5. HOW DO I KNOW IF MY CHARGING SYSTEM IS OK OR LARGE ENOUGH?

Last Updated on July 11, 2004

INDEX:

5.1. What If My "Battery" or "Alternator" Light Is On? (Or the Gauge Is Not Showing a "Charging" Condition?)

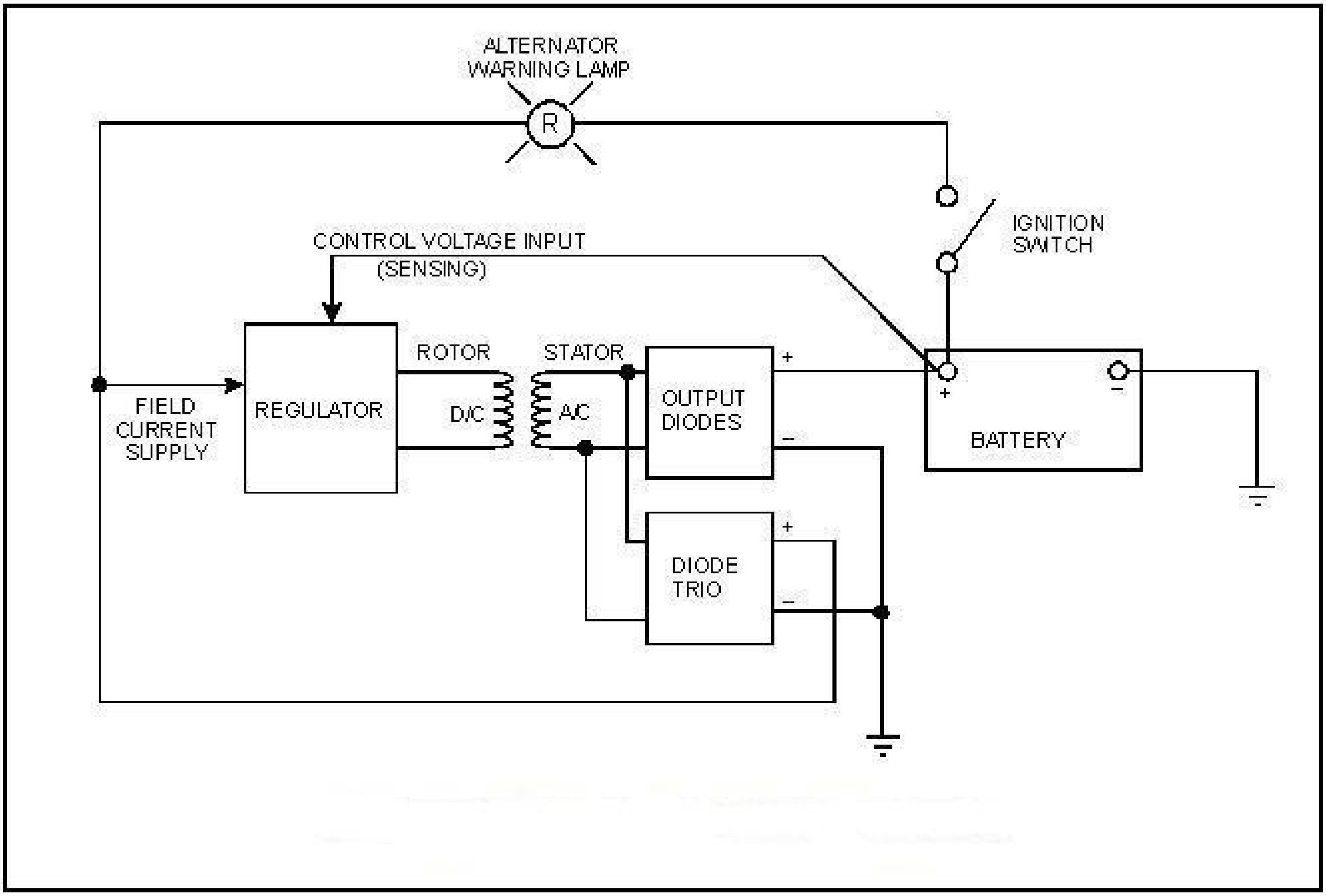
The "Battery" or "Alternator" light is an indication that there is a significant **mismatch** between the voltage that the charging system is producing and the battery voltage. Some vehicles use a voltmeter or current meter to indicate if the charging system is working. The battery and charging system **must** work together to provide the electrical power for the vehicle and to keep the battery recharged so it can restart the engine. The most common causes, in the order of priority, are:

- Low electrolyte levels
- Slipping or broken alternator belt
- Corrosion between the battery posts and the battery cable terminals
- Faulty charging system
- Defective battery

If the electrolyte levels, alternator belt is OK and the battery terminal connections are free from corrosion, then take your vehicle to an auto parts or battery store, and have the battery and charging system tested (highly recommended) or use the troubleshooting guide below. Some stores like Auto Zone, Sears, Wal-Mart, Pep Boys, etc. in the U.S. will test them for free. One of the first three simple faults in the list above has caused many a good battery to be replaced. A new battery can cause a weak alternator or starter to fail.

Referring to Dan Masters' diagram below, a vehicle's charging system is composed of an alternator (or DC generator), voltage regulator, battery, and indicator light or gauge. While the engine is running, the charging system's **primary** purpose is to provide power for the car's electrical load, for example, ignition, lighting, audio system, accessories, etc., and to recharge your vehicle's battery. Its output capacity is directly proportional to the RPM of the engine and alternator temperature. Charging systems are normally sized by the car manufacturers to provide at least 125% (when operating at high RPM) of the worst-case OEM (Original Equipment Manufacturer) electrical load, so that the car battery can be recharged. That is the reason that short, stop and go driving at night or in bad weather might not keep the battery fully recharged, especially if the electrical load has been increased with after market accessories, such as high power audio equipment.

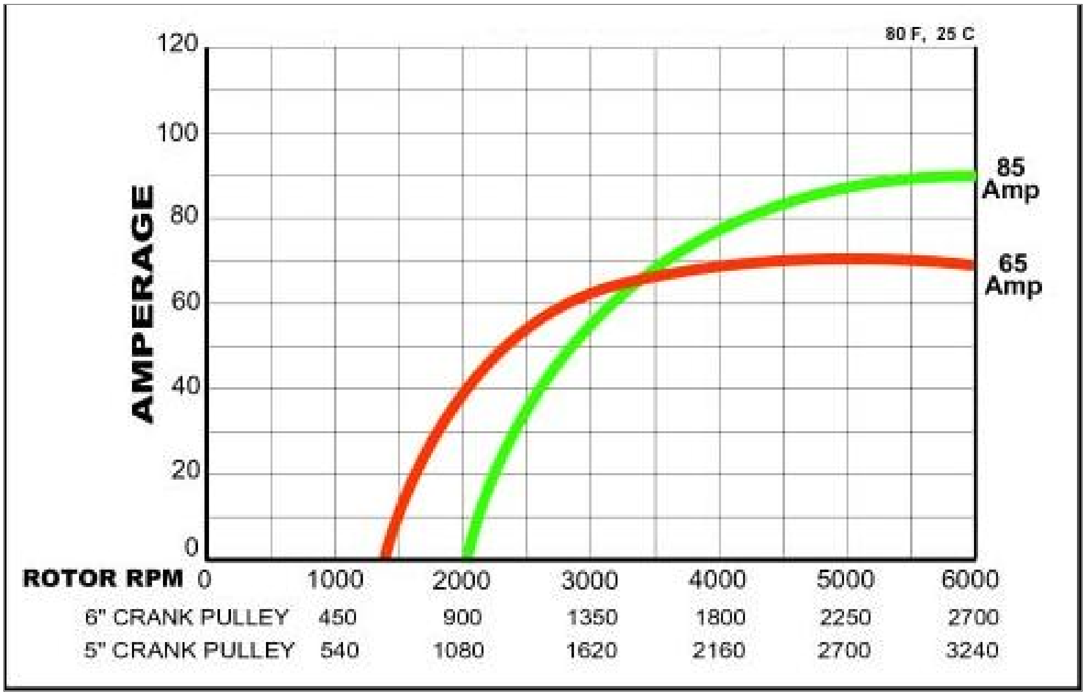
CHARGING SYSTEM FUNCTIONAL DIAGRAM



[Source: Vintage Triumph Register]

In the Balmar Alternator Output diagram below, the power output curves are shown 65 amp and 85 amp alternator. Note that the 65 amp alternator in this example, produces more current output (power) at a lower RPM that does the larger alternator until approximately 3300 RPM. Also note the difference that the crankshaft pulley size makes. A larger crankshaft pulley will create a higher alternator RPM; thus, causing the alternator to produce more power at a lower engine RPM. An alternation require one horsepower on a diesel engine to produce 20 to 25 amps and for gas engine 10 to 15 amps.

ALTERNATOR OUTPUT GRAPH

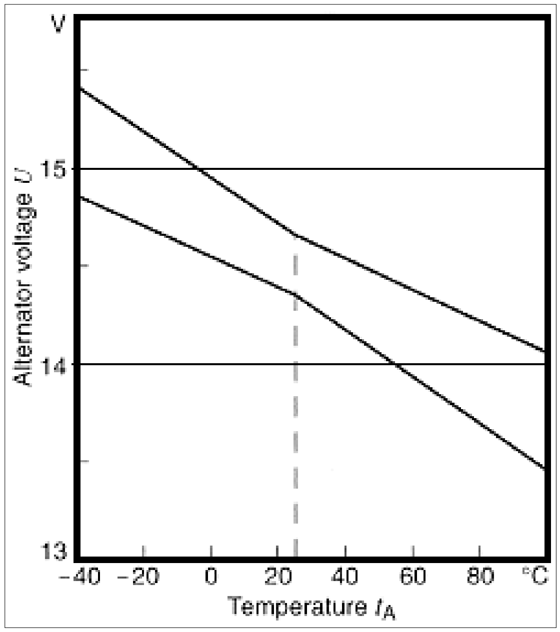


[Source: Balmar]

When the charging system fails, usually a "battery" or "alternator" warning indicator or light will come on or the voltage (or amp) gauge will not register "good". If you increase the engine speed and the alternator light becomes **brighter**, then the battery needs to be fully recharged and tested. If the light becomes **dimmer** then the problem is most likely in the charging system. The indicator (also known as an "idiot") light is a direct comparison between the voltage output of charging system and the voltage output of the battery. The next test requires use of a known-to-be-good, fully charged battery. Temporarily replace the old battery with this battery and run the engine at 2500 RPM or more for two minutes. Depending on the load and ambient temperature, the voltage should increase to between 13.0 and 15.1 volts during this period. Most vehicles with good charging systems will measure between 13.8 and 14.8 volts on a warm day, depending on the battery type that the charging system was designed for.

