DEEP CYCLE BATTERIES - FREQUENTLY ASKED QUESTIONS

A word of caution: lead acid batteries contain a sulphuric acid electrolyte, which is a highly corrosive poison that will produce gasses when recharged and explode if ignited. This will hurt you—BAD! When working with batteries, you need to have plenty of ventilation, remove jewellery, wear protective eye wear (safety glasses) and clothing, and exercise caution. Do NOT allow battery electrolyte to mix with salt water. Even small quantities of this combination will produce chlorine gas that can KILL you! Whenever possible, please follow the manufacturer's instructions for testing, jumping, installing, storing, charging and equalising batteries.

This FAQ assumes a 12-volt, six cell, negative grounded, lead acid battery found in most recreational applications in Australia. For six-volt batteries, divide the voltage by two; for eight-volt batteries, divide by 1.5; for 24-volt batteries, double the voltage; and for 48-volt batteries, multiple by four.

The technical stuff is in *italics.*

1. What is the bottom line?

1.1. Remove the surface charge before testing and check specific gravity in each cell. (Please see Section 3.)

1.2. People kill batteries faster than old age due to improper charging! Recharge as soon as possible after discharge. (Please see Section 6.)

1.3. Size charger so that it will recharge the battery over an eight to ten hour period. (Please see Section 6.)

1.4. Buy the freshest and largest ampere-hour battery that will fit your requirements. (Please see Section 4.)

1.5. Perform preventive maintenance, especially during hot weather. (Please see Section 7.7.)

1.6. Shallower the average discharge, the longer the total battery life. (Please see Section 7.5.)

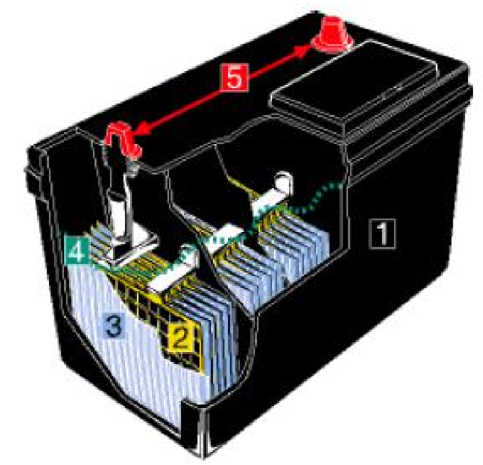
1.7. Temperature matters! **Heat kills** batteries and **cold reduces** the available capacity.

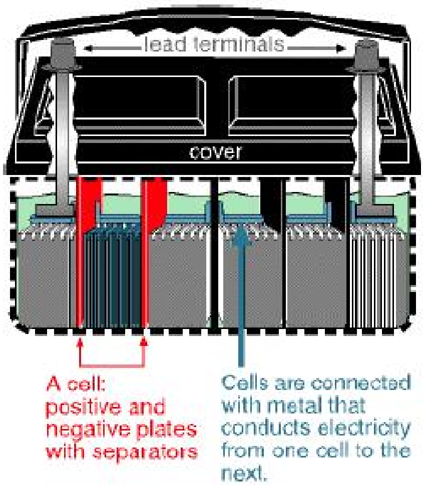
2. Why bother?

A good quality deep cycle lead acid battery will cost between $50 and $200 and, if properly maintained, will give you at least 150 deep discharge cycles. The purpose of a deep cycle battery is to provide power for trolling motors, golf carts, fork lift trucks, uninterruptible power supplies (UPS), and other accessories for marine and recreational vehicle (RV), commercial and stationary applications. Dead batteries almost always occur at the most inopportune times: across the lake, during bad weather, or on the 17th tee.

2.1. How is a battery made?

A twelve-volt deep cycle battery is made up of six cells, each producing 2.1 volts that are connected in series positive to negative. Each cell is made up of an element containing positive plates that are all connected together and negative plates, which are also all connected together. These plates are individually separated with thin sheets of electrically insulating, porous material ["envelopes" labelled #3 in the diagram below] that are used as spacers between the positive (usually light orange) and negative (usually slate grey) plates to keep them from electrically shorting to each other. The plates [#2 in the diagram below] within a cell, alternate with a positive plate, a negative plate and so on. A plate is made up of a metal grid that serves as the supporting framework for the active porous material which is “pasted” on it. In Europe, using solid lead positive “Plante” plates is popular.

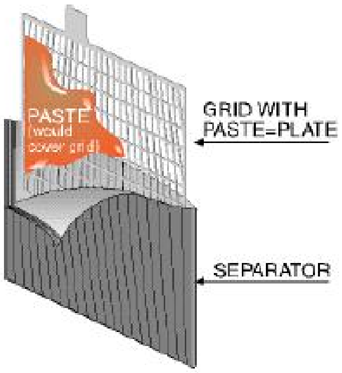




[Source: BCI]

After the “curing” of the plates, they are made up into cells, the cells inserted into a high-density tough polypropylene or hard rubber case. The cells are connected to the terminals [#5 in the diagram above], and the case is covered and filled with a dilute sulphuric acid electrolyte. The battery is initially charged or “formed” to convert yellow Lead Oxide (PbO or Litharge) into Lead Peroxide (PbO2), which is usually dark brown or black. The electrolyte is replaced and the battery is given a finishing charge.

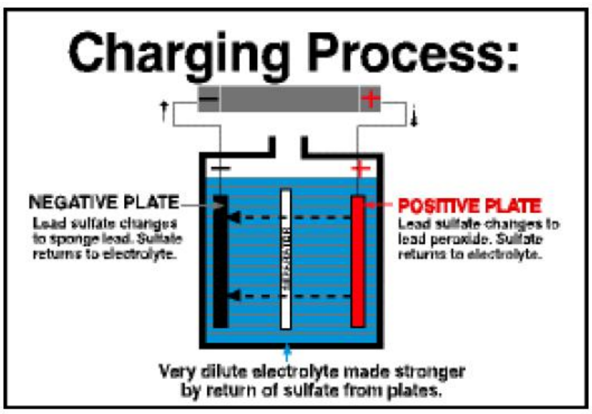
Some batteries are “dry charged,” meaning that the batteries are shipped without electrolyte and it is added and recharged when they are put into service.

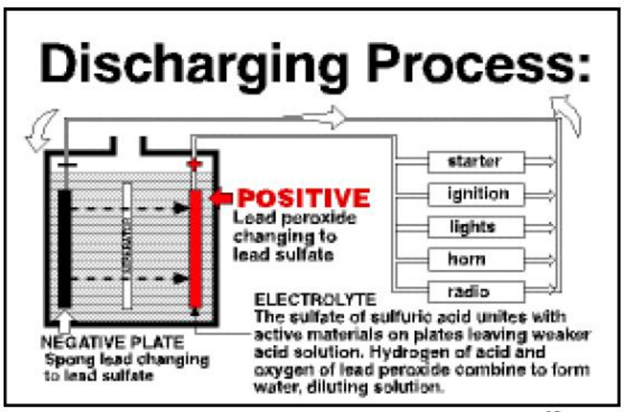


[Source: BCI]

Two important considerations in battery construction are porosity and diffusion. Porosity is the pits and tunnels in the plate that allows the sulphuric acid to get to the interior of the plate. Diffusion is the spreading, intermingling and mixing of one fluid with another. When you are using your battery, the fresh acid needs to be in contact with the plate material and the water generated needs to be carried away from the plate. The larger the pores or warmer the temperature, the better the diffusion.

