a process or device that converts electrical energy into mechanical movement. A starter motor and an alternator are electromechanical devices.

Electromotive Force (EMF) - voltage.

Electron (e) - A negatively charged particle that orbits the nucleus of an atom. When displaced from the orbit, the electron is free to flow as an electric current.

Electronic Load - An electronic device designed to provide a load to the outputs of a power supply, usually capable of dynamic loading, and frequently programmable or computer controlled.

Electropositive - The degree to which an element in a galvanic cell will function as the positive element of the cell. An element with a large electropositive will oxidize faster than an element with a smaller electropositive.

Electropositivity - The degree to which an element in a galvanic cell will function as the positive element of the cell. An element with a large electropositivity will oxidize faster than an element with a smaller electropositivity.

Element - The assembled set of positive and negative plates and separators that comprise a cell when inserted into a container.

EMF (electromotive force) - Which is another term for voltage.Electricity - The flow of electrons through conductive materials and devices.

EMI (Electromagnetic Interference) - Unwanted noise during the operation of a power supply or other electrical or electronic equipment.

End of Life (EOL) - The point in the operational life when a battery can only deliver 80% or less of rated capacity.

End Point Voltage (EPV, End voltage, Cutoff voltage, Final voltage) - At a battery's specific discharge rate, the voltage under load when the discharge is considered complete. Specified closed circuit voltage at which a service output test is terminated.

End-of-Discharge Voltage - The voltage of the battery at termination of a discharge.

Energy - Output capability; expressed as capacity times voltage, or watt-hours. The output capability of a cell or battery, usually expressed in watt-hours.

Energy Density - The ratio of a battery's energy-delivery capability to its weight or volume, measured in watt-hours per kilogram or watt-hours per cubic centimeter. The ratio of the energy available from a battery to its volume (Wh/L) or weight (Wh/kg).

Equalization - Equalization is a "supercharge" which is applied to the battery at intervals of from 2 to 8 weeks. This charge voltage is about 10% higher than the normal float or trickle charge. This ensures that the cells are all equally charged, and in flooded batteries makes sure that the electrolyte is fully mixed by the gas bubbles. Gelled and sealed batteries in general should be equalized at a much lower rate than flooded - usually the final charge cycle on a 3-stage charger is sufficient to equalize all the cells. Difference in capacity at various rates is caused by the time required for this feature.

Equalize Charge - The restoration of power in a battery at a maximum allowable voltage for a defined period of time. This brings all series-connected cells to a maximum state of charge and equalizes the charging voltage across the individual cells. See Charge.

Equalizing - Lead-Acid.Term used to describe the making uniform of varying specific gravities in different cells of the same battery, by adding or removing water or electrolyte.

Equalizing Charge - A charging method that equalizes the specific gravity or voltage levels of individual cells in a battery or a group of batteries connected in series.

E-Rate - Discharge or charge power, in watts, expressed as a multiple of the rated capacity of a cell or battery that is expressed in watt-hours. For example, the E/10 rate for a cell or battery rated at 17.3 watt-hours is 1.73 watts. (This is similar to the method for calculating C-Rate.)

ESR - Equivalent Series Resistance. The value of resistance in series with an ideal capacitor which duplicates the performance characteristics of a real capacitor.

Evaporation - Lead-Acid.Loss of water from electrolyte from heat or charging.

Expiry date - Expiration of guarantee period of a primary battery determined by each manufacturer conforming to the IEC. Because a secondary battery can be used over again by charging, it is unnecessary to show this. Note: IEC (International Electrotechnical Commission) is a worldwide organization of standardization comprised of all national electrotechnical committees.

Fast Charge - A recharge occurring at higher voltage and current capability to restore the battery to 95% state of charge in one to five hours. Typical fast charge time for a NiCd is 1 to 3 hours. The fast-charger detects the state of charge and switches to trickle charge when full-charge is reached. A high rate charge — typically above 20 amps — for one to five hours that provides a quick blast of energy. It is often used to get the battery to a recharge level that can restart a vehicle. Repeated fast charges overcharge the battery and reduce service life.

Fault Mode Input Current - The input current to a power supply with a short circuit on the output.

Ferroresonant Power Supply - Power supply used at higher power levels in fixed applications, since they are very heavy. Can only be used effectively when the line frequency is very stable as they are sensitive to variations of input AC frequencies.

Filling Plug - (Lead-Acid).The plug which fits in and closes the orifice of the filling tube in the cell cover.

Filter - An electronic device that allows only certain frequencies to pass.

Final Voltage - (see Cutoff voltage)

Finishing Rate - (Lead-Acid).The current in amperes at which a battery may be charged for twenty-four hours or more. Also the charging rate used near the end of a charge when cells begin to gas.

Float - The voltage at which the battery is "floated", or just enough current is supplied to equal the self-discharge of the battery. This is typically about 14.2 volts for a 12 volt battery.

Float Charge - A low, constant-current or constant-voltage charge that compensates for the self-discharge of a battery normally used in a standby application. Having a battery on continuous charge at a low recommended voltage to maintain the battery at a full state of power while minimizing overcharge. See Charge. Similar to trickle charge. Compensates for the self-discharge on a SLA battery

Float Charging - Method of recharging in which a secondary cell is continuously connected to a constant-voltage supply that maintains the cell in fully charged condition. Typically applied to lead acid batteries.

Float Service - An application where the battery is continuously connected to a charger and is seldom required to deliver any significant Ampere-Hours to the load. Typically, Float Service batteries are used for standby power in emergency lighting, cable TV, telecommunications, UPS systems, and automotive engine starting.

Float Voltage (Vf) - The voltage at which the battery is maintained on float charge. See Float Charge.

Floating Ground - The voltage reference point for an automobile, usually being the frame of the vehicle. See Ground.

Flooded Battery - A type of liquid, lead-acid battery. See Vented Battery.

Flooded Cell - A lead acid battery with a liquid electrolyte, or a vented cell where the gasses produced through overcharging are vented directly to the atmosphere.

Flooding - (Lead-Acid).Overflowing through the filling tube.

Forced Discharge - Discharging a cell in a battery, by the other cells or an external power source, below zero volts into voltage reversal.

Foreign Material - Objectionable substances.

Formation - The electro-chemical process through which the lead oxide (PbO) pasted onto the grids in manufacturing is converted to the active materials of lead dioxide (PbO2) on the positive plate and porous metallic lead (Pb) on the negative plate.

Forming - (Lead-Acid).Electro-chemical process of making pasted grid or other plate, types into storage battery plates. (Often confused with Developing.)

Frequency - The number of times that a periodic function, such as current or voltage, repeats the same sequence of values within a unit of time. It is measured in hertz.

Freshening Charge - The charging of batteries in storage to assure they are maintained in a near maximum state of charge and to ensure there is no deterioration of the battery plates due to self-discharge and sulfation. This process is usually performed using the recommended equalization or cycle service charging voltage. A charge given to a battery which has been standing idle, to keep it fully charged.

Fuse - A safety device in a circuit that melts "open" at a specific level of current in order to protect the circuit from shorts circuits and current surges. Device used for cutting off an electrical current in the event of an abusive condition. A circuit overload protective device containing a metallic component that melts when prescribed current limits are exceeded, thus opening the circuit.

Fusible Link - A type of fuse in a circuit consisting of a reduced number of strands of wire held together by solder.

Galvanic Cell - A combination of electrodes, separated by electrolyte, that is capable of producing electrical energy by electrochemical action.

Gassing - The evolution of gas from one or more of the electrodes in a cell. Gassing commonly results from local action (self-discharge) or from the electrolysis of water in the electrolyte during charging. The evolution of hydrogen and oxygen, along with other gasses, from the lead acid battery during periods of overcharging as a result of electrolysis of the water in the electrolyte. In lead-acid batteries the giving off of oxygen gas at positive plates and hydrogen at negatives, which begins when charge is something more than half completed-depending on the rate.

Some gassing is normal, but excessive gassing can indicate that the batteries are being overcharged. The gasses released are explosive if a spark or flame occurs, so adequate ventilation must be provided. Batteries normally start gassing at about 80-90% of full charge. A common fallacy is that you should stop charging as soon as the battery starts gassing. Most batteries start gassing at about 80% SOC, so if you quit charging at that point, you will never get a full charge. Most better chargers cut back on the current when the battery reaches this point to prevent excess gassing.