As in the Bosch Voltage Regulator example below, most voltage regulators are temperature compensated to properly charge the battery under different environmental conditions. As the ambient temperature decreases below 77° F (25° C), the charging voltage is increased to overcome the higher battery resistance. Conversely, as the ambient temperature increases above 77° F (25° C), the charging voltage is decreased. Other factors affecting the charging voltage are the alternator temperature, battery's condition, State-of-Charge (SoC), sulfation, electrical load and electrolyte purity.

VEHICLE CHARGING VOLTAGE GRAPH



[Source: Bosch]

If a battery terminal's voltage is below 13.0 volts with the engine running and the battery tests good after being recharged or if you are still having problems keeping the car battery charged, then have the charging system's output voltage and load tested. Also, have the car's parasitic load, the electrical load with the ignition key turned off, tested. (Please see Section 10.) A slipping alternator belt or open diode will significantly reduce the alternator's output capacity. If the output voltage is above 15.1 volts with the ambient temperature above freezing, if the battery's electrolyte level is frequently low, "boiling", or if there is a "rotten egg" odor present around the battery, then the battery is being overcharged and the vehicle's charging system should be tested.

[back to Index]

5.2. What If I Cannot Keep My Battery Charged and the Battery Tests OK?

The vehicle's electrical load is normally satisfied **first** by the charging system and then any remaining power is used to recharge the battery. For example, if the total electrical load is 14 amps and the charging system is producing 35 amps at 2500 RPM, then up to 11 amps will be available for recharging the battery, which will take approximately six minutes. If the charging system is operating at say a maximum capacity of 90 amps at 5000 RPM, then the battery usually will be recharged within two minutes. Now let us assume that the engine is idling and the charging system is only capable of producing 10 amps. Four amps from the car battery are required to make up the difference to satisfy the 14 amp electrical load and the battery is being discharged further. This is why making short trips, driving in stop-and-go traffic, or during bad weather, the starting battery may never get recharged and may even become "completely" discharged.

Using the example above, let's assume that an after-market, high-power audio system, electric winch or lights is installed that adds an additional 20 amps of load. With a total electrical load of 34 amps, at RPM below 2500, the battery will **never** be recharged with an 90 amp system. While the engine is running in this case, the battery must make up the deficit. The solution is to upgrade the charging system to 125% or more of the **new** worst-case load. In this example and based on stop-and-go driving habits, a high output charging system capable of 105 amps or more would be required to keep the battery fully charged. High alternator temperatures can further reduce the maximum output of a charging system, so cooling and sizing based on the continuous load matters. Heat kills alternators, so Bosch, for example, has water cooled models available.

[back to Index]

5.3. How Can I Test To Determine If Charging System Large Enough?

A simple test to determine if the charging system is large enough is to check the battery's State-of-Charge after the surface charge has been removed. If the State-of-Charge is consistently above 95%, then the charging system is fully recharging the car battery based on your driving habits and electrical load. If is is consistently below 80%, then you will want to consider upgrading your charging system to produce more current. There are several possibilities to increase the capacity of your charging system to include changing the pulley diameters, replacing the voltage regulator, upgrading the alternator, adding a second charging system (for a dual battery set up), etc. An auto electric or alternator rebuilding shop can assist you. If the SoC is inconsistent, the you might consider using a temperature compensated, "smart" charger with a quick disconnector to "top off" your battery. **If consistently under or overcharged, a lead-acid battery will lose capacity and prematurely fail.**

[back to Index]

<<<Previous [Home] [Top] Next>>>

10. WHAT CAUSES MY BATTERY TO DRAIN OVERNIGHT?

Last Updated on July 11, 2004

Parasitic (or ignition key off) drain is the cumulative load produced by electrical devices, for example, emissions computers, clocks, security alarms, radio presets, etc., that operate continuously after the engine is stopped and the ignition key has been switched off. **Normal parasitic loads are below 75 milliamps (.075 amps)**. When the parasitic load is greater than 75 milliamps (.075 amps), batteries will drain more quickly. Glove box, trunk, and under hood lights that do not automatically turn off when the door is closed or shorted diodes in alternators are the most common offenders. Cooling fans, power seat belt retractors, radios and dome lights left on, alarm systems, and electric car antennas have also caused batteries to drain overnight. Leaving your headlights on will generally discharge a fully charged car battery, with 90 minutes of Reserve Capacity (36 amp hours), within a couple of hours.

It is highly recommended, especially if you are using a sealed wet Maintenance Free (Ca/Ca) battery, to fully recharge it, remove the surface charge, and load tested both the battery and the charging system for latent damage from the deep discharge(s). You could have a bad battery. If the alternator is warm and the engine is cold, then check for a shorted diode in the alternator.

Below are some methods that are used to test the parasitic load with the engine **NOT** running, under hood light disconnected, all accessories switched off, and the vehicle doors closed:

- Connect a 12-volt bulb in series between the negative battery cable terminal clamp and the negative battery terminal. If the bulb continues to glow brightly, then start removing fuses or connections to the positive battery post one-at-a-time until the offending electrical component is identified by the bulb dimming.

- A better approach is to use a DC ammeter, for example a Fluke 175, inserted in series with the negative battery cable terminal clamp and the negative battery terminal or a clamp-on DC ammeter, like a Fluke 336 or i410 around the negative battery cable. Starting with the highest scale, determine the current load. If the load is above 75 milliamps (.075 amps) after the initial surge, then start removing fuses or connections to the positive battery post one-at-a-time until the offending electrical component is identified by the parasitic load dropping to within 75 milliamps (.75 amps).

- Additional troubleshooting techniques can be found in a guide from Exide at http://www.exide.com/products/trans/na/battery_care/electrical_parasitic_load.pdf.

<<<Previous [Home] [Top] Next>>>

11. CAN I INCREASE THE LIFE OF MY BATTERY?

Last Updated on July 11, 2004

The typical overall life of a good quality, well maintained battery is:

EXPECTED BATTERY SERVICE LIFE

Pasted Plate Car (used as a Deep Cycle)	0 to 12 months
Pasted Plate Car	4 to 5 years
Pasted Plate Marine/RV	to 4 years
Solid Plate Golf Cart	to 6 years
Gel Cell VRLA	to 8 years
AGM VRLA	to 8 years
Ni-Cad	to 10 years
Calcium Telecommunications (Stationary)	to 10 years
Fork Lift (Motive)	to 10 years
Manchex Industrial (Motive)	to 15 years
Wet Standard (Sb/Sb) Industrial (Stationary)	to 20 years
Ni-Fe	to 20 years

Here are some tips to increase car or deep cycle battery service life:

11.1. *Protect your car battery from high under hood temperatures with a heat shield or cover, keeping it full charged at all times, and well maintained are the* ***easiest*** *ways to extend it's life. In* ***hot*** *climates and during the summer, the electrolyte levels need to be checked more frequently.* In a study conducted by the Society of Automotive Engineers (SAE), the under hood temperature has increased more than 30% since 1985.

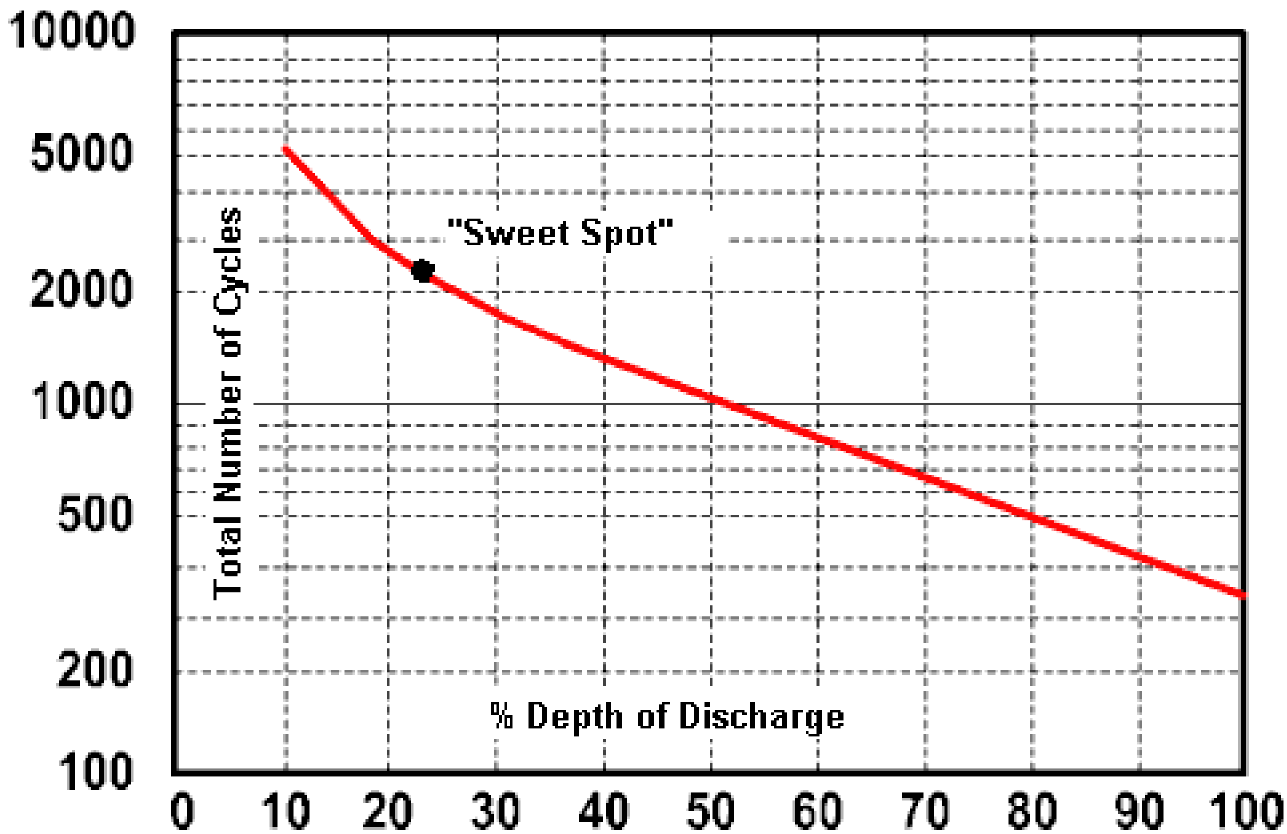
Chrysler studies have shown that relocating the battery outside the engine compartment has increased the average battery life by eight months. *Relocating the starting battery to the trunk or passenger compartment, as Mazda did in their Miata a number of years ago, is becoming more popular by the car manufacturers to protect the starting battery from the high under hood temperatures. However, sealed VRLA AGM or Gel Cell type batteries must be used because they normally do not produce gas when recharged.* **If a gel cell is used as a starting battery, the charging system voltages are very critical, may need to be lowered to keep from overcharging the battery.**