2.2. How does a battery work?





[Source: BCI]

Alternating two different metals such as Lead Dioxide (PbO_2), the positive plates, and Spongy lead (Pb) create a battery, the negative plates. Then the plates are immersed in diluted Sulphuric Acid (H_2SO_4), the electrolyte. The types of metals and the electrolyte used will determine the output of a cell. A typical lead-acid battery produces approximately 2.1 volts per cell. The chemical action between the metals and the electrolyte creates the electrical energy. Energy flows from the battery as soon as there is an electrical load, for example, a motor that completes a circuit between the positive and negative terminals. The electrical current flows as charged portions of acid (ions) between the battery plates and as electrons through the external circuit. The action of the lead-acid storage battery is determined by chemicals used, stateof- charge, temperature, porosity, diffusion, and load determine the action of the lead-acid storage battery.

2.3. Why do batteries die?

In cold climates, a battery normally "ages" as the active positive plate material sheds (or flakes off) due to the expansion and contraction that occurs during the discharge and recharge cycles. A brown sediment, sludge or "mud," builds up in the bottom of the case and can short the cell out. In hot climates, additional causes of failure are positive grid growth, positive grid metal corroding in the electrolyte, negative grid shrinks, plates buckling, and loss of water. Deep discharges, heat, vibration, over charging, under charging and non-usage accelerate this "aging" process. Another major cause of premature battery failure is lead sulphation. Please see Section 12 for more information on sulphation. Using tap water to refill batteries can produce calcium sulphate, which also will coat the plates and fill pores. Recharging a sulphated battery is like trying to wash your hands with gloves on. When the active material in the plates can no longer sustain a discharge current, the battery "dies."

Most of the "defective" batteries returned to manufacturers during free replacement warranty periods are good. This suggests that most sellers of new batteries do not know how to or fail to take the time to properly load test or recharge them.

3. How do I 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 for between $20 and $200.

Analog voltmeters are not accurate enough to measure the millivolt differences of a battery's state-of-charge or the output of the charging system. The purchase of a battery load tester is optional; if you use a golf cart or electric trolling motor every day, buy one. A more accurate way of testing the capacity of a lead acid battery is by using a conductance tester, such as a Midtronics.

3.1. Inspect

Visually inspect for obvious problems. For example, is there a loose or broken alternator belt, 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, refill to 1/4 inch (6 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.

3.2. Recharge

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 equalise it. (Please see Section 6.)

3.3. Remove Surface Charge

Surface charge is the uneven mixture of sulphuric 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 appear weak. You need to eliminate the surface charge by one of the following methods:

3.3.1. Allow the battery to sit for four to twelve hours to allow for the surface charge to dissipate.

3.3.2. Apply a load that is 33% of the ampere-hour capacity for five minutes and wait five to ten minutes.

3.3.3. With a battery load tester, apply a load of at least one half the battery's CCA rating for 15 seconds, wait five to ten minutes and then test the terminal voltage or specific gravity.

3.4. Measure The-State-Of-Charge

If the battery's electrolyte is above 110° F (43.3° C), allow it to cool. 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.

Digital Voltmeter Open Circuit Voltage	Approximate State-of-Charge	Hydrometer Average Cell Specific Gravity	Electrolyte Freeze Point
12.65	100%	1.265	-75° F (-59.4° C)
12.45	75%	1.225	-55° F (-48.3° C)
12.24	50%	1.190	-34° F (-36.7° C)
12.06	25%	1.155	-16° F (-26.7° C)
11.89	Discharged	1.120	-10° F (-23.3° C)

STATE-OF-CHARGE
[Source: BCI]

Electrolyte Temperature Fahrenheit	Electrolyte Temperature Celsius	Add or Subtract to Hydrometer's SG Reading	Add or Subtract to Digital Voltmeter's Reading
160°	71.1°	+.032	+.192
150°	65.6°	+.028	+.168
140°	60.0°	+.024	+.144
130°	54.4°	+.020	+.120
120°	48.9°	+.016	+.096
110°	43.3°	+.012	+.072
100°	37.8°	+.008	+.048
90°	32.2°	+.004	+.024
80°	26.7°	0	0
70°	21.1°	-.004	-.024
60°	15.6°	-.008	-.048
50°	10°	-.012	-.072
40°	4.4°	-.016	-.096
30°	-1.1°	-.020	-.120
20°	-6.7°	-.024	-.144
10°	-12.2°	-.028	-.168
0°	-17.8°	-.032	-.192

TEMPERATURE COMPENSATION
[Source: BCI]

Electrolyte temperature compensation will vary depending on the battery manufacturer's recommendations. 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. 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.

Temperature Compensation

For non-sealed batteries, check the specific gravity in each cell with a hydrometer and average the readings. 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. Some batteries have a built-in hydrometer, which only measures the state-of-charge in ONE of its six cells. If the built-in indicator is clear or light yellow, then the battery has a low electrolyte level and should be refilled and recharged before proceeding. If sealed, the battery should be replaced.

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 also replace the battery if one or more of the following conditions occur:

3.4.1. If there is a 0.05 (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. (Please see Section 6.)

3.4.2. 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 Step 3.2 above. Battery electrolyte is a mixture of 25% sulphuric acid and distilled water. It is cheaper to replace the electrolyte than to buy a new battery.

3.4.3. If digital voltmeter indicates 0 volts, you have an open cell.

3.4.4. If the digital voltmeter indicates 10.45 to 10.65 volts, 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.

3.5. Load Test

If the battery is fully charged or has a “good” built-in hydrometer indication, then you can test the capacity of the battery by applying a known load and measuring the time it take 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.

3.6. Recharge

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 sulphation.

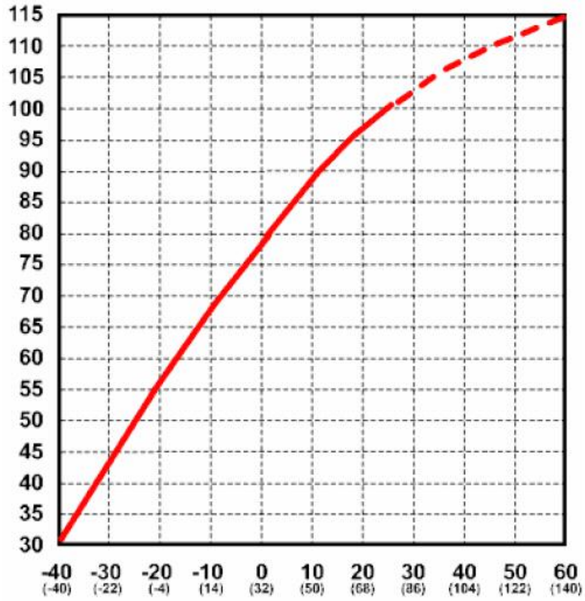
4. What do i look for in buying a new battery?