Gassing and sealed gel cells - (Lead-Acid) - Gelled cells will withstand much less gassing than AGM or flooded batteries. The gel can develop large bubbles or "pockets", which reduce battery capacity due to poor contact with the plates. It can also cause the gel to dry out from water loss, making these pockets permanent. Gelled batteries are charged at a slightly lower voltage than flooded, .1 to .3 volts less to avoid over-gassing. Some advertisements and product brochures have stated that gelled cells have a "high" capacity for taking a charge - this is NOT correct, as it is 1/2 to 1/4 the maximum current that a flooded or AGM battery can take. We have seen this statement in inverter and charger literature, not just battery product brochures.

Gassing Voltage - The charging voltage at which the cell will start to generate and expel gas.

Gel-Cell Battery - A recombinant-chemistry, lead-acid battery in which the electrolyte is immobilized by adding a gelling agent. Totally sealed and valve-regulated, it is nonspillable and does not require water addition. Gel-cell batteries are used in special applications such as telecommunications, wheel chairs and security alarm systems.

Gelled Electrolyte - A liquid electrolyte with fumed silica added as an immobilization technique. The result is a spill-proof battery capable of supporting an oxygen recombination cycle. See Oxygen Recombination Cycle.

Generator - A device that produces an electric current through magnetism.

Generator System - An equipment including a generator for automatically recharging the battery, in contradistinction to a straight storage system where the battery has to be removed to be recharged.

Gravimetric Energy - The ratio of the energy output of a cell or battery to its weight (Wh/kg). This term is used interchangeably with specific energy.

Gravity - (Lead-Acid).A contraction of the term "specific gravity," which means the density compared to water as a standard.

Grid - A lead-alloy framework that supports the active material of a battery plate and conducts current. In SLI batteries, it may contain antimony or calcium to make it more rigid. The grid provides the conductive path for the electron current during charging and discharging of the battery. The assembly of the grid and pasted active materials form the plate of the battery.

Ground - To connect to the earth or some conductor which takes the place of the earth. A voltage reference point. In an automobile, the ground (See Floating Ground) is the frame of the vehicle, referred to as a floating ground. In a dwelling, it may be a conducting path connected directly to earth. A large conducting body, such as the metal frame of a vehicle, used as a common return for an electric circuit and as an arbitrary zero of potential. When jump starting or installing a battery, it is important to identify the ground cable to avoid damage when attaching the cable to the ground. The negative (-) terminal of the battery is used as the ground in 99% of automotive applications today.Ground Cable - The cable which connects the ground - e.g., the metal frame of the vehicle - to the battery, normally to the negative (-) terminal.Group Size - The physical dimensions of a battery. BCI assigns letters and numbers for North American battery size types. All group-size-24 batteries, for example, have similar container dimensions, terminal orientation and terminal types.

Ground Fault Detection - The monitoring of voltage from a battery's terminals to ground in order to identify whether a short circuit to the ground exists.

Ground Loop - An unintentionally induced feedback loop caused by two or more circuits sharing a common electrical ground.

Group - An assembly of plates with like polarity, (either positive or negative) connected in parallel via a strap within a cell. Groups do not include separators.

Half Cell Voltage - The voltage of the positive and negative plates with respect to a third electrode, such as a mercury-mercuric sulfate probe, when immersed in the electrolyte.

Haversine - A waveform that is sinusoidal in nature, but consists of a portion of a sine wave superimposed on another waveform. The input current waveform to a typical off-line power supply has the form of a haversine.

Hazardous Waste - Waste that is classified by the government as potentially harmful to the environment. Lead and cadmium are examples of chemicals that are particularly hazardous.

Headroom - Used in conjunction with series pass regulators, and is the difference between the input and output voltages.

Heavy-Duty Battery (Commercial) - A lead-acid, liquid-electrolyte, starting battery used in medium and heavy-duty trucks, construction vehicles and other off-road vehicles.

Hertz (Hz) - The standard unit of frequency. A frequency of one complete cycle per second is a frequency of one hertz.

High Rate Discharge - A discharge at a current greater than that of the one hour discharge rate. Typically this is the one through 30 minute rates.

HiPot - Abbreviation for High Potential, and generally refers to the high voltages used to test dielectric withstand capability for regulatory agency electrical safety requirements.

Hold-Down - (Lead-Acid).Device for keeping separators from floating or working up.

Hold-Down Clips - (Lead-Acid).Brackets for the attachment of bolts for holding the battery securely in position on the car.

Hold-Up Time - The length of time a power supply can operate in regulation after failure of the AC input. Linears have very short hold-up times due to the CV squared energy storage product of their low voltage secondary side output capacitors. Switchers have longer times due to their higher voltage primary side energy storage capacitors.

Hot-Cranking Amps (HCA) - A rating similar to CCA that is used to define the current output of a storage battery at 80°F (27°C). These inflated ratings should not be confused with CCA.

Hourly Rate - A discharge rate, in amperes, of a battery which will deliver the specified hours of service to a given cutoff voltage.

Hydration Short - When a cell is over-discharged and not recharged within a short period, the plates' lead sulfate, which is more soluble in water than in acid, can go into solution with the low specific gravity electrolyte, and then penetrate the separators. Upon recharging, the lead sulfate in the separators is converted to lead and a short circuit develops through the separator.

Hydrogen (H2) - A colorless, odorless gas given off at the negative plate of a lead acid battery due to electrolysis of the water in the electrolyte during periods of overcharge. Hydrogen can reach an explosive level at a 4% concentration in air.

Hydrogen Flame - (Lead-Acid).A very hot and clean flame of hydrogen gas and oxygen, acetylene, or compressed air used for making burned connections.

Hydrogen Generator - (Lead-Acid).An apparatus for generating hydrogen gas for lead burning.

Hydrometer - (Lead-Acid) - An instrument used to check the specific gravity (strength) of the electrolyte in the battery. Most Lead-Acid batteries will be in the range of 1.1 to 1.3 specific gravity, with most fully charged batteries being about 1.23 to 1.30 (some hydrometers multiply this number by 1000, so 1.23 would read as 1230.) Hydrometers are inexpensive and can be purchased at any auto parts store. Some batteries manufactured for use in very hot or very cold climates may have stronger or weaker acid. If so, it is usually marked on the battery. See also Specific Gravity. A hydrometer is an instrument — normally a mechanical float type device but can be electronic — used to determine the state of charge of a battery by measuring the specific gravity of its electrolyte.

Hydrometer Syringe - (Lead-Acid).A glass barrel enclosing a hydrometer and provided with a rubber bulb for drawing up electrolyte.

I - Current.

IEC - International ElectroChemical Commission.Immobilized Electrolyte - An electrolyte made motionless by use of a gel additive or AGM separator. See also Gel-Cell Battery and Recombinant.Impedance (Z) - The total opposition that a battery offers to the flow of alternating current. Impedance is a combination of resistance and reactance.

IEEE - The acronym for the Institute of Electrical and Electronic Engineers, a group who publishes standards manuals concerning the selection, sizing, application, installation and maintenance of lead acid batteries.

Immobilized Electrolyte - Typically, liquid electrolyte is either absorbed into a blotter-type separator of glass fibers (AGM) or is converted to a gel, rendering it immobile. This ensures that there is no free liquid electrolyte and allows the battery to be used in any orientation without spillage. See Gelled Electrolyte.

Impedance (Z) - The resistive and reactive characteristics of a material that opposes the flow of current through the material. An AC signal is used to measure impedance.

Induced Noise - Noise generated in a circuit by a varying magnetic field produced by another circuit.

Inductor (L) - Numerous turns of wire, usually wrapped around some type of iron core, which present inductive reactance to the flow of an AC current. Also referred to as a choke, an inductor is typically used in circuits to eliminate the AC ripple from the output of a DC power source.

Initial Charge - The charge applied to a battery when it is first installed. The initial charging voltage is typically the same as that used for equalization.

Initial Drain - The current that a cell or battery supplies when first placed on load. Also referred to as starting drain.Insulator - A material — such as rubber, some plastics and glass — that is highly resistant to conducting electricity.

Initial test - Test conducted within 2 months of the production month.

Initial Voltage - Vi - The minimum voltage to which a battery first declines when a current is drawn from the battery.

Input Line Filter - An internally or externally mounted low-pass or band-reject filter at the power supply input which reduces the noise fed into the power supply.

Insulator - A non-conducting material such, as glass fibrous matting, plastic, or rubber.

Inter-cell Connector - An electrically conductive wire, buss bar or strap used to connect two individual cells in series or parallel.

Interconnect - Heavy cables, usually 10 to 20 inches in length used to connect 2 or more batteries into banks. These vary from #4 wire for smaller battery banks up to #4/0 (0000) for larger banks with large inverters.