11.2. *If possible, recharge a deep cycle battery every day it is used and as soon as possible after each use. When not in use, maintaining the battery's State-of-Charge at 100% by continuous float charging is best way to prevent permanent lead sulfation. If continuous float charging is not possible, recharge* ***before*** *the State-of-Charge drops below 80%.* ***Permanent sulfation kills***

approximately 85% of all deep cycle batteries. *(Please see [Section 16.](#))*

11.3. *Reducing the average DoD (Depth-of-Discharge) by proper deep cycle battery sizing will significantly increase a deep cycle 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 can last **five** times longer than one with a 50% DoD. Golf cart batteries will typically have an average 225 cycles at 80% DoD and 750 cycles at 50% DoD. *Avoid DoDs that are greater than 80%.* The "sweet spot" (optimum DoD for the greatest amount of power produced over the service life) is generally somewhere between 20% DoD and 60% DoD. For the AGM battery below the "sweet spot" is approximately 22.5% DoD.

AGM Life Cycles vs. Percent Depth-of-Discharge (DoD)



[Source: Concorde]

11.4. ***Never*** *discharge below 10.5 volts.* An adjustable low voltage disconnect set for an 80% DoD or less can limit the maximum Depth-of-Charge and protect the batteries and electrical appliances. Leaving your lights or other accessories on and fully discharging a car battery can ruin it, especially if it is a sealed, wet Maintenance Free (Ca/Ca) type or it is frozen. If this should occur, you should let your battery thaw, if frozen, fully recharge it with an external charger, remove the surface charge, and test the battery and charging system to determine if there is any latent or permanent damage.

11.5. *In **extremely cold** climates, keep the car battery fully charged, the engine and battery warm, and use low viscosity synthetic engine oil. Use AGM or Ni-Cad batteries in sub-zero temperatures.*

11.6. *In **hot** climates use the "hot climate or "South" versions of car batteries.* They have special plate and connecting strap formulations, lower Specific Gravity levels or increased the amounts of electrolyte to provide more "cooling". Using non-sealed Low Maintenance (Sb/Ca) car batteries is encouraged because you can add water. *"Watering" is required more often and add only distilled, demineralized or deionized water or, in a emergency, rain water. The plates must be covered at all times to prevent an internal battery explosion or sulfation. Do **not** overfill, and keep the top of the battery clean. Do **NOT** add electrolyte (battery acid) to a battery unless some electrolyte has spilled.* If the Specific Gravity levels are increased beyond the battery manufacturer's recommended limit, there will be a higher capacity level, but more maintenance and a shorter service life.

11.7. *Turning off all unnecessary accessories, rear window heater, climate control, and lights* ***before*** *starting your car will decrease the load on the battery while cranking, especially when it is* ***cold****.*

11.8. *Reducing the parasitic (key-off) load to below 75 milliamps.*

11.9. *In* ***cold*** *climates, increasing the diameter of the battery cables will reduce the voltage loss.*

11.10. *If required, equalize wet and some AGM batteries.* (Please see Section 9.)

11.11. *For vehicles not used at least once every two weeks, continuously float charge the car battery.* (Please see Section 13.)

11.12. *Provide adequate ventilation.* High ambient temperatures above 80° F (or 26.7° C) will shorten battery life because it increases positive grid corrosion, growth and VRLA "thermal runaway".

11.13. *Recharging* ***slowly*** *using the manufacturer's recommended voltages (compensated of temperature) and current.*

11.14. *Avoid shallow (below 10%) discharges of deep cycle batteries because lead dioxide builds up on the positive plates.* In other words, you should discharge a deep cycle battery between 10% DoD and 80% DoD.

11.15. *Use batteries with thicker plates and reduce the number of discharge-charge cycles.*

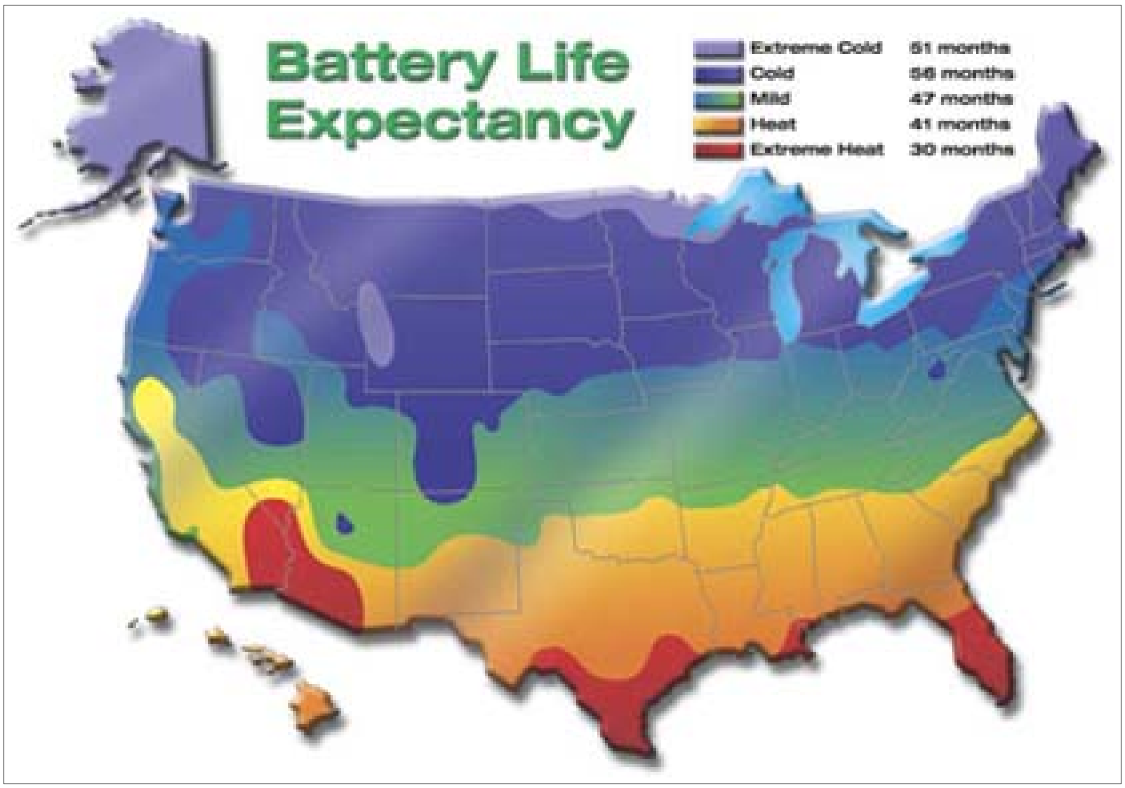
11.16. *Apply the correct battery type for the application, that is, starting for starting applications and deep cycle for motive and stationary deep cycle applications.*

<<<Previous [Home] [Top] Next>>>

12. WHAT ARE THE COMMON CAUSES OF PREMATURE BATTERY FAILURES?

Last Updated on July 11, 2004

Normally, premature battery failures are caused by one or more of the failures listed below. Prior to 1980, plate or grid shorts were the most common failure. Since then the manufacturers have significantly improved the life expectancy by using improved separators, plate alloys to reduce corrosion, and heat shields. By relocating sealed AGM and Gel Cell batteries to the passenger compartment (or trunk), also has considerably **decreased** premature battery failures. Batteries that have been in use for longer periods of time will typically fail from multiple causes. **All batteries will fail at some point in time.**



[Source: Interstate Batteries]

12.1. **Water Loss! (Car) and Sulfation! (Deep Cycle and Motorcycle)**

12.2. **Water Loss! (Car) and Sulfation! (Deep Cycle and Motorcycle)**

12.3. **Water Loss! (Car) and Sulfation! (Deep Cycle and Motorcycle)**

12.4. For car batteries, high under hood **heat** or overcharging causes a loss of water (which account for over **50%** of the failures); accelerated positive grid corrosion and growth; increased self discharge; or plate-to-strap shorts.

12.5. Sulfation from water loss, undercharging, excessive temperatures or prolonged periods of non-use account for approximately 85% of the deep cycle and starting (e.g. Motorcycle) battery failures that are not in use. (Please see Section 16.) Data Power Monitoring Corp. reports that 90% of the deep cycle VRLA battery failures are due to the battery itself.

12.6. Deep discharges, such as leaving your lights on.

12.7. Misapplication, for example, using a starting battery in a deep cycle application, a motive deep cycle battery instead of a stationary for a UPS, an under sized battery (or battery bank) that causes discharges greater than the battery was designed for or a mismatch to the charging system.

12.8. Excessive vibration due to a loose hold down clamp.

12.9. Calcium or magnesium sulfation from using **tap** or reverse osmosis water.

12.10. Freezing a discharged battery.

12.11. Undercharging which reduces capacity due to incomplete conversion of sulfate back to lead which causes plate, cracked grids and cell shorts.

12.12. Old age (positive plate shedding).

12.13. Fast recharging at rates greater than C/4 (amp hour capacity/four hours).

12.14. Temperatures above 80° F (26.7° C), especially above 100° F (37.8° C) causing VRLA battery "thermal runaway".

<<<Previous [Home] [Top] Next>>>

6. HOW DO I JUMP START MY VEHICLE?

Last Updated on July 11, 2004

Please wear glasses in the unlikely event of a car or deep cycle battery explosion and save your eyes.