4.1. Ampere-Hour (or Reserve Capacity) Rating

The most important consideration in buying a deep cycle battery is the Ampere-Hour (AH) or Reserve Capacity (or Reserve Minutes) rating that will meet or exceed your requirements and how much weight you can carry. Most deep cycle batteries are rated in discharge rates of 100 hours, 20 hours, or 8 hours. The higher the discharge, the lower the capacity due to the Peukert Effect and the internal resistance of the battery.

Reserve Capacity (RC) is the number of minutes a fully charged battery a 80^{o} F (26.7 ^{o}C) is discharged at 25 amps before the voltage falls below 10.5 volts. To convert Reserve Capacity (RC) to Ampere-Hours at the 25 amp rate, multiple RC by 0.4167. More ampere-hours (or RC) are better in every case. Within a BCI group size, the battery with higher ampere-hours (or RC) will tend to have longer lives and weigh more because of thicker plates and more lead.

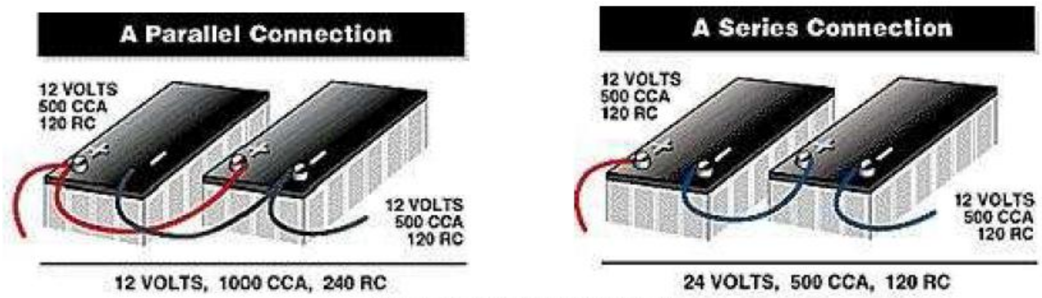
The following graph shows the effects of temperature on the capacity of a battery:



CAPACITY vs. TEMPERATURE °C
[Source: Concorde]

If more ampere-hours are required, you can connect two (or more) new and identical 12-volt batteries in parallel. You can also connect two larger new and identical six-volt batteries in series by attaching the negative terminal of the first battery to the positive terminal of the second battery. If you connect two 12-volt batteries in parallel that are identical in type, age and capacity, you can potentially double the total capacity. If you connect two that are not the same type, you will either overcharge the smaller of the two, or you will undercharge the larger of the two.

The recommended parallel and series connections are as follows:



[Source: Interstate Batteries]

When connected this way, the batteries will discharge and recharge equally. When connecting in series or parallel and to prevent recharging problems, do NOT mix old and new batteries or ones of different types. Cable lengths should be kept short and cable must be sized large enough to prevent significant voltage drop; there should be a maximum of 0.2 volts (200 millivolts) or less drop between batteries.

4.2. Type

Car batteries are especially designed for high initial cranking amps (usually 200 to 400 amps for five to 15 seconds) to start a car and for shallow (10% or less) discharges. They are not designed for deep cycle discharges. Deep cycle (and marine) batteries are designed for prolonged discharges at lower current and not for high current discharges. The plates in a car battery are more porous and thinner than in deep cycle batteries and use sponges or expanded metal grids instead of solid lead. A deep cycle battery will typically outlast two to ten car batteries when used in deep cycle applications. In warm weather, starting an engine will typically consume less that 5% of a car battery’s capacity. In contrast, deep cycle (or marine) batteries are used for applications that will consume between 20 and 80% of the battery’s capacity.

A “dual” or starting marine battery is a compromise between a car and a deep cycle battery that is specially designed for marine applications. A deep cycle or “dual marine” battery will work as a starting battery if it can produce enough current to start the engine, but not as well as a car battery. For saltwater applications, AGM or gel cell batteries are highly recommended to prevent chlorine gas.

For RVs, a car battery is normally used to start the engine and a deep cycle battery is used to power the RV accessories. The batteries are connected to a diode isolator. When the RV's charging system is running, both batteries are automatically recharged.

The two most common types of deep cycle batteries are flooded (also known as wet or liquid electrolyte) cell and valve regulated (VR). These types are divided into Marine and RV batteries. There are 50% depth-of-discharge limits and sponge lead plates batteries, and there are the more expensive Deep Cycle (traction and stationary) batteries with 80% depth-of-discharge limits, solid lead plates, and longer lives.

4.2.1. Flooded (Wet) Cell

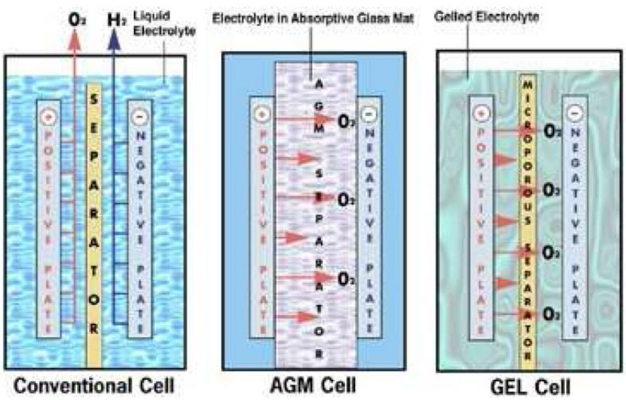
Flooded cell deep cycle batteries are divided, like their car battery counterparts, into low maintenance (the most common) and maintenance free (or sealed), which is based on their plate formulation. Low maintenance batteries have leadantimony/ antimony or lead-antimony/calcium (dual alloy or hybrid) plates whereas the maintenance free batteries use

lead-calcium/calcium. The advantages of maintenance free batteries are less preventive maintenance, up to 250% less water loss, faster recharging, greater overcharge resistance, reduced terminal corrosion, up to 40% more life cycles, and up to 200% less self discharge. However, they are more prone to deep discharge (dead battery) failures due to increased shedding of active plate material and development of a barrier layer between the active plate material and the grid metal.

Further, if sealed, they tend to have a shorter life in hot climates because lost water cannot be replaced. Automobile industry liability lawyers prefer this type of battery because consumers are less likely to be injured. Finally, maintenance free batteries are generally more expensive than low maintenance batteries.