Internal Impedance - The opposition exhibited by a circuit element (cell or battery) to the flow of an alternating current (a/c.) of a particular frequency as a result of resistance, induction and capacitance.

Internal Resistance (Ri) - The resistance to the flow of an electric current within the cell or battery. The opposition exhibited by a circuit element to the flow of direct current (D.C.). In a cell, the internal resistance is the sum of the ionic and electronic resistances of the cell components. Expressed in ohms, the total DC resistance to the flow of current through the internal components (grids, active materials, separators, electrolyte, straps, intercell welds and terminals) of the battery. Resistant component in a battery that makes discharge reaction slow.

Internal short circuit - Direct contact electrically between the positive electrode and negative electrode caused by damage to the separator or gasket, or the presence of a conductor piercing the separators. A battery will become completely exhausted before use.

Inverter - A power supply which produces an AC output, usually from a DC input.

Ion - An atom with more or fewer electrons than required to remain in equilibrium. Out of equilibrium, the atom becomes negatively or positively charged and can act as a current carrier. Ions, rather than electrons, are the current carriers of an electrolyte.

IR Drop (IR) - The reduction in total voltage appearing at the terminals of a battery when a load is applied. It is the product of the battery's current, expressed in amperes (A or I), multiplied by the internal resistance, expressed in ohms.

Isolation - Two circuits that are completely electrically separated with respect to DC potentials, and almost always also AC potentials. In power supplies, it is defined as the electrical separation of the input and output via the transformer.

Isolation Voltage - The maximum AC or DC voltage which maybe continuously applied from input to output and/or chassis of a power supply.

Jar - The container in which the cell element and electrolyte are contained. For Lead-Acid batteries it is the hard rubber container holding the element and electrolyte.

Jumper Cables - Portable cables used to convey current from one battery to another. See Cable.

Key-Off Drain - An electrical discharge, such as that caused by a vehicle computer memory or alarm system, that draws power from the car battery when the vehicle is not running. See also Drain.

Kilo (K) - Metric prefix for 1000. For example, one kilovolt would be 1000 volts.

Kilovolt-Ampere (KVA) - One thousand volt-amperes. The output of a UPS is typically rated in volt-amperes.

Kilowatt (kW) - One thousand watts.

Kilowatt-hour (kwh) - Watts times Hours. If you have something that uses 1000 watts, and you use it for one hour, it will use 1 kwh. If it uses 10 watts for 100 hours, that is also 1 kwh.

Lead Alloy - A mixture of lead and another metal, (commonly antimony, tin or calcium) created to enhance certain characteristics of the metals during either the manufacturing process or its application.

Lead Burning - (Lead-Acid).Making a joint by melting together the metal of the parts to be joined.

Lead Dioxide - PbO2 - The active material of the positive plate in a battery.

Lead Oxide - PbO - Particles of oxidized lead are combined with water and sulfuric acid and made into a paste. They are then applied to the lead acid battery grids. Later, the lead oxide is converted to active material through the formation process. See Formation.

Lead Poisoning - The symptoms of lead poisoning are: gums darken or become blue, indigestion, colic, constipation, loss of appetite, muscular pain. In the later stages there is muscular weakness and paralysis. The hands become limp and useless.

Lead Sulfate - PbSO4 - The product resulting from the discharge of the active materials of the plates. This may be the result of an active discharge of the battery or local action.

Lead-Acid Battery - A rechargeable electrochemical device used to store and produce electrical energy. The active materials are lead dioxide, sulfuric acid and metallic lead. The individual cell has a nominal voltage of two volts DC. This is still the most popular battery used today its main application is for the automobile industry, although it has a growing number of other applications. Its advantages are low cost, high voltage per cell and good capacity life. Disadvantages are poor low temperature characteristics, it is relatively heavy, and it cannot be left in a discharged state for too long without being damaged. Related Batteries: Absorbent Glass Matt (AGM) Gel/Gel Cell Sealed Lead Acid. I is a storage battery with an active material of lead and lead peroxide and with an electrolyte solution of water and sulfuric acid. Maintenance-free, low-maintenance and gel-cell batteries are types of lead-acid batteries

Leakage Current - A term relating to current flowing between the AC supply wires and earth ground. The term does not necessarily denote a fault condition. In power supplies, leakage current usually refers to the 60 Hertz current which flows through the EMI filter capacitors which are connected between the AC lines and ground (Y caps).

Leakage resistance - Enduring characteristics against leakage.

Limiting Current - The maximum current drain under which the particular battery will perform adequately under a continuous drain. The rate is based on whatever drain rate reduces the running voltage to 1.1 volts.

Line Regulation - The change in output voltage when the AC input voltage is changed from minimum to maximum specified. It is usually a small value, and may be near zero with current mode control.

Lithium Battery - Lithium primary batteries are non-rechargeable batteries used in devices requiring long life and low, steady power, such as digital watches, computers and smoke detectors. Some types of lithium batteries are specifically designed for applications with high power requirements, such as wireless microphones and flash units. A primary battery (non-rechargeable) that is quickly entering mainstream electronic designs, particularly in consumer, portable equipment and non-volatile memory back up applications where small size, long life and low cost are the primary requirements. Lithium batteries have superior cold temperature performance and a shelf life of 5-10 years.

Lithium Ion (Li-Ion) - One of the newer rechargeable battery technologies, Li Ion batteries can deliver 40% more capacity than comparably sized NiCd batteries and are one of the lightest rechargeable batteries available today. Li Ion batteries are the batteries of choice in notebook computers, wireless telephones and many camcorder models. They are also one of the more expensive rechargeable technologies. Advantages are that they are very light weight, have smaller cells, and have increased capacity. They are used in a lot of today's cellphones and computers, however they tend to be a little more expensive.

Load - External device or method through which a battery is discharged. A circuit's built-in resistance — e.g., the starting motor, headlights or resistor — that discharges the battery when operating. The amount of current supplied by a battery to the device being powered.

Load Bank - An assembly of resistive elements connected in parallel or series-parallel to present a load of pre-determined amperes to the battery. There are both DC and AC rated load banks, and they may not be used interchangeably.

Load Current - The discharge current provided by a battery, or drawn by a battery powered device.

Load Regulation - The change in output voltage when the load on the output is changed.

Load Tester - An instrument that discharges a battery using an electrical load while measuring voltage. It determines the battery's ability to perform under actual operating conditions. Hand-held resistive device used to place a test current on the battery while the resulting battery terminal voltage drop is monitored.

Local Action - A reaction between the sulfuric acid electrolyte and the active materials of the plates resulting in the slow discharge of the plates and in the formation of lead sulfate on the plates and consumption of the acid in the electrolyte. Evidence of local action includes declining electrolyte specific gravity and terminal voltage. The condition can be reversed by application of a freshening charge to the battery. Local action is increased at elevated temperatures.

Low Voltage Disconnect (LVD) - The voltage at which most load controllers and inverters will disconnect from the battery to avoid totally draining the battery too far down. This is usually at about 10.5 to 11.2 volts for a 12 volt system. Also called Low Voltage Cutoff.

Low-Maintenance Battery - Normally a lead-acid battery, it may require periodic water addition under normal service conditions. A dual-alloy battery, it typically uses a low antimony lead alloy in the positive (+) grid and a calcium-lead alloy in the negative (-) grid.

Lug - (Lead-Acid).The extension from the top frame of each plate, connecting the plate to the strap.

mA - MilliAmp.

Magnetic Amplifier - Sometimes abbreviated "Mag Amp," a saturating inductor which is placed in series with a power supply output for regulation purposes.

mAH - Milliamp-hour.

Maintenance-Free Battery (MF) - A battery that does not require water addition under normal service conditions. Both positive (+) and negative (-) grids are made of lead/calcium. In terms of electrolyte maintenance, VRLA batteries require no addition of water.

Manganese Dioxide - A primary battery (non-rechargeable) similar to that of the alkaline battery though not as strong in total energy. Available in the same size as Alkaline and Carbon/Zinc ("AA", "AAA", "C","D", 9volt) the Manganese Dioxide chemistry is noted for its ability to retain its charge while being stored at high temperatures and operates well at temperatures as low as -40°C with little loss of capacity.

Margining - Adjusting a power supply output voltage up or down from its minimal setting in order to verify system performance margin with respect to supply voltage. This is usually done electrically by a system-generated control signal.