If done incorrectly, jumping a dead battery can be **dangerous** and **financially risky**. These procedures are ONLY for vehicles are both negatively grounded and that the electrical system voltages are the SAME. These procedures would also apply to using emergency jump starters. The rule for jump starting a dead battery is ALWAYS **POSITIVE** to **POSITIVE** and **NEGATIVE (-)** to the **ENGINE BLOCK or FRAME** away from the dead starting battery. Reverse this rule to disconnect. The American Automobile Association estimates that of the 275 million vehicles that will traveling in the U.S. during the Summer of 2003, 7.4 million (or 2.7%) will break down. Of that number, 1.3 million (or 17.7%) will require a battery jump to start their engine.

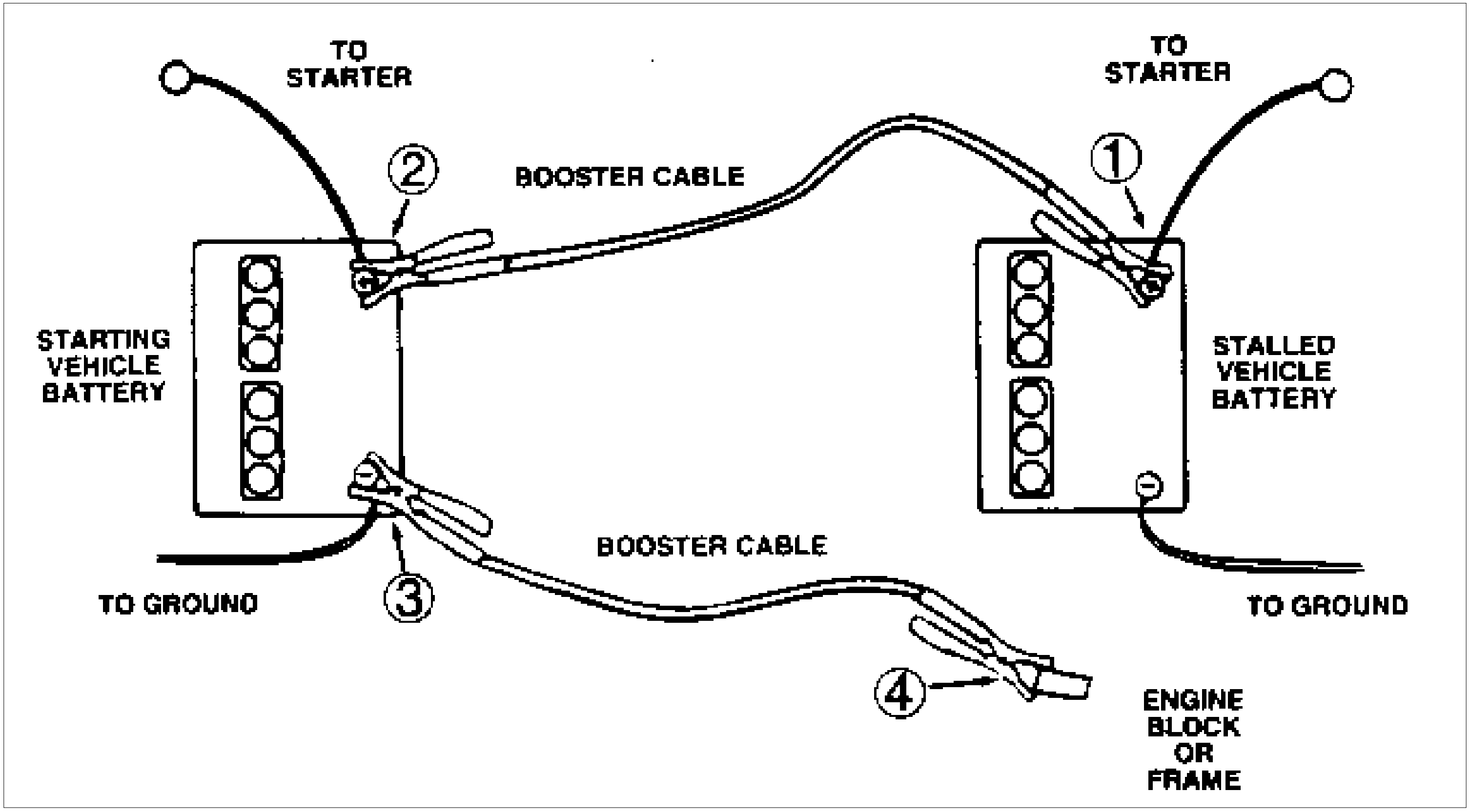
In **cold** weather, a good quality jumper cables (or booster cables) with eight-gauge wire is necessary to provide enough current to the disabled vehicle to start the engine. *Larger diameter wire is better because there is less voltage loss.* Please check the owner's manual for **BOTH** vehicles or jump starter **BEFORE** attempting to jump-start. Follow the manufacturers' procedures, for example, some vehicles should not be running during a jump-start of a disabled one. However, starting the disabled vehicle with the good vehicle running can prevent having both vehicles disabled. **Avoid** the booster cable clamps touching each other or the **POSITIVE** clamp touching anything but the **POSITIVE (+)** post of the battery, because momentarily touching the block or frame can short the battery and cause extensive and costly damage.

6.1. If **below freezing**, insure that the electrolyte is NOT **frozen** in the dead battery. If **frozen**, do **NOT** jump or boost the battery if the case is cracked or until the battery has been full thawed out, recharged, tested. *When the electrolyte freezes, it expands which can damage the plates or plate separators, which can cause the plates to warp and short out. With any completely dead battery, cell reversal can occur.* The electrolyte in a **dead** battery will **freeze** at approximately 20°F (-6.7°C). If the battery has been sitting for several weeks and frozen, then the battery has probably sulfated as well. Please Sections 16 and 13 for more information. If the battery has been sitting for hours or a few days then the problem is either an excessive parasitic load like leaving the headlights on or a faulty charging system. Please see Sections 10 or 9, respectively.

6.2. Without the vehicles touching, turn off all accessories, heaters and lights on **both** vehicles, especially an electronic appliances, such as a radio or audio system and insure there is plenty of battery ventilation.

6.3. Start the vehicle with the good battery and let it run for at least two or three minutes at medium RPM to recharge it. Check the **POSITIVE (+)** and **NEGATIVE (-)** terminal markings on both batteries **before** proceeding.

JUMP STARTING



[Source: BCI]

6.4. Connect the **POSITIVE** booster cable (or jump starter) clamp (usually **RED**) to the **POSITIVE (+)** terminal post on the dead battery [Step 1 in the diagram above]. Connect the **POSITIVE** clamp on the other end of the booster cable to the **POSITIVE (+)** terminal post on the good starting battery [Step 2]. *If the **POSITIVE (+)** battery terminal post is not accessible, the **POSITIVE** connection on the starter motor solenoid from the **POSITIVE (+)** terminal post of the battery could be used.*

6.5. Connect the **NEGATIVE** booster cable clamp (usually **BLACK**) to the **NEGATIVE (-)** terminal on the good battery [Step 3]. Connect the **NEGATIVE** booster cable (or jump starter) clamp on the other end of the jumper cable to a clean, unpainted area on the engine block or frame on the disabled vehicle [Step 4] and **away** from the battery. This arrangement is used because some sparking will occur and you want to keep sparks as far away from the battery as practical in order to prevent a battery explosion.

6.6. If using jumper cables, let the good vehicle continue to run at medium RPM for five minutes **or more** to allow the dead battery to receive some recharge and to warm its electrolyte. If there is a bad cable connection, do not wiggle the cable clamps connected to the battery terminals because sparks will occur and a battery explosion might occur. To check connections, first disconnect the **NEGATIVE** clamp from the engine block or frame, check the other connections, and then reconnect the engine block or frame connection last.

6.7. If using jumper cables, some vehicle manufacturers recommend that you turn off the engine of the good vehicle to protect its charging system prior to starting the disabled vehicle. Check the owner's manual; otherwise, leave the engine running so you can avoid being stranded should you not be able to restart the good vehicle.

6.8. If using jumper cables, start the disabled vehicle and allow it to run at high idle. If the vehicle does not start the first time, recheck the connections, wait a few minutes, and try again.

6.9. Disconnect the jumper or jump starter cables in the **REVERSE** order, starting with the **NEGATIVE** clamp on the engine block or frame of the disabled vehicle to minimize the possibility of an explosion.

6.10. As soon as possible, fully recharge the dead or starting battery with an external battery charger, remove the surface charge and load test the battery and charging system for latent or permanent damage as a result of the deep discharge. This is especially important if you had a frozen battery or a sealed Maintenance Free (Ca/Ca) battery. A vehicle's charging system was not designed to recharge a dead battery and could overheat and be damaged *(bad diodes or burned stator)* doing so.

In the event that the jumper or jump starter cables were REVERSED and there is no power to all or part of the vehicle, test the fusible links, fuses, circuit breakers, battery, charging system and emissions computer and, if bad, reset or replace. Their locations and values should be shown in the vehicle's Owner's Manual. If replacing the faulty parts do not repair the electrical system, having it repaired by a good auto electric repair shop is highly recommended.