4.2.2. Valve Regulated

Gas-recombinant Valve Regulated Lead Acid (VRLA) batteries are generally divided into two groups, gel cell and Absorbed Glass Mat (AGM). VRLA batteries are spill proof, so they can be used in semi-enclosed areas, are totally maintenance free, and have a longer shelf life. Their greatest disadvantage is the high initial cost (two to three times) but arguably can have an overall lower total cost of ownership due to a longer lifetime and no "watering" labour costs, only IF they are properly maintained and recharged.

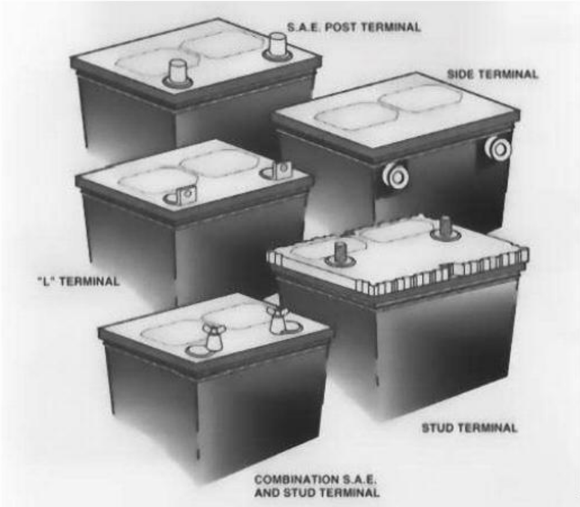


[Source: Hawker]

4.3. Size and Terminals

In North America, a Battery Council International (BCI) group number (e.g., U1, 24, 27, 31, 8D, etc.) is based on the physical case size, terminal placement and terminal polarity. In Europe, the EN, IKC, Italian CEI, and German DIN standards are used and in Asia, the Japanese JIS standard is used. Within a group, the ampere-hour or RC ratings, warranty and battery type will vary in models of the same brand or from brand to brand. Generally, batteries are sold by model, and some of the group numbers are sold for the same price. This means that for the same money you can potentially buy a physically larger battery with more ampere-hour or RC than the battery you are replacing. Be sure that the replacement battery will fit, the cables will correct to the correct terminals, and that the terminals will not touch anything else.

There are six types of battery terminals—SAE Post, GM Side, "L", Stud, combination SAE and Stud, and combination SAE Post and GM Side. For automotive applications, the SAE Post is the most popular, followed by GM Side and then the combination "dual" SAE Post and GM Side. "L" terminal is used on some European cars, motorcycles, lawn and garden devices, snowmobiles, and other light duty vehicles. Stud terminals are used on heavy duty and deep cycle batteries. The positive SAE Post terminal is slightly larger (by 1/16") than the negative one. Terminal locations and polarity will vary.



[Source: BCI]

4.4. Battery Freshness

Determining the "freshness" of a battery is sometimes difficult. NEVER buy a non-sealed wet lead acid battery that is MORE than THREE months old or a sealed (VRLA) battery that is MORE than SIX months old. This is because by then it has started to sulphate unless it has periodically been recharged (this is not the usual practice of many retailers) or it is "dry charged". The exceptions to this recommendation are AGM and Gel Cell batteries, which can be stored up to 12 months before the state-of-charge drops 80% or below. Please see Section 12 for more information on sulphation.

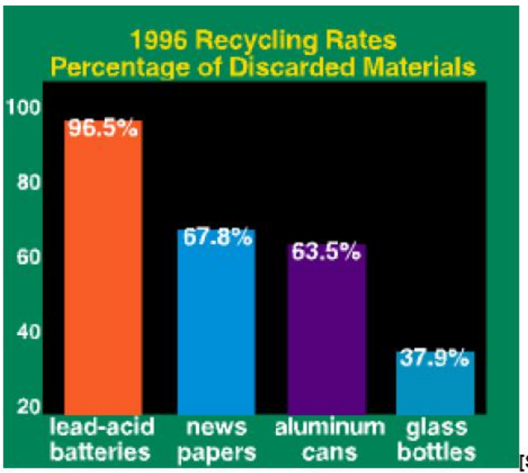
Dealers will often place their older batteries in storage racks so they will sell first. The new batteries can often be found in the rear of the rack or in a storage room. The date of manufacture is stamped on the case or printed on a sticker.

5. How do I install a battery?

5.1. Thoroughly wash and clean the old battery, battery terminals and case or tray with warm water to minimise problems from acid or corrosion. Heavy corrosion can be neutralised with a mixture of 500g of baking soda to 4 litres of warm water. Wear safety goggles and, using a stiff brush, brush away from yourself. Also, mark the cables so you do not forget which one to reconnect.

5.2. Turn off all electrical switches in the vehicle and shut off the ignition switch. Disable any alarm systems. Remove the NEGATIVE cable first because this will minimise the possibility of shorting the battery when you remove the other cable. Secure the negative cable so that it cannot "spring" loose and make electrical contact. Next remove the POSITIVE cable and then the hold-down bracket or clamp. If the hold down bracket is severely corroded, replace it.

Dispose of the old battery by exchanging it when you buy your new one or by taking it to a recycling centre. According to BCI, over 96% of the old battery lead is recycled, making batteries one of the most completely recycled of all recycled items. Please remember that batteries contain large amounts of harmful lead and acid, so please dispose of your old battery properly for safety and to protect our fragile environment.



[Source: BCI]

5.3. After removing the old battery, be sure that the battery tray or box and cable terminals or connectors are clean. Auto parts stores sell a cheap wire brush that will allow you to clean the inside of terminal clamps and the terminals. If the terminals, cables or hold down brackets are severely corroded, replace them. Corroded terminals or swollen cables will significantly reduce starting capability.

5.4. Use paraffin oil-soaked felt washer pads found at auto parts stores or thinly coat the terminal, terminal clamps and exposed metal around the battery with a high temperature grease or petroleum jelly (Vaseline) to prevent corrosion. Do not use the felt or metal washers between the mating conductive surfaces with side, stud or “L” terminal batteries. Use of stainless steel and other metal washers and bolts have also caused problems with electrolysis and high resistance.

5.5 Place the replacement battery so that the NEGATIVE cable will connect to the NEGATIVE (-) terminal. Reversing the polarity of the electrical system will severely damage or DESTROY it. It can even cause the battery to explode.

5.6. After replacing the hold-down bracket, reconnect the cables in reverse order, i.e., attach the POSITIVE cable first and then the NEGATIVE cable last.

5.7. Before using the battery, check the electrolyte levels and add distilled water to cover the plates. Check the state-ofcharge and recharge if necessary. Then recheck the electrolyte levels after the battery has cooled and top off with distilled water as required, but do not overfill.