Marine-Cranking Amps (MCA) - A rating that is used to define the number of amps that a lead-acid marine battery at 32°F (0°C) can deliver for 30 seconds and maintain at least 1.2 volts per cell (7.2 volts for a 12-volt lead-acid battery). This artificially high rating should not be confused with CCA. How many amps the battery will supply for 30 seconds at 32 degrees F (0 C) before the voltage drops to 1.2 volts per cell (7.2 volts for a 12 volt battery). See also CCA. This was originally an advertising term to make marine batteries look better.

Maximum Gravity - (Lead-Acid).The highest specific gravity which the electrolyte will reach by continued charging, indicating that no acid remains in the plates.

Memory Effect - A phenomenon in which a cell, operated in successive cycles to less than full, depth of discharge, temporarily loses the remainder of its capacity at normal voltage levels (usually applies only to Ni-Cd cells). Note, memory effect can be induced in NiCd cells even if the level of discharge is not the same during each cycle. Memory effect is reversible.

Metal Hydride - An intermetallic compound or alloy in which hydrogen has been absorbed-, also, the negative electrode in a nickel-metal hydride battery.

Mho - A unit of electrical conductance equal to the reciprocal of resistance. Mho is the backward spelling of Ohm.

Micro (u) - Metric prefix meaning 1/1,000,000. One microampere is equal to 0.000001 amperes.

Midpoint Voltage - The voltage of a battery midway in the discharge between the start of the discharge and the end voltage.

Milli (m) - Metric prefix meaning 1/1,000.

MilliAmp (mA) - One one-thousandth of an amp. A 1/1000th of an amp, e.g.: One milliampere is equal to 0.001 amperes.

Milliamp-hour (mAH) - One one-thousandth of an amp-hour. 1.0Ah = 1000mAh

Minimum Load - The minimum load current/power that must be drawn from the power supply in order for the supply to meet its performance specifications. Less frequently, a minimum load is required to prevent the power from failing.

Monoblock - A battery consisting of two or more series-connected cells in a single container. A 12 volt battery is a monoblock consisting of 6 series-connected 2 volt cells.

Monocell - A single-cell battery. Several monocells may be connected to provide increased voltage or capacity.

Mossing - Mossing can occur in vented cells where sloughed active positive material will circulate in the electrolyte and reform as negative material as it touches and adheres to the negative plate. It can result in shorted cells when it occurs at the top of the plates and bridges the separators. This process is also referred to as treeing.

Mud - (Lead-Acid).(See Sediment.)

Multicell - See Monoblock.

Multimeter - Also known as a volt-ohm-meter (VOM), it is an instrument designed to do a variety of electrical testing, including voltage, amperage and resistance.

Negative (-)- A terminal or electrode which has an excess of electrons. Normally refers to the negative (-) battery terminal, which is the point from which electrons flow during discharge. The negative (-) terminal cap or cable is typically black, designating negative (-). See also Ground.

Negative (-) Plate - The negative (-) electrodes of a battery composed of "spongy" lead on a grid. See also Active Material. The gray plate in a lead acid battery. It contains the metallic lead active material, and expels the electron current during discharge.

Negative Terminal - The terminal of a battery from which electrons flow in the external circuit when the cell discharges.

Nickel Cadmium (NiCD) Batteries - One of the most proven and historically most widely used rechargeable batteries. Very dependable and "robust" but contain cadmium and have relatively low capacity when compared to other rechargeable systems. Very good high rate discharge capabilities make them very popular in high drain applications. Used in a lot of older devices and still today in a lot of power tools for their discharge capabilities. 1.2 volt average.

Nickel Metal Hydride (NiMh) Batteries - Interchangeable with most NiCd batteries, nickel metal hydride (NiMh) batteries generally deliver 10-25% greater capacity than NiCds and are environmentally more friendly than NiCds since they do not contain cadmium. Used in many wireless phone and camcorders. 1.2 Volt average.

Nickel-Iron (NiFe) - A battery constructed of Nickel and Iron plates. Extremely long life, but low efficiency (as low as 60%). Note: some batteries with a "NiFe" label are NiCad. Nickel-Iron batteries were formerly made by the NiFe company, but apparently the only source now is imports from Hungary.

Noise - An undesirable signal that is irregular and is riding on top of the desired signal.

Nominal Voltage - The characteristic operating voltage or rated voltage of a battery. The approximate open circuit voltage of a cell or battery. For example, the nominal voltage of a lead acid battery is 2 volts per cell, but the actual voltage is higher and is a function of the electrolyte specific gravity. The nominal voltage of a given voltage of a cell that is accepted as an industry standard. (Cell voltage of 1.2 and 1.25 volts are used for NiCD and NiMH batteries.) Suitable approximate value of voltage used to identify the voltage of a battery. For example): Alkaline manganese battery; 1.5V, Lithium manganese dioxide battery; 3.0V

Nonaqueous Batteries - Cells that do not contain water, such as those with molten salts or organic electrolytes.

OCV - open-circuit voltage.

Off Line - A power supply which receives its input power from the AC line, without using a 50/60 Hz power transformer prior to rectification and filtering, hence the term "off line" power supply.

Ohm - A unit of electrical resistance. When one volt is applied across a resistor with one ohm of resistance, a current of one ampere will flow through the resistor. A measure of resistance that causes one volt to produce a current of one ampere. Its symbol is the Greek letter omega. The smaller the wire conductor the greater is the resistance. Six hundred and sixty-five feet of No. 14 wire (size used in house lighting circuit) offers I ohm resistance to current flow.

Ohm's Law - The formula that describes the amount of current flowing through a circuit. Ohm's Law - In a given electrical circuit, the amount of current in amperes (I) is equal to the pressure in volts (V) divided by the resistance, in ohms (R). Ohm's law can be shown by three different formulas: To find Current I = V/R To find Voltage V = I x R To find Resistance R = V/I

Ohmmeter - An instrument used to measure resistance in an electrical circuit.

Ohm's Law - An equation — E (Volts) = I (Current) x R (Resistance) — that expresses the relationship between volts, amps and ohms in an electrical circuit with resistance. I = V/R - Equation used in circuit analysis which states that the current flowing through a circuit is proportional to the voltage applied and is inversely proportional to the resistance of the circuit.

Oil of Vitriol - (Lead-Acid).Commercial name for concentrated sulphuric acid (1.835 specific gravity). This is never used in a battery and would quickly ruin it.

Open Battery Rack - A frame on which individual batteries are mounted. They are totally exposed to view for ease of visual inspection and maintenance.

Open Circuit - A circuit that has a broken or interrupted path, preventing current flow. An interrupted conductive path or circuit. The circuit's switch would be in the OFF position, and current could not flow.

Open Circuit Voltage (OCV) - Voltage across the terminals of a battery when no external current is flowing. The difference in potential between the terminals of a cell when the circuit is open (i.e., a no-load condition).

Opportunity Charging - Used with batteries in cycle service, it is the charging of the battery between partial discharges rather than waiting for the battery to be completely discharged.

Output Impedance - The ratio of change in output voltage to change in load current.

Output Noise - The AC component that may be present on the DC output of a power supply. Switch-mode power supply output noise has two components: a lower frequency component at the switching frequency of the converter and a high frequency component due to fast edges of the converter switching transitions. Noise should always be measured directly at the output terminals with a scope probe having an extremely short grounding lead.

Over discharge - The process of discharging a cell or battery beyond its cutoff voltage and possibly into voltage reversal.

Overcharge - The forcing of current through a cell after all the active material has been converted to the charged state, that is, continued charging after reaching 100 percent state-of-charge. Overcharging Lead-Acid batteries is one of the most destructive elements in battery life (the other is long term undercharging). Most batteries don't die a natural death, they are murdered - usually by overcharging. Overcharging causes the plates to disintegrate and shed. These particles end up on the bottom of the cell. Eventually, the cells will short out, fall apart, break apart, or generally die. Overcharging also increases water loss tremendously, causing even more problems. Gelled cells can be damaged faster than flooded, and flooded can be damaged faster than AGM batteries by overcharging. Water loss is a particular problem with sealed gel cells, as the water cannot be replaced. In some cases, severe overcharging can also cause considerable heat in cheaper batteries with high internal resistance, causing plates to buckle and cases to warp and break. See also discharge. Some poorly designed charge controls compound the problem by both overcharging and undercharging.

Overcharging - Continued charging of the battery after it has reached 100% capacity. The forcing of current through the battery after it is fully charged. Overcharging reduces service life and can damage the battery. The battery can no longer absorb any further charge and the charge current turns into heat, causing damage to the battery.