<<<Previous [Home] [Top] Next>>>

2. WHY BOTHER?

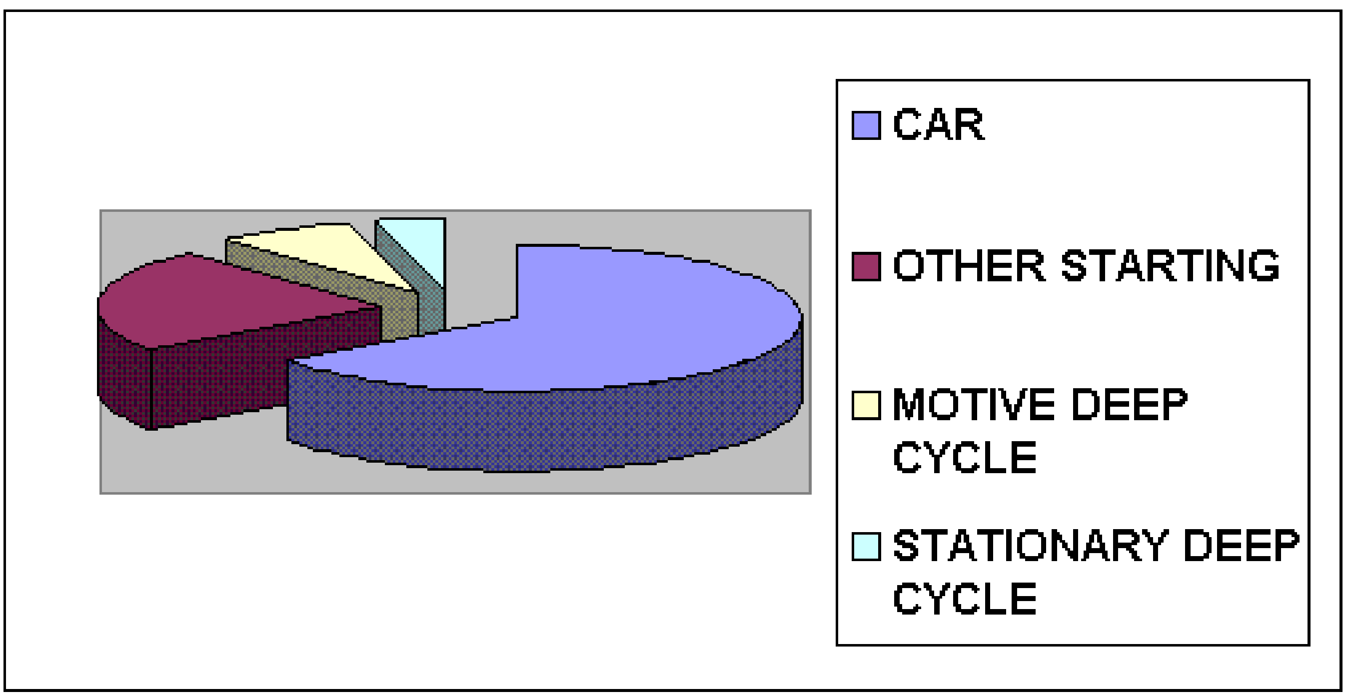
Last Updated on July 11, 2004

INDEX:

Because only the rich can afford cheap batteries.....

A lead-acid battery (also know as an "accumulator") is a secondary (rechargeable) electrochemical device that stores chemical energy and releases it as electrical energy upon demand. When a battery is connected to an external device, such as a motor, chemical energy is converted to electrical energy and direct current flows through the circuit. The terms of the quantity of lead-acid batteries that are produced, starting batteries represent approximately 88% of the total. The total breaks down to 65% Car, 23% Other Starting Batteries (motorcycle, etc.), 8% Deep Cycle Motive (wheelchairs, golf carts, fork lift trucks, etc.), and 4% Deep Cycle stationary (backup, UPS, standby, etc.).

BATTERY PRODUCTION



In the order of importance, the four major purposes of a car or **"SLI"** (Starting, Lighting and Ignition) battery, as it is known in the battery industry, are:

- To **start** the engine.

- To filter or stabilize the pulsating DC power from the vehicle's charging system.
- To provide extra power for the lighting, two-way radios, audio system and other accessories when their combined load **exceeds** the capability of the vehicle's charging system. This commonly occurs while the vehicle's engine is idling.
- To supply a source of power to the vehicle's electrical system when the charging system is not operating.

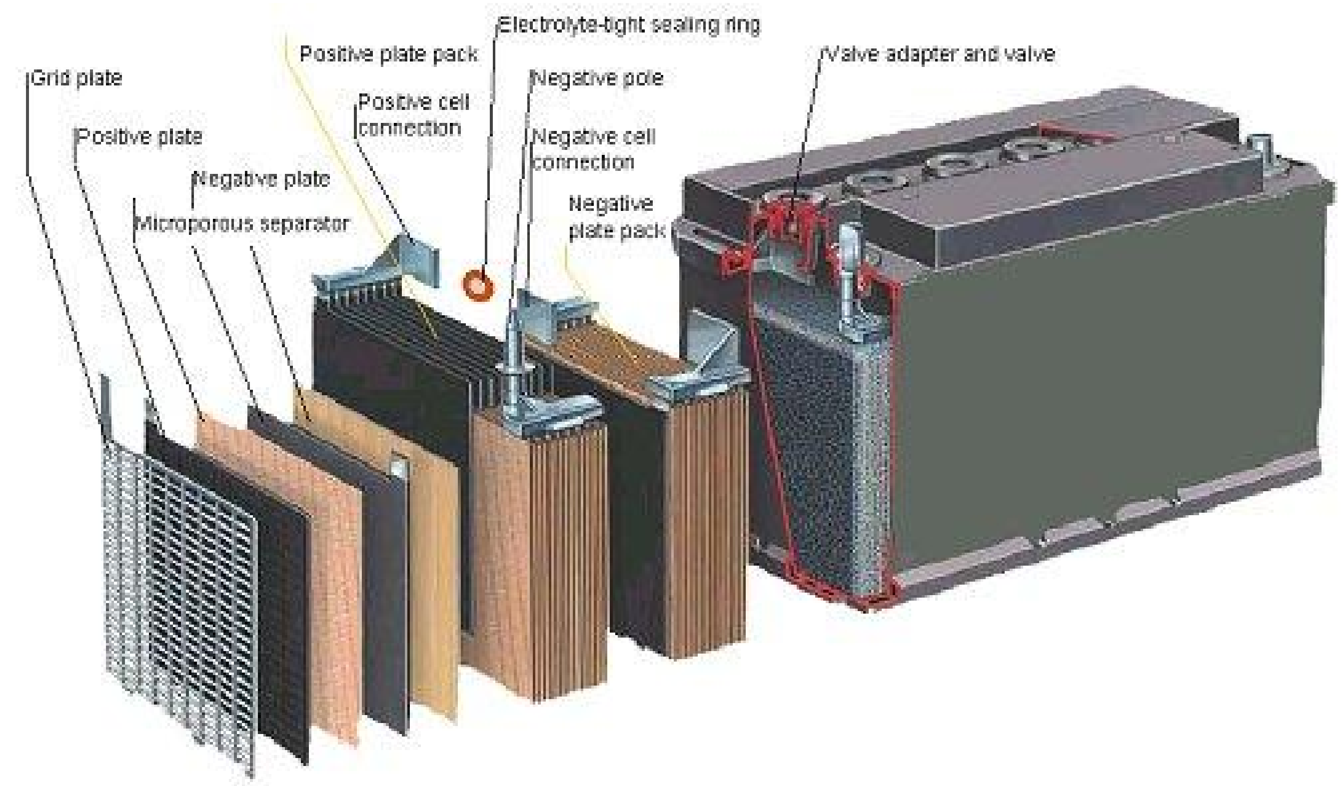
A good quality car battery will cost between $50 and $100 and, if properly maintained, it should last five years or more. With a 5% compounded annual growth rate, worldwide retail sales of car lead-acid batteries represent roughly 63% of the estimated $30 billion annually spent on batteries. In North America, BCI reports that of the 106.6 million car batteries that were sold in 2001, of which approximately 80% were for replacement and 20% were for original equipment. For 2003, Eurobat estimates that in Western Europe 58.5 million car batteries will be sold and 71% will be replacement (after market) and 29% will be OEM (Original Equipment Manufacturer). At the Robert W. Baird Industrial Technology Conference, Johnson Controls reported of the 350 million starting batteries that will be made in the world in 2004, Johnson Controls is the largest manufacturer with 24% of the total followed by Exide with 14%, GS Yuasa (pending merger of Yuasa and Japan Storage Battery) with 10%, Delphi with 7%, Matsushita with 4%, East Penn with 3%, FIAMM with 3%, and all others with 35%.

The purpose of a deep cycle battery is to provide power for wheelchairs, trolling motors, golf carts, boats, fork lift trucks, uninterruptible power supplies (UPS), and other accessories for marine and recreational vehicle (RV), commercial and stationary applications. A good quality wet deep cycle (or "leisure") battery will cost between $50 and $300 and, if properly maintained and used, will give you at least 200 deep discharge-charge cycles. For differences between a car and deep Cycle battery, please see Section 7.1.8. Purportedly, Exide and EnerSys are the two largest deep cycle battery manufacturers in the world.

2.1. How is a Battery Made?

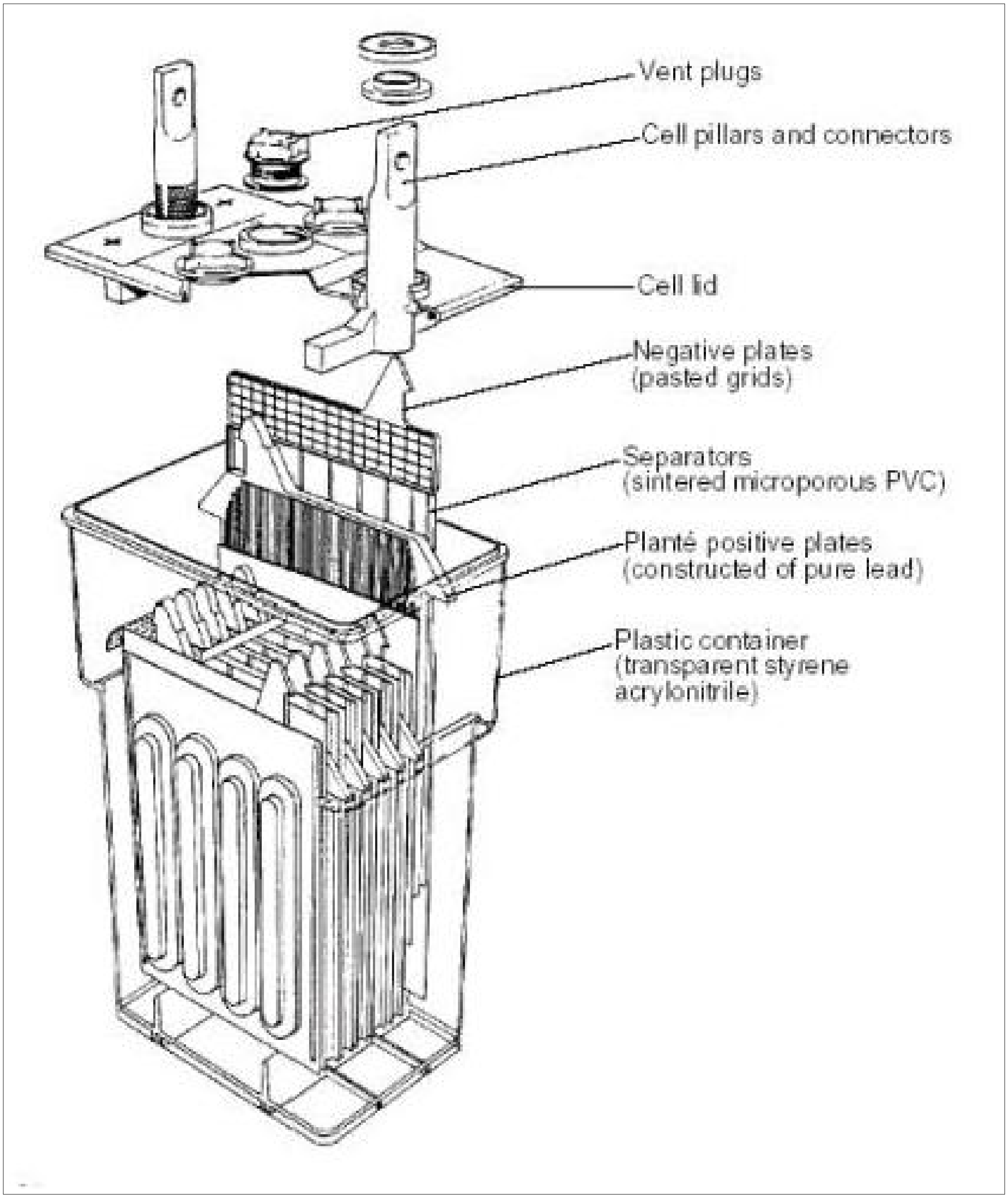
A 12-volt lead-acid battery is made up of six cells, each cell producing approximately 2.1 volts that are connected in series from **POSITIVE (+)** terminal of the first cell to the **NEGATIVE (-)** terminal of the second cell and so on. Each cell is made up of an element containing positive plates that are all connected together and negative plates, which are also all connected together. They are individually separated with thin sheets of electrically insulating, porous material "envelopes" or "separators" (in the diagram below) that are used as spacers between the positive (usually **light orange**) and negative (usually **slate gray**) plates to keep them from electrically shorting to each other. The plates (in the diagram below), within a cell, alternate with a positive plate, a negative plate and so on.