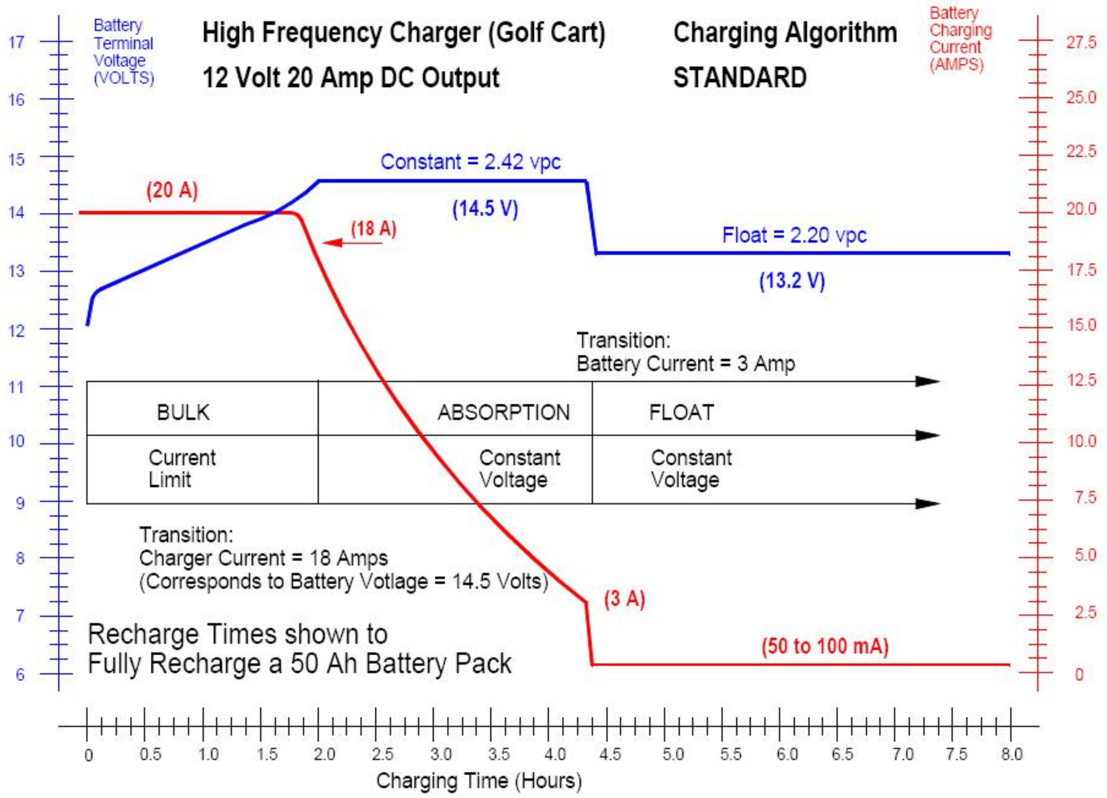
6. How do I recharge my battery?

There are up to four phases of battery charging—bulk, absorption, equalisation and float. The bulk stage is where the charger current is constant and the battery voltage increases. You can give the battery whatever current it will accept not to exceed 20% of the ampere-hour rating and this will not cause overheating. The absorption phase is where the charger voltage is constant and current decreases until the battery is fully charged. This normally occurs when the charging current drops off to 1% or less of the ampere-hour capacity of the battery. For example, the ending current for a 100 ampere-hour battery is 1.0 amp or less.

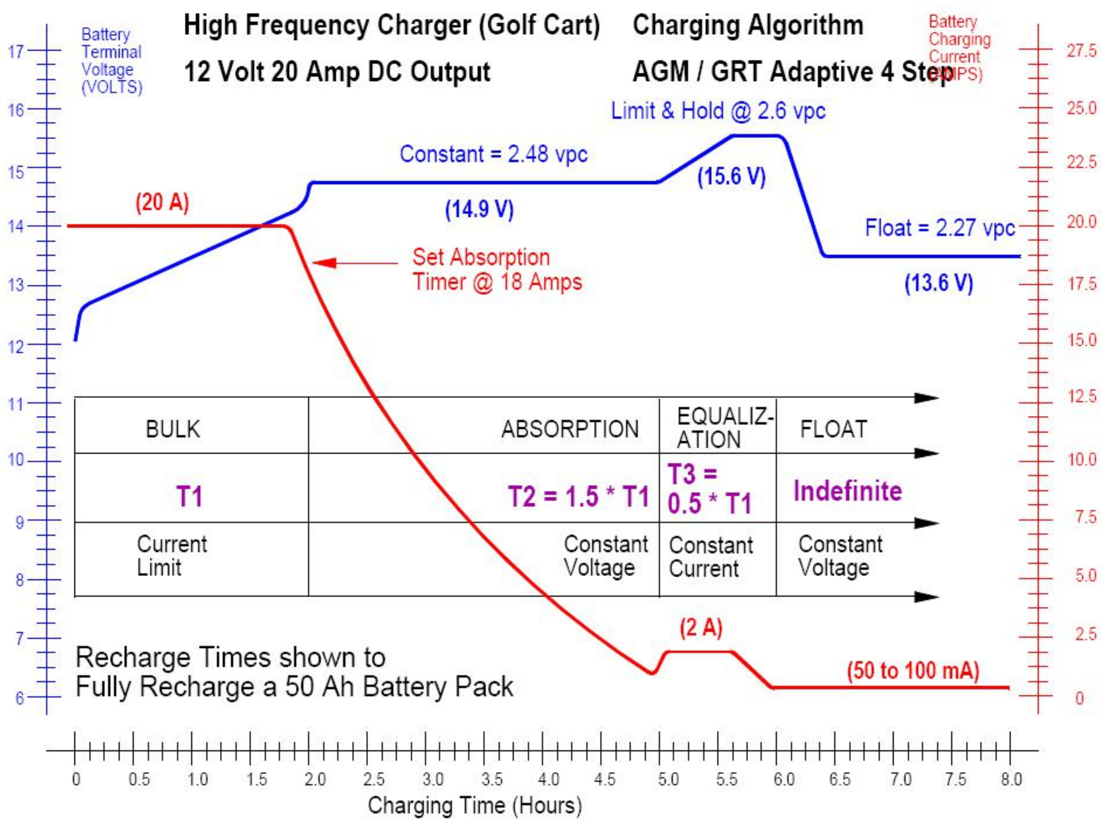
The optional equalising phase is a controlled 5% overcharge, which equalises and balances the voltage and specific gravity in each cell, the effect of increasing the charge voltage. Equalising reverses the build-up of chemical effects like stratification, where acid concentration is greater in the bottom of the battery. It also helps remove sulphate crystals that might have built up on the plates. The frequency recommendation varies by manufacturer from once a month to once a year, from 10 to 100 deep cycles, or when a specific gravity difference between cells reaches .03. To equalise, fully recharge the battery; next, increase the charging voltage to the manufacturer’s recommendations (if you cannot find one, ADD 5%). Heavy gassing should start occurring (**be VERY CAREFUL about safety precautions**). Take specific gravity readings in each cell once per hour. Equalisation has occurred once the specific gravity values no longer rise during the gassing stage.