Over-Discharge - Discharge of a battery to a voltage lower than that recommended for the particular discharge rate. The carrying of discharge beyond proper cell voltage; shortens life if carried far enough and done frequently.

Overvoltage Protection - A circuit which either shuts down the power supply or crowbars the output in the event of an overvoltage condition.

Oxidation - A chemical reaction that results in the release of electrons by an electrode's active material.

Oxygen Evolution - The production of oxygen gas at the positive plate as a result of the electrolysis of water in the electrolyte during overcharging.

Oxygen Recombination Cycle - In a VRLA battery, the process whereby the oxygen evolved at the positive plate diffuses through the separator to react with the negative plate and suppresses water loss. This is the characteristic that distinguishes the VRLA battery from vented lead acid batteries.

Parallel - Term used to describe the interconnection of cells or batteries in which all the like terminals are connected together. Results in increased capacity.

Parallel Circuit - A circuit in which the current has more than one path to follow. In this configuration, two batteries of equal rating are wired together positive (+) to positive (+) and negative (-) to negative (-). In parallel, the RC (Reserve Capacity) and CCA (Cold Cranking Amps) double while the voltage remains the same as the weakest individual battery.

Parallel Connection - Batteries connected in parallel means that all the Positive (+) terminals are connected together, and all of the Negative (-) terminals are connected together. Batteries wired in parallel supply the same voltage but higher current. The amp-hour ratings add for each battery, but the voltage stays the same. New batteries should not be paralleled with old ones. (See also Series Connection).

Passivation - The phenomenon by which a metal, although in conditions of thermodynamic instability, remains indefinitely unattached because of modified or altered surface conditions.

Paste - (Lead-Acid).The mixture of lead oxide or spongy lead and other substances which is put into grids.

Pasted Plate - A lead alloy grid to which the active materials, in a paste form, have been applied.

Pasting - The process of applying a paste consisting of lead oxide, water and sulfuric acid to the lead alloy grid of the plate.

Peak Power - The absolute maximum output power that a power supply can produce without immediate damage. Peak power capability is typically well beyond the continuous reliable output power capability and should only be used infrequently.

Performance Capacity Test - A capacity test performed under the same conditions as the original acceptance capacity test to determine what, if any, degradation of capacity has occurred. Any capacity below 80% of rating is indicative of the need to replace the battery. See Acceptance Capacity Test.

Pilot Cells - Cells within a battery selected to represent the state of the entire battery .See Cells.

Plantè Plate - Named for its 1859 developer, Gaston Plantè this is one type of positive plate used in a lead acid battery. It is a solid lead plate on which the active materials are electrochemically formed rather than having been pasted onto the plate.

Plate - A composite of a grid framework and the chemical active material. See Positive Plate and Negative Plate. (Lead-Acid).The combination of grid and paste properly "formed." Positive

Polarity - In electricity, the condition of being positive or negative. Refers to the charges residing at the terminals of a battery. The particular state of a battery terminal, either positive (+) or negative (-).

Polarization - Voltage deviation from equilibrium caused by charge or discharge. The electrical potential reduction of electrodes, typically arising from prolonged or rapid discharge of the battery. The lowering of the potential of a cell or electrode from its equilibrium value caused by the passage of an electric current.

Positive (+) - A terminal or electrode which has a shortage of electrons. Normally refers to the positive (+) battery terminal, which is the point to which electrons in the external circuit flow during discharge. Sometimes the positive (+) terminal cap or cable is red, designating positive (+).

Positive (+) Plate - The positive (+) electrodes of a battery composed of lead peroxide on a grid. See also Active Material. The thick, brown to black plate in a lead acid battery containing the lead dioxide active material. Typically, the characteristics of the positive plate will determine the life and performance of the battery.

Positive Temperature - A thermally reactive device which becomes highly resistive at a specific Coefficient (PTC) temperature or current.

Positive Terminal - The terminal attached to the battery positive plate group and to which external load and charger connections are made. The terminal of a battery toward which electrons flow through the external circuit when the cell discharges.

Post - (Lead-Acid).The portion of the strap extending through the cell cover, by means of which connection is made to the adjoining cell or to the car circuit.

Potential Difference - Voltage or electromotive force (EMF). Abbreviated P. D. Found on test curves. Synonymous with voltage.

Power (W or watt) - The rate at which work is done. Power is measured in watts. P (Power) = E (Voltage) x I (Current). During discharge, the battery output power in watts is equal to the terminal voltage multiplied by the output current in amperes.

Power Factor - The ratio of true power to apparent power in an AC circuit. In power conversion technology, power factor is used in conjunction with describing the AC input current to the power supply. The ratio of real power to apparent power. pf = watts/volts x amperes.

Primary - The input section of an isolated power supply which is connected to the AC mains and hence has dangerous voltage levels present.

Primary Battery - A battery that is non-rechargeable. The active materials on the primary battery are irreversibly converted during the chemical reaction which produces energy. A battery which is not intended to be recharged and is discarded when the battery has delivered all of its electrical energy.

Primary Cell - A cell designed to produce electric current through an electrochemical reaction that is not efficiently reversible. The cell, when discharged, cannot be efficiently recharged by an electric current. Alakline, lithium, and zinc air are common types of primary cells. Note: When the available energy drops to zero, the cell is usually discarded. Primary cells may be further classified by the types of electrolyte used.

Prismatic Cell - The positive and negative plates are stacked rather than rolled as done in a cylindrical cell.

Pulse Current - A periodic current drain of higher than normal drain rates.

R - Resistance.

Rapid Charge - A charge time that is between slow charge and fast charge (typically 3 to 6 hours for a NiCd).

Rate - Number of amperes for charge or discharge. Also used to express time for either.

Rate Sensitivity - Typically refers to battery performance under various discharge loads with operating voltage being the defining characteristic.

Rated Capacity - The ampere-hours or watt-hours a battery delivers under standard conditions at a specified discharge rate to a specified end point voltage. See Standard Conditions and Standard Discharge Rate.

Rated Capacity (Dry Cell) - The average capacity delivered by a cell or battery on a specified load and temperature to a cutoff voltage, as designated by the manufacturer. Rated capacity is usually determined by an accelerated test approximating the cell or battery's capacity in typical use.

Rated Capacity (Flooded) - The CCA, RC or amp-hours that a battery can deliver at a given rate of discharge, end voltage and temperature. These ratings are often displayed on the outside of the battery.

Rated Output Current - The maximum load current that a power supply can provide at a specified ambient temperature.

Ratings - Batteries are rated in several ways. Automotive and marine starting batteries are rated in CCA, or Cold Cranking Amps. However, batteries used in photovoltaic systems are rated in Ampere Hours (AH). This rating tells you how many amps the battery will put out if discharged over a specified period of time, usually 8 or 20 hours. A 100 AH battery will give you 1 amp for 100 hours, or 100 amps for one hour. AH is a the measure of capacity for deep cycle batteries.

RC - Reserve capacity.

Rechargeable - Capable of being recharged; refers to secondary cells or batteries.

Rechargeable Battery - A cell or battery capable of being recharged. Refers to secondary batteries. A galvanic battery which, after discharge, may be restored to the fully charged state by the passage of an electrical current through the cell in the opposite direction to that of discharge. (Secondary battery): Source of electrical energy obtained by the direct conversion of chemical energy designed to be charged by any other electrical source. It is also called a storage battery or accumulator.

Recombinant - The process in which the oxygen formed at the positive (+) plate diffuses to the negative (-) plate, reacts with the lead and suppresses water loss. In a recombinant (immobilized electrolyte) chemistry battery, gassing is recombined within the sealed battery so that water addition is unnecessary. The process whereby the oxygen formed at the positive plate diffuses to the negative plate, reacts with the lead and suppresses water loss.

Recombination - State in which the gasses normally formed within the battery cell during its operation, are recombined to form water.

Recondition - One or more deep discharge cycles below 1.0 volt/cell at a very low, controlled current. Recondition helps to revert large crystals to small desirable sized, often restoring the battery to it's full capacity.

Reconditioning - See Conditioning.

Rectifier - As a circuit component, it converts AC power to DC power. It is also used to describe a DC power supply used to charge the battery and power the critical load. Device that changes alternating current to direct current.

Rectify - To convert alternating current into direct current.

Recycling - The recovery of reusable lead, acid and plastic from spent lead acid batteries.

Reduction - A chemical process that results in the acceptance of electrons by an electrode’s active material.

Regulation - The ability of a power supply to maintain an output voltage within a specified tolerance as referenced to changing conditions of input voltage and/or load.

Regulation Band - The total error band allowable for an output voltage. This includes the effects of all of the types of regulation: line, load, and cross.