CAR BATTERY CONSTRUCTION



[Source: Eurobat]

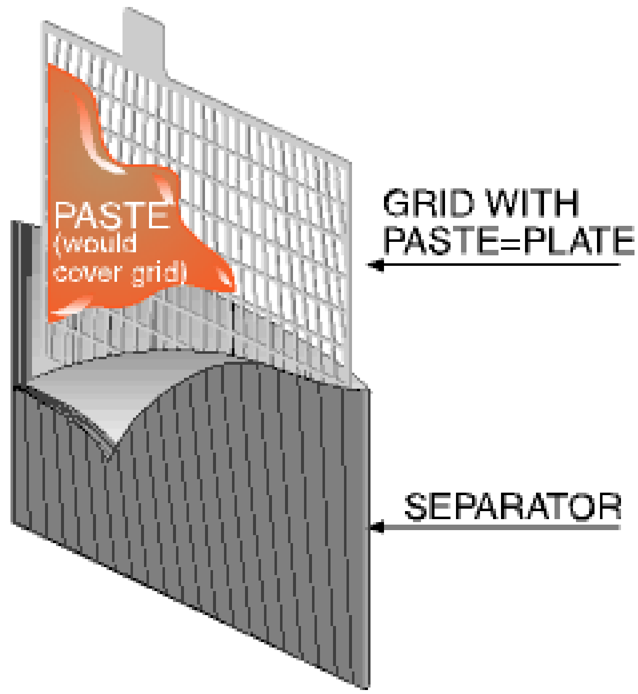
DEEP CYCLE BATTERY CONSTRUCTION



[Source: US Department of Energy]

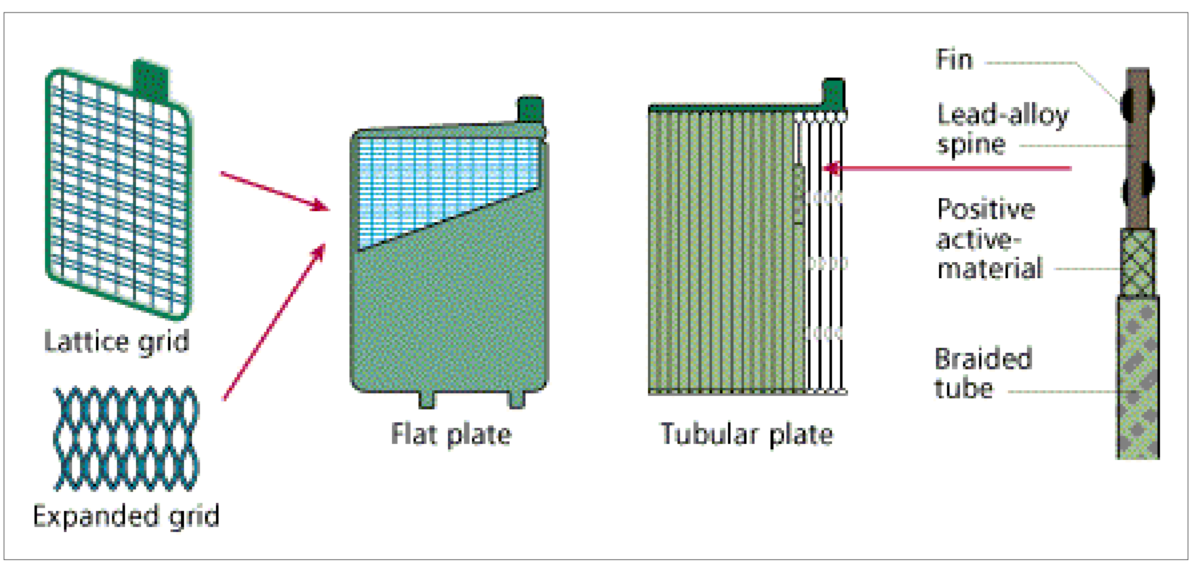
The most common plate in use today is made up of a metal grid that serves as the supporting framework for the active porous material that is "pasted" on it. After the "curing" of the plates, they are made up into cells, and the cells are inserted into a high-density tough polypropylene or hard rubber case. The positive plates in cells are connected in parallel to the external **POSITIVE (+)** terminal and the negative plates in each cell are connected to the **NEGATIVE (-)** external terminal. Instead of pasted Lead Oxide, some batteries are constructed with more expensive solid lead cylindrical (spiral wound); Manchester or "Manchex" (buttons inserted into the grid); tubular; or prismatic (flat) solid lead (Planté) positive plates. The case is covered and then filled with a dilute sulfuric acid electrolyte. The battery is initially charged or *"formed"* to convert the active **yellow** Lead Oxide *(PbO or Litharge)* in the positive plates (cathode) into Lead Peroxide *(PbO_2)*, which is usually **dark brown** or **black**. The active material in the negative pasted plates (anode) becomes sponge Lead*(Pb)*, but with a very porous structure which is **slate gray**. If sponge Lead is rubbed with a hard object, it will be silvery in color. The electrolyte is replaced and the battery is given a finishing charge. A "Wet charged" battery is a wet lead-acid battery shipped with electrolyte in the battery and a "dry charged" battery is shipped without electrolyte. When dry charged batteries are sold, electrolyte (battery acid) is added, allowed to soak into the plates, is charged (or "formed"), and put into service. This avoids having to maintain the batteries until they are sold.

PASTED PLATE

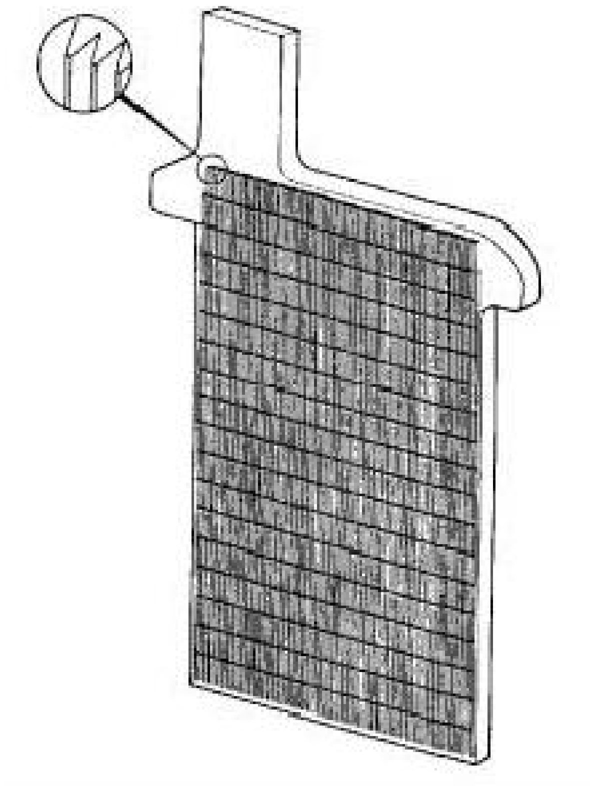


[Source: BCI]