The optional float phase is where the charge voltage is reduced, held constant and used indefinitely to maintain a fully charged battery. Please refer to Section 9 for more information about storing batteries and float charging them.

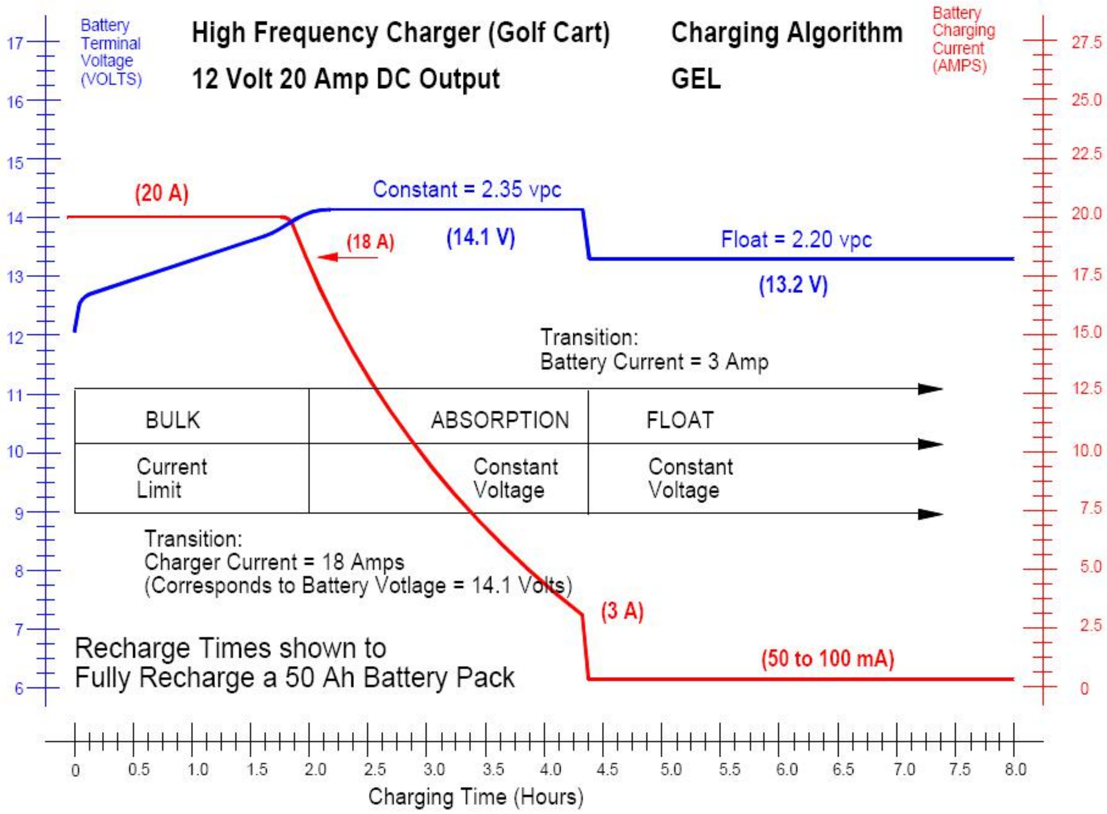
Standard Deep Cycle (Lead-Antimony/Antimony) **[Source: Deltran]**



Absorbed Glass Mat Deep Cycle (AGM) **[Source: Deltran]**



Gel Cell Deep Cycle **[Source: Deltran]**



It is important to use the battery manufacturer's charging recommendations whenever possible for optimum performance and life. **In addition to the earlier cautions, here are some more words of caution:**

6.1. **NEVER, NEVER disconnect a battery cable from a vehicle with the engine running** because the battery acts like a filter for the electrical system. Unfiltered [pulsating DC] electricity can damage expensive electronic components, e.g. emissions computer, radio, charging system, etc. Turn off all electrical switches and components, turn off the ignition and then disconnect the battery.

6.2. For non-sealed batteries, check the electrolyte level. Make sure it is covering the plates, and it is not frozen BEFORE starting to recharge.

6.3. Do NOT add distilled water if the electrolyte is covering the top of the plates because during the recharging process, it will warm and expand. After recharging has been completed, RECHECK the level.

6.4. Reinstall the vent caps BEFORE recharging, recharge ONLY in well-ventilated areas, and wear protective eye ware.

Do NOT smoke or cause sparks or flames while the battery is being recharged because batteries give off explosive gasses.

6.5. If your battery is an AGM or a sealed flooded type, do NOT recharge with current ABOVE 12% of the battery's RC rating (or 20% of the ampere-hour rating). Gel cells should be charged over a 20-hour period and never over the manufacturer's recommended level or over 14.1 VDC.

6.6. Follow the battery and charger manufacturer's procedures for connecting and disconnecting cables and other steps to minimise the possibility of an explosion or incorrectly charging the battery. You should turn the charger OFF before connecting or disconnecting cables to a battery. Do not wiggle the cable clamps while the battery is recharging, because a spark might occur, and this might cause an explosion. Good ventilation or a fan is recommended to disperse the gasses created by the recharging process.

6.7. If a battery becomes hot, over 110^{O} F (43.3^{O} C), or violent gassing or spewing of electrolyte occurs, turn the charger off temporarily or reduce the charging rate. This will also prevent 'thermal runaway" that can occur with VRLA batteries.

6.8. Insure that charging with the battery in the car with an external MANUAL charger will not damage the vehicle's electrical system with high voltages. If this is even a remote possibility, then disconnect the vehicle's battery cables from the battery BEFORE connecting the charger.

6.9. If you are recharging gel cell batteries, a manufacturer's charging voltages can be very critical. Sometimes, you might need special recharging equipment. In most cases, standard deep cycle chargers used to recharge wet batteries cannot be used to recharge gel cell and AGM batteries because of their charging profiles; using them will shorten battery life or cause "thermal runaway". Match the charger (or charger's setting) for the battery type you are recharging or floating.

Use an external constant current charger, which is set not to deliver more than 12% of the RC rating of the battery and monitor the state-of-charge. Timers that will cut-off the charger will help prevent overcharging the battery. For discharged batteries, the following table lists the recommended battery charging rates and times:

Reserve Capacity (RC) Rating	Slow Charge (*R* recommended*)*	Fast Charge (Not recommended)
80 Minutes or less [32 ampere hours or less]	15 Hours @ 3 amps	5 Hours @ 10 amps
80 to 125 Minutes [32 to 50 ampere hours]	21 Hours @ 4 amps	7.5 Hours @ 10 amps
125 to 170 Minutes [50 to 68 ampere hours]	22 Hours @ 5 amps	10 Hours @ 10 amps
170 to 250 Minutes [68 to 100 ampere hours]	23 Hours @ 6 amps	7.5 Hours @ 20 amps
Above 250 Minutes [over 100 ampere hours]	24 Hours @ 10 amps	6 Hours @ 40 amps

The BEST method is to SLOWLY recharge the battery at 70^{O} F (21.1^{O} C) over a 10 to 20 hour period (C/10 to C/20) using an external constant voltage (or tapered current charger) because the acid has more time to penetrate the plates and there is less mechanical stress on the plates. C-rate is a measurement of the charge or discharge of battery overtime. It is expressed as the Capacity of the battery divided by the number of hours to recharge or discharge the battery. For example, assume that the ampere-hour capacity of the battery is 220, then it would take 11 hours to recharge or discharge the battery using a C/20 rate. A constant voltage or "automatic" charger applies regulated voltage at approximately 13.8 to 16 volts, based on the manufacturer's recommendations and temperature. A 10 amp constant voltage charger will cost between $30 and $60 at an auto parts store is suitable for most simple recharging or charging applications.