Reserve Capacity (RC) - A measurement of the minutes a battery can supply 25 amperes to an end point voltage of 1.75 volts per cell. This rating is used with automotive (SLI) and marine batteries. BCI defines it as "the number of minutes a new, fully-charged battery at 80ºF (27ºC) can be discharged at 25 amps and maintain a voltage equal to or higher than 1.75 volts per cell" (i.e., 10.5 volts for a 12-volt battery). This rating represents the time the battery will continue to operate essential accessories in the event of a charging system failure. Reserve capacity is sometime used to rate deep cycle batteries. It is the number of minutes that a battery can maintain a useful voltage (over 1.75 VPC) at a constant 25 amp discharge rate at 80 degrees F. Reserve capacity is probably a more useful measure than AH for batteries that run heavy loads, although most batteries also have tables that show the AH capacity at different discharge rates. AH is approximately equal to RC X .60.

Resistance (R) - The opposition to the free flow of current in a circuit. The degree to which the flow of electrons is opposed by the material the electrons must pass through. Resistance is measured in ohms. See also Internal Resistance.

Resistance Material - (usually lamps or wire) of low conductivity inserted in a circuit to retard the flow of current. By varying the resistance, the amount of current can be regulated. Also the property of an electrical circuit whereby the flow of current is impeded. Resistance is measured in ohms. Analogous to the impediment offered by wall of a pipe to flow of water therein.

Resistor (R) - A circuit component used to oppose the flow of current. A device, with electrical resistance, that is used in an electrical circuit for current control and efficient operation.

Retainer - A glass fiber mat attached to the ribbed side of a separator and placed against the positive plate in the assembled element. A retainer's function is to hold the sloughed positive active material in place and thus improve the plate cycle life.

Reversal - Reversal of polarity of cell or battery, due to excessive discharge, or charging in the wrong direction. See Reversed Polarity.

Reverse Voltage Protection - A protection circuit that prevents the power supply from being damaged in the event that a reverse voltage is applied at the input or output terminals.

Reversed Polarity - The changing or reversing of the normal polarity of a battery, which commonly occurs when battery cables or charging cables are connected backwards.

RFI - An abbreviation for Radio Frequency Interference, which is undesirable noise produced by a power supply or other electrical or electronic device during its operation. In power supply technology, RFI is usually taken to mean the same thing as EMI.

Rheostat - An electrical appliance used to raise or lower the resistance of a circuit and correspondingly to decrease or increase the current flowing.

Ri - Internal resistance.

Ribbed - Lead-Acid, See Separator.

Ripple and Noise - The amplitude of the AC component on the DC output of a power supply usually expressed in millivolts peak-to-peak or RMS. For a linear power supply it is usually the frequency of the AC mains. For a switching power supply, it is usually the switching frequency of the converter stage.

Rubber Sheets - (Lead-Acid).Thin, perforated hard rubber sheets used in combination with the wood separators in some types of batteries. They are placed between the grooved side of the wood separators and the positive plate.

Safety Ground - A conductive path to earth that is designed to protect persons from electrical shock by shunting away any dangerous currents that might occur due to malfunction or accident.

Safety Vent - A venting mechanism designed into a cell which activates under specific conditions of abuse to relieve internal pressure.

Seal - The structural part of a galvanic cell that restricts the escape of solvent or electrolyte from the cell and limits the ingress of air into the cell (the air may dry out the electrolyte or interfere with the chemical reactions).

Sealed Battery - A maintenance-free battery with nonremovable vent caps.

Sealing - (Lead-Acid).Making tight joints between jar and cover; usually with a black, thick, acid-proof compound.

Secondary - The output section of an isolated power supply which is isolated from the AC mains and specially designed for safety of personnel who might be working with power on the system.

Secondary Battery - A battery made up of secondary cells. See Storage Battery; Storage Cell. A battery that can be recharged and reused many times.

Secondary Cell - A rechargeable cell.

Secure Waste Landfill - A landfill designed for disposal of normal household trash but which meets government standards designed to protect the environment.

Sediment - The material shed from the positive and negative plates in a vented (liquid electrolyte) cell. It settles to the bottom of the cell into the sediment basin. (Lead-Acid). Loosened or worn out particles of active material fallen to the bottom of cells; frequently called' "mud."

Sediment Space - (Lead-Acid). That part of jar between bottom and top of bridge.

Seismic Rack - A reinforced battery stand with cell retaining rails designed to withstand the forces imposed during a earthquake.

Self Discharge - Discharge that takes place while the battery is in an open-circuit condition. Capacity loss during storage due to internal leakage between the positive and negative cell plates. All batteries will "self discharge" if sitting idle, even with no load. The rate can vary considerably with the type of battery and the age. A brand new AGM deep cycle will self discharge at about 2% a month, while an old conventional golf cart battery may be as high as 2% per day. The higher the temperature during storage, the greater the rate of self discharge.

Self-Discharge Rate - The rate at which a cell or battery loses its capacity when standing idle.

Separator - The permeable membrane that allows the passage of ions, but prevents electrical contact between the anode and the cathode. An insulating material, usually rubber, plastic or glass fibrous matting, used to isolate the positive and negative plates and prevent them from touching one another or shorting out. An insulative divider between the positive (+) plates and negative (-) plates of an element that allows the flow of current to pass through it and prevents positive (+) and negative (-) electrodes from touching and creating a short circuit. An ionic permeable electronically non-conductive spacer or material which prevents electronic contact between electrodes of opposite polarity in the same cell. The separator in old Lead-Acid cells: An insulator between plates of opposite polarity; usually of wood, rubber or combination of both. Separators are generally corrugated or ribbed to insure proper distance between plates and to avoid too great displacement of electrolyte.

Sequencing - The technique of establishing a desired order of activating the outputs of a multiple output power supply.

Series - The interconnection of cells in such a manner that the positive terminal of the first is connected to the negative terminal of the second, and so on, resulting in increased voltage.

Series Circuit - A circuit in which the current has only one path to follow. In this configuration, two batteries of equal rating are wired together positive (+) to negative (-). In series, the battery voltage increases while the RC and CCA remain the same as the weakest individual battery.

Series Connection - Batteries connected in series have the Positive (+) terminal of one battery tied to the Negative (-) terminal of the next battery. Power is taken from the two terminals at the end of the series string. Batteries wired in series supply the same current but the voltage is higher - for example four six-volt batteries in series will supply 24 volts. The amp-hour rating will be that of the smallest battery if different types are connected. If old and new batteries are used together, the maximum current will be that of the weakest battery. See also Parallel Connection.

Series/Parallel Circuit - A circuit in which some of the terminals are connected in series to increase total voltage, and some are connected in parallel to increase total capacity. The amount of voltage and capacity depends on the exact number of series and parallel connections.

Service Life - The period of time during which the battery continues to meet the requirements of the application but is not at less than 80% of the rated capacity. The period of useful life of a battery before a predetermined end-point voltage is reached.

Shallow Cycle - Cycles where the battery consumes less than 5% of its capacity during the discharge. Automotive (SLI) batteries typically experience shallow cycles during engine starting.

Shallow Cycling - Charge and discharge cycles which do not allow the battery to approach it’s cutoff voltage. Shallow cycling of NiCd cells lead to “memory effect”. Shallow cycling is not detrimental to NiMH cells and it is the most beneficial for lead acid batteries.

Shelf Life - The amount of time a cell or battery will retain a specified percent of its rated capacity, typically under ambient storage conditions. For a dry cell, the period of time (measured from date of manufacture), at a storage temperature of 21 degrees C (69 degrees F), after which the cell retains a specified percentage (usually 90%) of its original energy content. The duration of storage under specified conditions at the end of which the battery still retains the ability to give a specified performance.

Short Circuit - A condition in which a short electrical path is unintentionally created. An example would be setting a wrench on top of a battery touching the terminals. Batteries can supply thousands of amps if short circuited, melting the wrench, the terminals, and showering sparks and molten metal. This is not a good thing, and may be harmful to people and other living things. An unwanted electrical connection between a negative and positive source. Short circuits can damage the battery and equipment and can cause sparks or fire. A short circuit in a battery cell may be permanent enough to discharge the cell and render the battery useless. A metallic connection between the positive and negative plates within a cell. The plates may be in actual contact or material may lodge and bridge across. If the separators are in good condition, a short circuit is unlikely to occur.

Short circuit current - Surges of current across the terminals of a battery when it is short-circuited. That current delivered when a cell is short-circuited (i.e., the positive and negative terminals are directly connected with a low-resistance conductor). The initial value of the current obtained from a battery in a circuit of negligible resistance.