FLAT AND TUBULAR PLATE

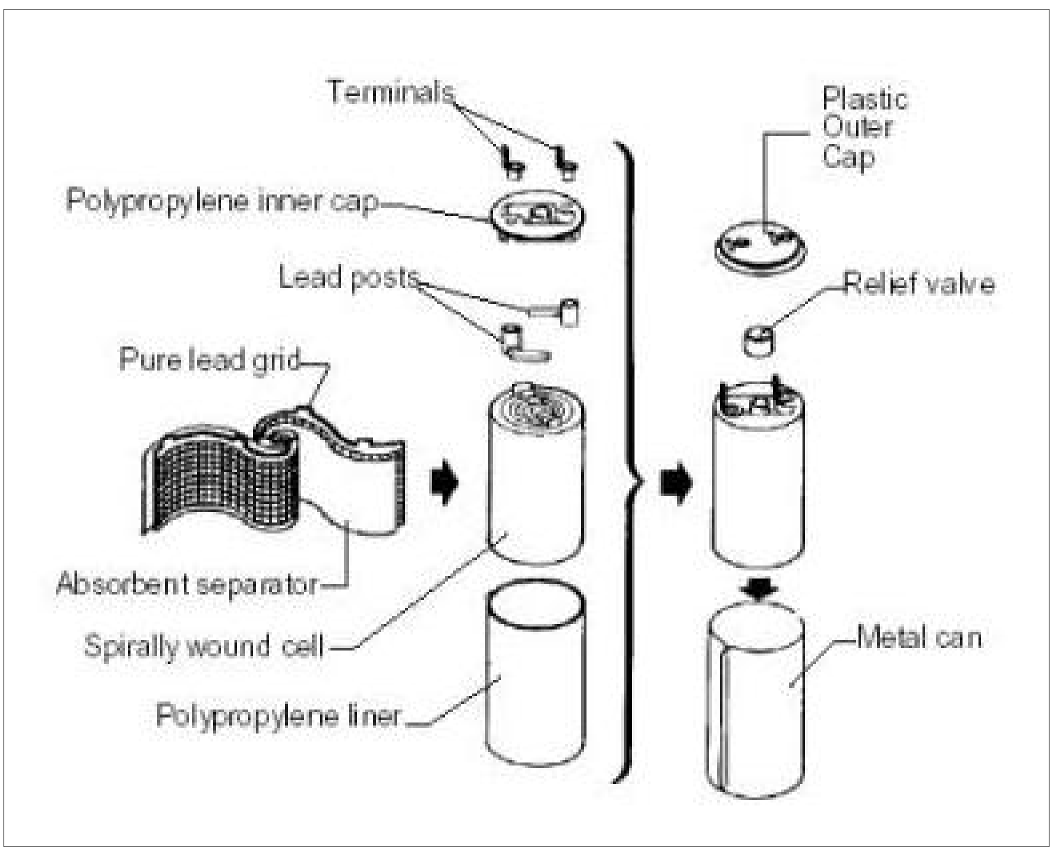


PLANTE PLATE



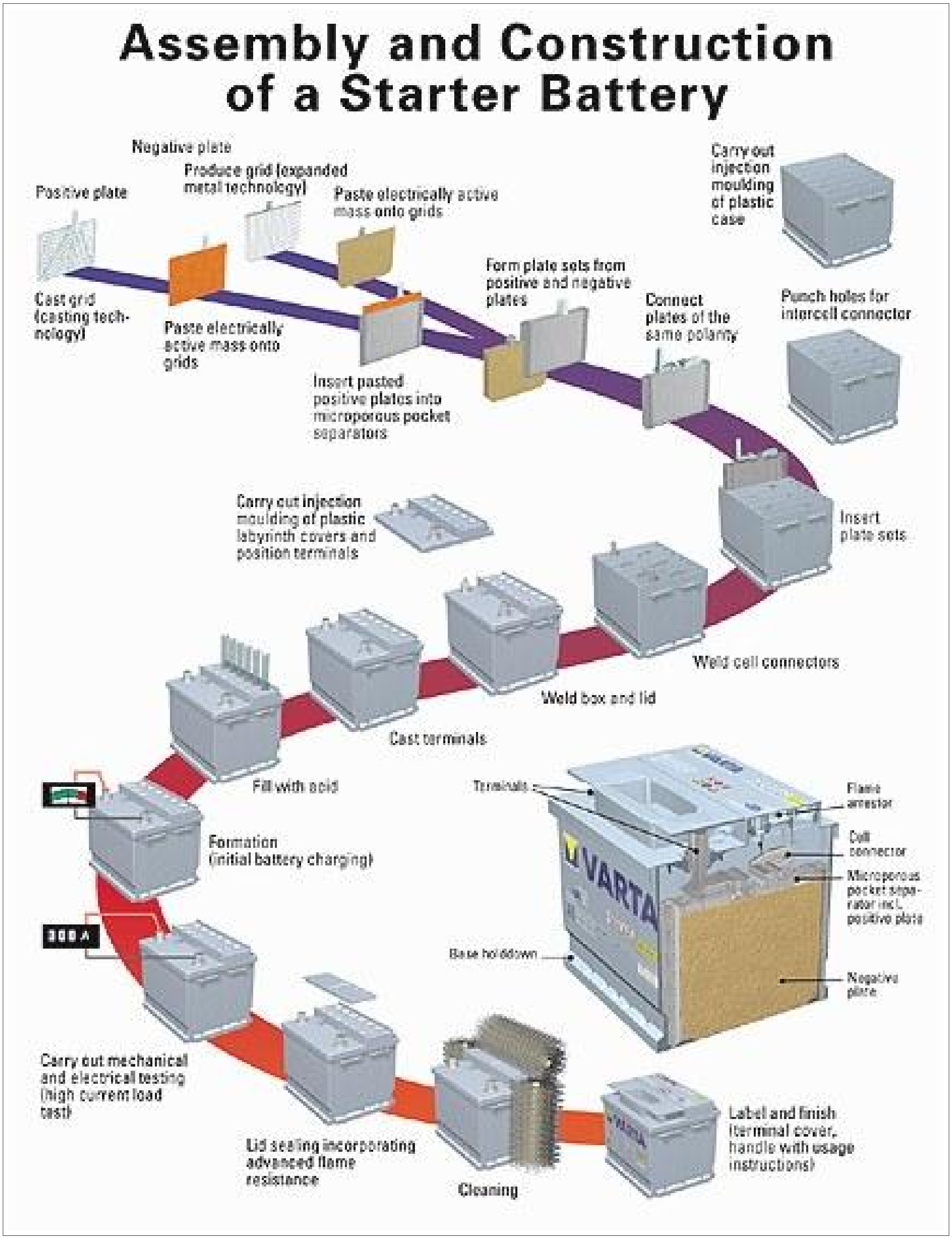
[Source: US Department of Energy]

SPIRAL WOUND PLATE



[Source: US Department of Energy]

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 electrolyte, the better the diffusion.



[Source: Varta]

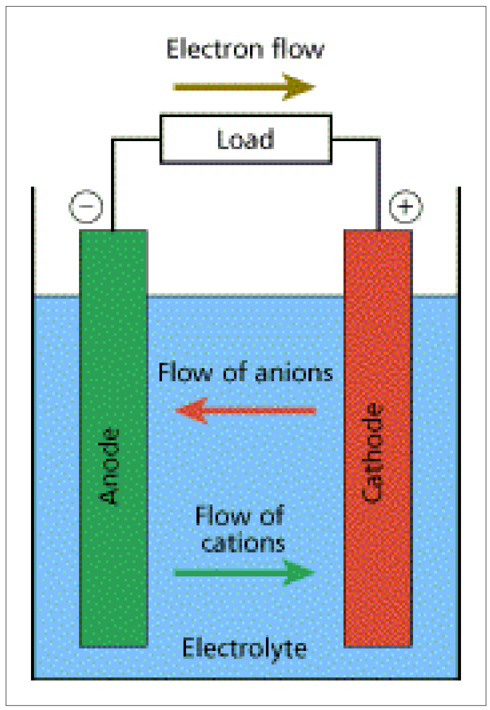
There is an excellent detailed description of how battery is made, equipment used and quality assurance on the Best Manufacturing Practices Web site at http://www.bmpcoe.org/library/books/navso%20p-3676/index.html.

[back to Index]

2.2. How Does a Battery Work?

DISCHARGING PROCESS

$PbO_2 + Pb + 2H_2SO_4$ → $2PbSO_4 + H_2O$



CHARGING PROCESS (Reverse of Discharging Process)

$2PbSO_4 + H_2O$ → $PbO_2 + Pb + 2H_2SO_4$

A battery is created by alternating two different metals such as Lead Dioxide *(PbO_2)*, the positive plates, and Sponge lead *(Pb)*, the negative plates. Then the plates are immersed in diluted Sulfuric Acid *(H_2SO_4)*, the electrolyte. The types of metals and the electrolyte used will determine the output of a cell. A typical fully charged lead-acid battery produces approximately 2.11 volts per cell. The chemical action between the metals and the electrolyte (battery acid) creates the electrical energy. Energy flows from the battery as soon as there is an electrical load, for example, a starter motor, that completes a circuit between the positive and negative terminals. 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, State-of-Charge, temperature, porosity, diffusion, and load. A cycle is defined as one discharge and one recharge of the battery.

A more detailed description of how a battery works can be found on the BCI web site at http://www.batterycouncil.org/works.html.

[back to Index]

2.3. How do Batteries Die?

When the active material in the plates can no longer sustain a discharge current, the car battery "dies". Normally a battery "ages" as the active positive plate material sheds (or flakes off) due to the normal expansion and contraction that occurs during the discharge and charge cycles. This causes a loss of plate capacity and a **brown** sediment, called sludge or "mud," that builds up in the bottom of the case and can short the plates of a cell out. In **hot** climates, additional causes of failure are positive grid growth, positive grid metal corrosion, negative grid shrinkage, buckling of plates, or **loss of water**. Deep discharges, heat, vibration, fast charging, and overcharging all accelerate the "aging" process. **At approximately 50%, the number one cause of premature car battery failure is loss of water caused from high under hood heat or overcharging and for Deep Cycle batteries it is sulfation, at an estimated 85%.** *Sulfation is caused when a battery's State-of-Charge drops below 100% for long periods or under charging. Hard lead sulfate crystals fills the pours and coats the plates. Please see Section 16 for more information on sulfation. Recharging a sulfated battery is like trying to wash your hands with gloves on.*

In a **hot** climate, the harshest environment for a battery, a Johnson Controls survey of junk batteries revealed that the **average** life of a car battery was 37 months. In a separate North American study by BCI, the average life was 48 months. In a study by Interstate Batteries, the life expectancy in **extreme heat** was 30 months. If your car battery is more than three years old and you live in a **hot** climate, then your battery is probably living on borrowed time. Abnormally slow cranking, especially on a cold day, is another good indication that your battery is going bad. It should be externally recharged, surface charge removed, and load tested. Dead batteries almost always occur at the most inopportune times. You can easily spend the cost of a new battery or more for an emergency jump start, tow or for a taxi ride.

Most of the "defective" batteries returned to manufacturers during free replacement warranty periods are good. This strongly suggests that some sellers of new batteries do not know how to or fail to take the time to properly recharge and test batteries. This situation is improving with the widespread use of easy to use conductance type battery testers like those made by Midtronics used to predict the capacity of the batteries.

[back to Index]

2.4. Why Are Vehicles Negatively Grounded?

The best explanation to this question comes from a 1978 Rolls-Royce Enthusiasts' Club service manual.