More expensive three stage microprocessor controlled chargers are available that will automatically provide bulk, absorption and float charging. A four-stage charger will provide an equalising charge in addition to the bulk, absorption and float charging.

An excellent automatic constant voltage battery charger is a 15-volt regulated power supply adjusted to the manufacturer's recommendations or, if not available, to voltage ranges below with the electrolyte at 70^{O}F (21.1 ^{O}C):

Battery Type	Charging Voltage	Float Voltage	Equalising Voltage
Wet Low Maintenance	*14.4*	*13.2*	*15.1*
Wet Maintenance Free	*14.8*	*13.4*	*15.5*
Sealed & VRLA	*14.4*	*13.2*	*15.1*
AGM	*14.4*	*13.6*	*15.5*
Gel Cell	*14.1*	*13.2*	*N/A*
Wet Deep Cycle	*14.5*	*13.2*	*15.8*

Charging Voltages

To compensate for electrolyte temperature, which has a negative temperature compensation coefficient, adjust the charging voltage .0028 (2.8 millivolts) volts/cell/degree F.

For example, if 30°F (-1.1 °C), then INCREASE the charging voltage to 15.07 volts for a wet, low maintenance battery. If 100°F (37.8°C), then DECREASE the charging voltage to 13.90 volts.

If left unattended, a cheap, unregulated trickle battery charger can overcharge your battery because they can "boil off" the electrolyte. Do NOT use fast, high rate, or boost chargers on any battery that is sulphated or deeply discharged. The electrolyte should NEVER bubble violently while recharging because high currents only create heat and excess explosive gasses.

7. Can I increase the life of my battery?

The typical life of a deep cycle battery is:

Battery Type	Years Of Use
Marine	Up to 6 years
Golf Cart	Up to 6 years
Gelled deep cycle	Up to 8 years
AGM	Up to 10 years
Ni-Cad	Up to 10 years
Telecommunications (Float Mode)	Up to 15 years
Fork Lift	Up to 10 years
Industrial (Traction)	Up to 20 years
Industrial (Stationary)	Up to 20 years
Ni-Fe	Up to 20 years

7.1. Recharging slowly and keeping your battery well maintained are the best ways to extend the life of your battery.

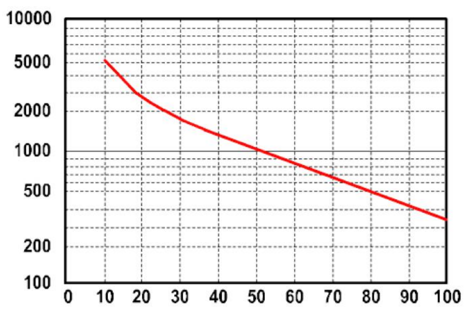
7.2. Recharge a deep cycle battery as soon as possible after each use to prevent sulphation. Leaving a battery connected to an energised charging source will also dramatically lengthen its service life.

7.3. In warmer climates and during the summer, "watering" is required more often. Check the electrolyte levels and add distilled water, if required. Never add electrolyte to a battery that is not fully charged—just add distilled water and do not overfill. The plates must be covered at all times.

7.4 High ambient temperatures (above 80° F [26.7 ° C]) will shorten battery life because it increases positive grid corrosion and growth.

7.5 Shallower the average depth-of-discharge (DoD), increases the battery life. For example, a battery with an average of 50% DoD will last twice as long or more as an 80% DoD; a 20% DoD battery will last five times longer than a 50% DoD.

For example, golf cart batteries will average 225 cycles at 80% DoD and increase to 750 cycles at 50% DoD. Try to avoid DoD that is less than 10% or greater than 80%. Industrial traction and stationary deep cycle batteries are designed for 80% DoD and most marine and RV deep cycle batteries are designed for 50% DoD.



Depth-of-Discharge (DoD) [Source: Concorde]

7.6 When in storage, recharging when the State-of-Charge drops to 80% or below will prevent lead sulphation.

7.7 Maintaining the correct state-of-charge while in storage, electrolyte levels, tightening loose hold-down clamps and terminals, and removing corrosion is normally the only preventive maintenance required for a deep cycle battery.

7.8 Avoid “opportunity charging." Size the battery so that there is a minimum of one cycle per day.

7.9 NEVER discharge below 10.5 volts.

8. What art the most common causes of premature battery failures?

8.1. Loss of electrolyte due to heat or overcharging,

8.2. Lead sulphation in storage (See Section 12),

8.3. Undercharging,

8.4. Old age (positive plate shedding) or “Sludging”,

8.5. Excessive vibration,

8.6. Freezing or high temperatures,

8.7. Using tap water which causes calcium sulphation,

8.8. Positive grid corrosion or growth due to high temperatures,

8.9. Fast recharging at rates greater than C/10.

9. How can I store batteries?

Batteries naturally self-discharge 1% to 15% per month while in storage, and lead sulphation will start occurring when the state-of-charge drops below 80%. If left in a vehicle, disconnecting the negative cable will reduce the level of discharge by eliminating the parasitic load. Cold will slow the self-discharge process down and heat will speed it up. Use the following six simple steps to store your batteries:

9.1. Physically inspect for damaged cases, remove any corrosion, and clean and dry the battery tops.

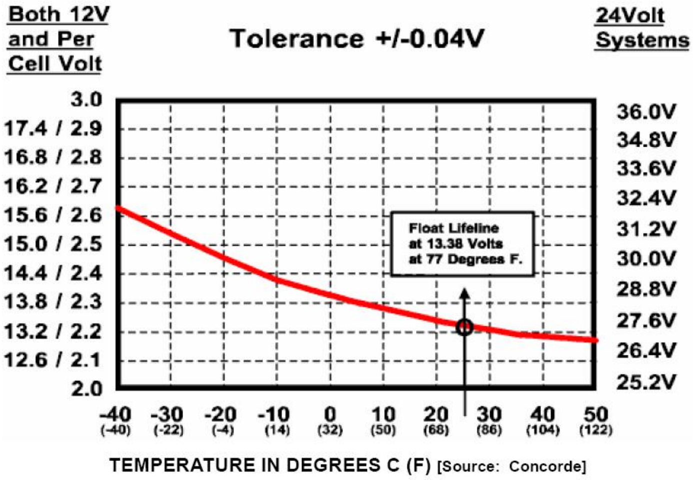
9.2. Fully recharge the batteries.