Silver/Oxide - A primary battery (non-rechargeable) it is a major contribution to miniature power sources, and is well suited for hearing aids, instruments, photoelectric exposure devices and electronic watches. These cells are primarily made in the smaller “button” sizes.

SLI - The acronym for a Starting, Lighting and Ignition battery. An SLI battery's design is optimized for high rate cranking current delivery and is used in automotive applications. It is not designed to provide long life in continuous float service.

Slow Charge - Recharging a battery at a low current rate; for example, charging a battery at the C/20 rate or lower would be a slow charge. Typically an over-night charge lasting abut 14 hours at a charge current of 0.1C. Battery does not require instant removal when fully charged.

Slow Charging - Charging at a rate of about 5-10% of a battery's rated capacity. Example: 50 AH battery x 10% = 5-amp charge.

Smart Battery - Battery with internal circuit enabling some communication between the battery and the user. Some batteries feature a capacity indicator only, others offer an external bus to interface with the equipment the battery power and the intelligent charger.

Smart Charger - A charger which is able to interact with the battery.

Soft Cell - A cell whose voltage rises above its defined boundaries during charging. This voltage rise may be caused by high cell impedance as a result of prolonged battery storage, very cold battery temperature or lack of electrolyte.

Solenoid - (1) A term used to mean coil or inductor. (2) A type of relay that switches the starter current "off" in an automobile after the engine engages.

Spacers - (Lead-Acid).Wood strips used in some types to separate the cells in the case, and divided to provide a space for the tie bolts.

Specialty Battery - Any battery other than an SLI battery.

Specific Energy - The ratio of the energy output of a cell or battery to its weight (Wh/kg). This term is used interchangeably with gravimetric energy density.

Specific Gravity (SG) - In a lead-acid battery, the weight of sulfuric acid compared to the weight of an equal volume of pure water. Specific Gravity, or gravity, is a measure of the density of a liquid as compared to that of water, which has a SG of 1.000. For example, pure sulfuric acid has a specific gravity of 1.835. Lead acid battery electrolyte is a mixture of water and sulfuric acid, which typically has a specific gravity of between 1.200 and 1.300. It indicates the strength and is measured by the hydrometer. (Lead-Acid) - The measurement used to express electrolyte strength. SG compares the weight of the electrolyte to water, which has a SG of 1.000. SG changes somewhat with temperature, so most hydrometers come with a correction chart. A full charge should be about 1.265 at 77 degrees F (25 degrees C). This changes with temperature. This cannot be measured in sealed batteries. Pure acid has a SG of 1.835. A fully discharged battery will have a SG of about 1.12. SG should not be measured right after water is added as the reading will not be accurate until the electrolyte is fully mixed. This could take hours or days - an equalization charge will speed this up considerably. The SG in many AGM batteries may be as high as 1.365, but there is no practical way to measure it. If you get new batteries, you should fully charge them and equalize them and THEN take a specific gravity reading for future reference, as not all manufacturers use exactly the same SG, and SG may also vary for the same battery sold in different climates.

Spiral Wound - An electrode structure of high surface area created by winding the electrodes and separator into a spiral-wound jelly-roll configuration.

Spray - (Lead-Acid).Fine particles of electrolyte carried up from the surface by gas bubbles. (See Gassing.)

Standard Conditions - Varying between countries, a widely recognized and specific set of temperatures and end point voltages by which a battery's output is measured. In North America, standard conditions are 77°F (25°C) to an end point voltage of 1.75 volts per cell. In some countries, the standard conditions are 68°F (20°C) to an end point voltage of 1.8 volts per cell. See Standard Discharge Rate and Rated Capacity.

Standard Discharge Rate - A function of the intended application, the accepted rate at which the battery delivers current. For example, an 8 hour rate is normally used for telecommunications batteries, a 20 hour rate is used for general purpose batteries, and a 15 minute rate is used for UPS batteries.

Standby - The use of batteries in which they are charged by an application to be ready for use if the primary power to the application fails. Also called float or backup. A backup power supply. See also Float Charge and Uninterrupted Power Supply.

Standby Current - The input current drawn by a power supply when shut down by a control input (remote inhibit) or under no load.

Starting Battery - A starting-lighting-and-ignition battery (SLI).

Starting Rate - (Lead-Acid).A specified current in amperes at which a discharged battery may be charged at the beginning of a charge. The starting rate is reduced to the finishing rate when the cells begin to gas. It is also reduced at any time during the charge if the temperature of the electrolyte rises to or above 110' Fahrenheit.

Starting-Lighting-and-Ignition Battery (SLI) - A battery primarily used to start a vehicle and to provide power for lights and accessories. SLI batteries include automotive, deep-cycle and heavy-duty commercial starting batteries.

Starvation - (Lead-Acid).The result of giving insufficient charge in relation to the amount of discharge, resulting in poor service and injury to the battery.

State of Charge (SOC) - The capacity remaining in a battery. Expressed as a percentage, the quotient of the remaining ampere hours (AH) in a battery divided by the rated capacity of the battery. The condition of a battery in terms of rated capacity remaining at a given point in time. See also Open-Circuit-Voltage Chart, Specific-Gravity Chart and Depth of Discharge.

Stationary Battery - A battery used in a fixed position and usually mounted in a rack, cabinet or stand, as opposed to a battery used in a mobile application.

Storage - Store the battery under specified conditions for a given time.

Storage Battery - An assembly of identical cells in which the electrochemical action is reversible so that the battery may be recharged by passing a current through the cells in the opposite direction to that of discharge. While many non-storage batteries have a reversible process, only those that are economically rechargeable are classified as storage batteries. Synonym: Accumulator; Secondary Battery. See Secondary Cell.

Storage Cell - An electrolytic cell for the generation of electric energy in which the cell after being discharged may be restored to a charged condition by an electric current flowing in a direction opposite the flow of current when the cell discharges. Synonym: Secondary Cell. See Storage Battery.

Strap - The lead casting that joins the element plates of like polarity in parallel. The leaden casting to which the plates of a group are joined.

Stratification - A condition in which the concentration of acid is greater at the bottom of the battery than at the top. Normally caused by continued undercharging. The tendency of the heavier sulfuric acid in the electrolyte solution to separate from the water and settle to the bottom of the container.

Sulfation - Growth of lead sulfate crystals in Lead-Acid batteries which inhibits current flow. Sulfation is caused by storage at low state of charge. The creation of lead sulfate (PbSO4) on the positive and negative plates of the lead acid battery during normal discharge and self discharge. Even though Lead Sulfate is created in the materials of plates during normal discharging, this term is used to describe the generation of a different form (large crystals) of Lead Sulfate which will not readily convert back to normal material when the battery is charged. Sulfation occurs when a battery is stored too long in a discharged condition, if it is never fully charged, or if electrolyte has become abnormally low due to excessive water loss from overcharging and/or evaporation. Often sulfation can be corrected by charging very slowly (at low current) at a higher than normal voltage, usually at about 2.4 to 2.5 volts per cell at 1/2 to 8 amps (depending on battery size). This will gradually remove the sulfation in many cases. This term is also often misused to explain almost any battery homicide. Sulfation Growth of lead sulfate crystals in SLA batteries which inhibits current flow. Sulfation is caused by storage at low state of charge.

Sulfuric Acid - H2SO4 - The active material of the electrolyte in a lead acid battery.

Sulphate - Common term for lead sulphate. ($PbSO_4$.)

Sulphate Reading - A peculiarity of cell voltage when plates are considerably sulphated, where charging voltage shows abnormally high figures before dropping gradually to normal charging voltage.

Sulphated - Term used to describe cells in an under-charged condition, from either over-discharging without corresponding long charges or from standing idle some time and being self discharged.

Surge - An abnormally high voltage lasting for a short period of time.

Switch - A mechanical device used for opening and closing a circuit. A device placed in an electric circuit to open (disconnect) or close (connect) the conductive path.

Switching Frequency - The rate at which the DC voltage is switched on and off during the pulse width modulation process in a switching power supply.

Taper Charge - A charge regime delivering moderately high-rate charging current when the battery is at a low state of charge and tapering the current to lower rates as the battery becomes more fully charged.

Temperature Coefficient - The average output voltage change expressed as a percent per degree centigrade of ambient temperature change. This is usually specified for a pre-determined temperature range.

Temperature Cutoff - A protective or safety device (e.g., thermostat, PTC, etc.) which senses temperature in a battery and opens or cuts off the electrical circuit if the specified temperature is exceeded, thus preventing a further rise in temperature due to the charge or discharge of a battery.

Terminal - A connection point on a device or component, e.g., a battery terminal. A device at the end of a cell or wire for making a connection to an adjoining cell or wire. Part to which outside wires are connected.

Terminal Voltage - The voltage at the battery terminals.

Thermal Protection - A power supply protection circuit which shuts the power supply down in the event of unacceptably high internal temperatures.

Thermal Runaway - A condition whereby a cell on charge or discharge will destroy itself through internal heat generation caused by high overcharge or high rate of discharge or other abusive conditions. A condition where a battery generates more heat than can be dissipated and eventually melts the plastic jar.

Thermistor - A temperature sensitive resistor usually made from specially processed oxides that are used to sense end of charge temperature rises and terminates high rate charging.

Thermostat - A temperature sensitive switch.

Top-Up Charge - A low rate charge following the main charge, designed to ensure maximum capacity.

Tracking - A characteristic in a multiple output power supply where any changes in the output voltage of one output caused by line, load, and/or temperature are proportional to similar changes in accompanying outputs.

Transfer Time - The amount of time it takes a stand-by or off-line type UPS to sense a power interruption and switch from utility output to inverter output. Normally expressed in milliseconds. See also Switching Time. Transformer

Transformer - Normally used to obtain a voltage higher or lower than the commercial line voltage and to provide circuit isolation from the source, it is composed of primary and secondary coils of wire wrapped around an iron core. The transformer provides an AC voltage on the secondary coil equal to the ratio of turns of wire on the primary to secondary windings.

Treeing - See Mossing.

Trickle Charge - Maintenance charge to compensate for battery's self-discharge. A charge at a low rate, balancing losses through local action and/or periodic discharge, to maintain a cell or battery in a fully charged condition. A very low rate constant current charge to maintain a battery at a full state of charge.

Trickle Charging - A method of recharging in which a secondary cell is either continuously or intermittently connected to a constant-current supply that maintains the cell in fully charged condition.

Trolling Battery - Another name for deep cycle battery. A trolling motor will use about 20-30 amps, so a 105 AH (group 31)deep cycle battery will run the motor for about 3 to 4 hours. Used for small electric trolling motors.

True Power - In an AC circuit, true power is the actual power consumed. It is distinguished from apparent power by eliminating the reactive power component that may be present.

UPS (Uninterruptible Power Supply) - A power supply which continues to supply power during a loss of input power. Two types are the stand-alone UPS, which is located external to the equipment being powered, and the battery back-up power supply, which is embedded in the equipment being powered, such as a POWER-ONE SPM series high power product with a G5 battery back-up module.

Utilization factor - Ratio of usable capacity against theoretical capacity.

Valve - Provides for release of excessive pressure developed within the cell and prevents entry of the outside atmosphere into the cell.

Valve-Regulated Lead-acid Battery (VRLA) - A lead-acid battery that is sealed with the exception of a one-way valve that opens to the atmosphere when the internal gas pressure in the battery exceeds the atmospheric pressure by a pre-selected amount. VRLA batteries are sometimes called recombinant batteries.

Vent - A normally sealed mechanism that allows for the controlled escape of gases from within a cell. It can be an opening allowing for the free escape of gasses from the lead acid battery. It may have a condensing chamber to minimize exhaust of electrolyte mist and/or a flame arresting device to prevent ignition of gasses within the cell by an outside source, but is otherwise open to the atmosphere.

Vent, Vent Plug or Vent-Cap - Hard or soft rubber part inserted in cover to retain atmospheric pressure within the cell, while preventing loss of electrolyte from spray. It allows gases formed in the cell to escape, prevents electrolyte from spilling, and keeps dirt out of the cell.

Vented Battery - A battery in which the gaseous products of electrolysis and evaporation are allowed to escape into the atmosphere as they are generated. These batteries are commonly referred to as flooded batteries.

Venting - When gas or electrolyte escapes through a valve or vent.

Volt orVoltage (E or V) - The commercial unit of pressure in an electric circuit. Voltage is measured by a voltmeter. Analogous to pressure or head of water flow through pipes. NOTE. - Just as increase of pressure causes more volume of water to flow through a given pipe so increase of voltage (by putting more cells in circuit) will cause more amperes of current to flow in same circuit. Decreasing size of pipes is increasing resistance and decreases flow of water, so also introduction of resistance in an electrical circuit decreases current flow with a given voltage or pressure. The unit of measure for electrical potential or pressure, which is also called electromotive force (EMF). Volts = Amps x Ohms. The unit of measurement of electromotive force, or difference of potential, which will cause a current of one ampere to flow through a resistance of one ohm. Named for Italian physicist Alessandro Volta (1745-1827). A unit of force sufficient to carry one ampere of current through one ohm resistance. Also called electromotive force (EMF), it is the electrical pressure that forces electron flow in a complete circuit. See Volt Ampere, Current, and Ohm.

Voltage Balance - The difference in magnitudes, in percent, of two output voltages that have equal nominal voltage magnitudes but opposite polarities.

Voltage Delay - Time delay for a battery to deliver the required operating voltage after it is placed under load.

Voltage Depression - An abnormal drop in voltage below expected values during the discharge of a battery.

Voltage Drop - The net difference in the electrical potential (voltage) when measured across a resistance (ohms). Its relationship with current is described in Ohm's Law.

Voltage Regulator - A device that limits the charging voltage in a circuit. A device that regulates the output of a generator or alternator by controlling the current and voltage.

Voltage Reversal - The changing of the normal polarity of a battery due to over discharge.

Voltage, cutoff - Voltage at the end of useful discharge. (See Voltage, end-point.)

Voltage, end-point - Cell voltage below which the connected equipment will not operate or below which operation is not recommended.

Voltage, nominal - Voltage of a fully charged cell when delivering rated current.

Voltage-Keyed - A system that incorporates a mechanical identifier on batteries and devices to ensure only batteries of the correct voltage are connected to the device.

Voltmeter - An instrument used to measure the voltage in a circuit or the state of charge of a battery by measuring its open-circuit voltage.

Volt-ohm-meter (VOM) - Multimeter.

Volumetric Energy Density - The ratio of the energy output of a cell or battery to its volume (Wh/L).

VPC - Volts per cell - a six volt battery has 3 cells, a 12 volt has 6. All Lead Acid batteries are 2 volts (nominal) per cell.

VRLA - The acronym for Valve Regulated Lead Acid battery See Valve Regulated Lead Acid Battery.

W - Watt.

Wall - Lead-Acid Jar sides and ends.

Wall-less Design - A battery design where the structural support for the cells is formed by an open plastic framework.

Warm-up Time - The time required after initial turn on for a power supply to achieve compliance to its performance specifications

Washing - Removal of sediment from cells after taking out elements; usually accompanied by rinsing of groups, replacement of wood separators and renewal of electrolyte.

Watt (W) - A term used to measure power. The commercial unit of electrical power. A measurement of energy, arrived at by multiplying the voltage by the amperage. W = Amps x Volts. 120 volts 1 amp is the same as 12 volts 10 amps. It is also amps x amps x resistance. One horsepower = about 750 watts. A battery that can supply 220 AH at 12 volts is equal to 2640 watts. Watt-hours or kilowatt-hours (kwh) is how many watts times the number of hours. If a microwave pulls 1000 watts for 10 minutes, then it has used 1000/6, or 167 watt-hours. .

Watt Hour (WHr) - A unit of work. The product of power, expressed in watts, multiplied by the time, expressed in hours, over which the power is produced. The unit of electrical work. It is the product of power expended by time of expenditure, e.g., 10 amperes flowing under 32 volts pressure for 8 hours gives 2560 watt hours. Watt-Hour = Watts x Hours.

Wet Cell - A cell, the electrolyte of which is in liquid form and free to flow and move.

Z - Impedance.

Zinc Chloride - A chemistry used in some heavy-duty batteries.

Zinc/Air Cell - A primary battery (non-rechargeable) that was commonly used for applications such as watches and hearing aids. In relation to their physical size, Zinc/Air batteries store more energy per unit of weight (in terms of 220 W h/kg) than any other primary type. A dry-cell battery system that uses oxygen and catalyzed carbon as the cathode and zinc as the anode to produce electricity.

Reference Links:

http://www.ccbbattery.com/vip/w16388.htm

http://www.greenbatteries.com/batteryterms.html

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http://www.powerstream.com/1922/battery_1922_WITTE/batteryfiles/chapter11.htm

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