9.3. Check the electrolyte levels and add distilled water as required, but avoid overfilling.

9.4. Store in a cool dry place, but not below 32^{o} F (0^{o} C).

Depending on the ambient temperature and self-discharge rate, periodically test the state-of-charge using the procedure in Section 4. When the state-of-charge drops below 80%, recharge the batteries using the procedures in Section 6. An alternative would be to connect an automatic voltage regulated, solar panel or “smart trickle” charger to “float” batteries. Based on the manufacturer’s recommendations, use an automatic or smart charger that has been manufactured for this purpose and battery type. You may also use a setting of 13.02 to 13.8 volts for wet batteries and 13.2 to 14.1 volts for VRLA batteries, compensated for temperature, and the correct automatic or smart charger that has been designed not to overcharge the batteries.

The following graph from Concorde demonstrates the effect of temperature on float voltage requirements.



9.5. Equalise only wet (flooded) or AGM batteries, when you remove the batteries from storage; use the procedure in Section 6.

10. WHAT ARE SOME OF THE MYTHS ABOUT BATTERIES?

10.1. Storing a battery on a concrete floor will discharge them.

A hundred years ago when battery cases were made of porous materials, such as wood, storing batteries on concrete floors would accelerate their discharge. Modern battery cases made of polypropylene or hard rubber, which are better sealed, so external leakage, causing discharge, is no longer a problem. However, the top of the battery must be clean and dry. Temperature stratification within large batteries could accelerate the internal “leakage” or self-discharge if the battery is sitting on a cold floor in a warm room or is installed in a submarine.

10.2. Driving a car will fully recharge a battery.

Some of factors affecting a car charging system’s ability to charge a battery are: how much current from the alternator is diverted to the battery to charge it, how long the current is available and the temperature. Generally, idling the engine or on short “stop-and go trips” during bad or hot weather or at night will not recharge a battery. A long daytime trip in warm weather should recharge a battery.

10.3. A battery will not explode.

Recharging a wet lead-acid battery normally produces hydrogen and oxygen gasses. While spark retarding vent caps help prevent battery explosions, they occur when jumping, connecting or disconnecting charger or battery cables, and starting the engine. While not fatal, battery explosions cause thousands of eye and burn injuries each year.

When battery explosions occur when starting an engine, here is the usual sequence of events: One or more cells had a high concentration of hydrogen gas (above 4.1%) because the vent cap was clogged or a defective valve did not release the gas. The electrolyte levels fell below the top of the plates due to high under hood temperatures, overcharging, or poor maintenance. A low resistive bridge or “treeing” formed between the top of the plates such that when the current started to flow, it caused an arc or spark in one of the cells. That combination of events ignites the gas, blows the battery case cover off and spatters electrolyte all over the engine compartment. The largest number of battery explosions while starting an engine occurs in hot climates.

When an explosion happens, thoroughly rinse the engine compartment with water, and then wash it with a solution of 500g baking soda to 4.5L of warm water to neutralise the residual battery acid. Then thoroughly rewash the engine compartment with water. Periodic preventive maintenance (please see Section 7.7.), working on batteries in wellventilated areas or using Valve Regulated Lead Acid (AGM or gel cell) type batteries can significantly reduce the possibility of battery explosions.

10.4. A battery will not lose its charge sitting in storage.

Depending on the type of battery, it has natural self-discharge or internal electrochemical “leakage” at a 1% to 15% rate per month that will cause it to become sulphated and fully discharged over time. Higher temperatures accelerate this process. A battery stored at 95^{O}F (35^{O}C) will self discharge twice as fast than one at 75^{O}F (23.9^{O}C). (Please see Section 9.)

10.5. Maintenance free batteries never require maintenance.

In hot climates, water in the electrolyte is “decomposed” due to the high temperatures and normal charging of a wet maintenance free battery. Water can also be lost due to excessive charging voltage or charging currents. Non-sealed batteries are recommended in hot climates so they can be refilled with distilled water when this occurs. Please see Section 7.7. for other preventive maintenance that should be performed on “maintenance free” batteries.

10.6. Test the alternator by disconnecting the battery with the engine running.

A battery as like a voltage stabiliser or filter to the pulsating DC produced by the charging system. Disconnecting a battery while the engine is running can destroy sensitive electronic components, for example, emission computer, audio system, cell phone, alarm system, etc., or even the charging system itself. These damages can occur because the voltage can rise to 40 volts or more. In the 1970s, removing a battery terminal was an accepted practice to test charging systems of that era. That is not the case today. Just say NO if anyone suggests this.

10.7. Pulse chargers, aspirins or additives will revive sulphated batteries.

Using pulse chargers or additives is a very controversial subject. Most battery experts agree that there is no conclusive proof that more expensive pulse chargers work any better than constant voltage chargers to remove sulphation. They also agree that there is no evidence that additives or even aspirins provide any long-term benefits.

10.8. On really cold days turn your headlights on to “warm up” the battery up before starting your engine.

While there is no doubt that turning on your headlights will increase the current flow in a car battery; it also consumes valuable capacity that could be used to start the engine. Therefore, this is not recommended. For extremely cold temperatures, externally powered battery warmers, battery blankets, or engine block heaters are highly recommended. AGM and Ni-Cad batteries perform better in extremely cold temperatures than wet cell batteries.

10.9. Batteries last longer in hot climates than in cold ones.

Batteries last approximately two thirds as long in hot climates as cold ones. Heat kills batteries, especially sealed wet lead acid batteries.

10.10 Deep cycle batteries have a memory.

Lead acid deep cycle batteries do not have the so called “memory effect” that first generation Ni-Cad batteries have.

11. How long will a deep cycle 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 of the battery, load and temperature. For a fully charged battery at 70^{O}F (21.1^{O}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.

12. How can I revive a sulphated battery?

Lead sulphation occurs when a lead sulphate compound is deposited on the lead electrodes of a storage battery; this is a problem if the lead sulphate 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 sulphate, 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.

12.1. Light Sulphation

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 sulphate crystals. If the battery gets above 110^{O}F (43.3^{O}C) then stop charging and allow the battery to cool down before continuing. DO NOT drop the battery in the belief that the vibration will loosen and remove the sulphation. This action will kill a battery due to fractures of the cells and internal connections.

12.2. Heavy Sulphation

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 the old 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^{O} F (43.3^{O} 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 sulphate crystals are more soluble in distilled water than in electrolyte. As they are dissolved, the sulphate is converted back into sulphuric acid and the specific gravity rises. These techniques will only work with some batteries. We have had some success with our 3 step chargers having recovered 8 year old AGM type batteries from the grave to around 95-100% capacity.

13. How can I reduce the 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.