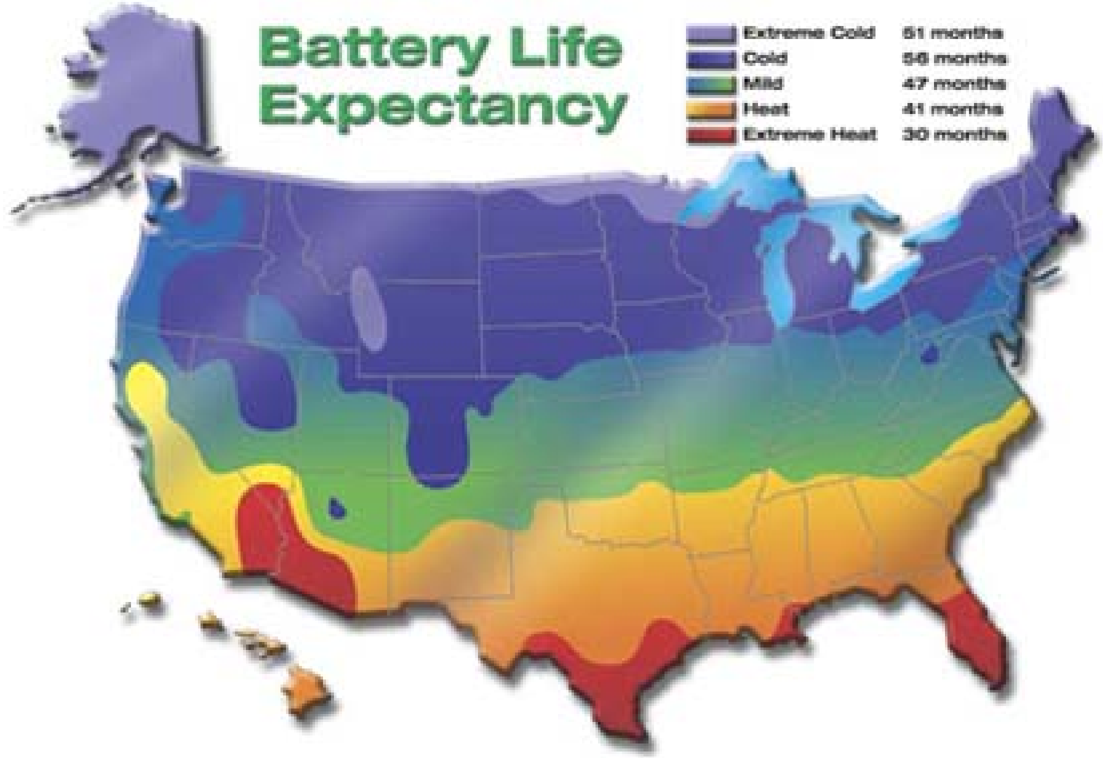
"...it has been found that cars wired positive earth [ground] tend to suffer from chassis and body corrosion more readily than those wired negative earth. The reason is perfectly simple, since metallic corrosion is an electrolytic process where the anode or positive electrode corrodes sacrificially to the cathode. The phenomenon is made use of in the "Cathodic Protection" of steel-hulled ships and underground pipelines where a less 'noble' or more electro-negative metal such as magnesium or aluminum is allowed to corrode sacrificially to the steel thus inhibiting its corrosion."...

For more information on cathodic protection, please read Roger Alexander's article, *An idiots guide to cathodic protection*. By 1956, all the North American manufactured cars and trucks, except the Metropolitan, were using negative (or earth) grounding. For more specific information on grounding systems used in North American vehicles, please go to Antique Automobile Radio's chart on http://www.antiqueautomobileradio.com/battery.htm.

.

[back to Index]

<<<Previous [Home] [Top] Next>>>


Battery Life Expectancy
Extreme Cold 51 months
Cold 56 months
Mild 47 months
Heat 41 months
Extreme Heat 30 months

The *Deep Cycle Battery Frequently Asked Questions (FAQ)* has been integrated into the *Car and Deep Cycle Battery Frequently Asked Questions (FAQ)*

It is now located at

http://www.batteryfaq.org/carfaq.htm

Just click the above URL to get there,
or wait a few seconds to go there automatically
and thanks for visiting!

Please don't forget to change your bookmarks!

8. HOW DO I INSTALL NEW BATTERIES?

Last Updated on July 11, 2004

While working with car or deep cycle lead-acid batteries, please wear glasses to protect your eyes in the unlike event of an explosion.

In a recent marketing study in the U.S., consumers (or non-professional battery installers) installed almost 60% of the approximately 82 million replacement car batteries that were made in 1999. Car batteries were the fourth most popular item purchased among auto parts. The same study indicated that Wal-Mart (*EverStart*) has surpassed Sears (*DieHard*) as the number one car battery seller in the United States with Auto Zone (*DuraLast*) as the most popular of the U.S. auto parts stores for car batteries.

Below are some questions you need to ask yourself because the installation of a replacement battery and disposal of the old one is usually included in the purchase price at some auto parts and battery stores:

- A car battery weights between 30 and 60 pounds (13.6 and 27.3 Kg) and deep cycle battery can weigh several hundred pounds (or kilos), so do I want to install it myself?
- What do I do with the old battery if not exchanged for the new one? This is especially important if the batteries are not lead-acid, for example, Ni-Cad. **The proper disposal of a non lead-acid battery could cost more that a new battery.**
- How can I save the radio station presets, emissions computer settings, or security codes before disconnecting the old starting battery
- Do I want to risk an injury or holes in my clothes?

If you decide to proceed, following is a list of easy steps to replace your battery and assumes that there the electrical and charging systems are in good condition:

8.1. Fully **charge** and **test** the new battery. (Please see Section 9 for charging and Section 4 for testing the battery.)

8.2. If a non-sealed wet battery, check the **electrolyte levels** after the battery has reached room temperature and "top off" to the proper level with distilled, deionized or demineralized water as required, but do **not** over fill. **The plates need to be covered with electrolyte at all times to prevent an internal battery explosion or sulfation.** Please see Section 3.2 for electrolyte fill levels.

8.3. Thoroughly wash and clean the old battery, battery terminals and tray (case or box) with warm water to minimize problems from acid or corrosion. Please see Section 3.4 for more information on corrosion.

8.4. **Mark all of the battery cables** so you will know how to reconnect to proper battery post or terminal and check the cables and cable terminals closely for damage. A loose terminal connection, bad crimp or cut cable will cause a high resistance and a large voltage drop when high current is running though it. **If the cables are reversed, you can do extensive damage to your electrical system.**

8.5. For Car battery installations, to prevent voltage spikes from damaging electronic equipment such as the emissions computer and to save the radio station presets, emissions computer and security code settings, temporarily connect a second 12-volt battery in parallel to the electrical system **before** disconnecting the first battery. If active when the key is off, a cigarette lighter plug can be used to easily connect a 12-volt parallel battery. Cigarette lighter adapters are available at electronics stores and "Computer Memory Saver" with a 9-volt battery are available at some auto parts stores, like JC Whitney for about $10.

8.6. Turn **off** all the electrical switches and breakers and electronic and electrical accessories and appliances. Without using a hammer on the battery cable terminals or posts, remove the **NEGATIVE (-)** cable first because this will minimize the possibility of shorting the battery when you remove the other cables. Secure the negative cable so that it cannot "spring" loose and make electrical contact. Next remove the **POSITIVE (+)** cable. Please remember that the battery terminal connector on the end of the **POSITIVE (+)** battery cable maybe "hot" (or have voltage on it), so put it in a small plastic bag or cloth around it so that it will not touch the metal frame or engine components.

8.7. Carefully lift the old battery out and dispose of it by exchanging it when you buy your new replacement battery or by taking it to a recycling center. For additional information on recycling batteries, go to http://www.batterycouncil.org/recycling.html. Please remember that batteries contain large amounts of harmful lead, acid and other chemicals, so take great care with safety and please dispose of your old battery properly to protect our fragile environment.

8.8. After removing the old battery, insure that the battery tray or box, cable terminals, and connectors are clean. Auto parts or battery stores sell an inexpensive brass wire brush that will clean the inside of post terminal clamps and the post terminals. If the terminals, cables or hold-down brackets are corroded, replace them. A broken hold down bracket will cause excessive battery vibration and that will cause a premature failure. Replace any battery cables that are corroding, swelling or other damage with equal or larger diameter cable. *Larger cable is better because there is less voltage drop.* Please see Exide's *Voltage Drop in Cables* for additional information.

8.9. Check the positive and negative terminal markings on the replacement battery and position it so that the **NEGATIVE (-)** cable will connect to the **NEGATIVE (-)** terminal. **Reversing the polarity of the electrical system can severely damage or DESTROY it. It can even cause the battery to explode.**

8.10. After replacing and tightening the hold-down bracket, remove any plastic caps or covers on the terminals of the replacement battery, and reconnect the cables in reverse order, that is, attach the **POSITIVE (+)** cable **first** and the **NEGATIVE (-)** cable last. For General Motors-type side terminals, check the length of the bolt and do **not** over tighten, or you could crack the battery case. Connections need to be periodically checked for corrosion (or oxidation) and retightened, including the grounding cables to the vehicle's frame and engine block.

8.11. To prevent corrosion, coat the terminals and exposed metal parts. Please see Section 3.4 for more information on corrosion.

8.12. Remove the parallel battery and rest all the switches and breakers, if required.

8.13. Test the new battery by starting your engine or with an electrical load.

Some vehicles are have battery electrolyte level sensors. For Toyota and Nissan, use the sensor bypass information at http://www.exide.com/products/trans/na/battery_care/toyota_nissan.pdf and for Mazda use http://www.exide.com/products/trans/na/battery_care/toyota_nissan.pdf. A good source of information for measuring maximum cable and connector voltage drops can be found at Exide's *Caring For Your Battery*

*Wire sizing and cable lengths are very important because wiring that is not large enough or different lengths will cause excessive voltage loss and undercharged batteries or, in some cases, a **fire**. Batteries connected in parallel should have the same cable lengths and size from the charging or discharging source. Use of buss bars are highly recommended for larger deep cycle battery installations. A good source of information of wire sizing can be found at http://www.solarexpert.com/Photowiring.html. Using properly sized fuses or circuit breakers is also very important because they can provide protection for the wiring from over heating and for the electrical appliances.* Series, parallel, and series-parallel battery connection wiring diagrams can be found in Section 7.3.2. Connections will need to be periodically retightened. A good source of information on measuring for maximum voltage drops can be found at Exide's *Caring For Your Battery*.

*Insure there is adequate ventilation for the batteries so the gas can dissipate while recharging and the batteries can stay cooler. In other words, do **NOT** use sealed battery boxes, even with sealed Gel Cell or AGM VRLA batteries.* Some batteries will require up to 30 "preconditioning" cycles before they will produce their rated capacity. This is because the acid needs to fully penetrate the pores of the newly formed plates.

<<<Previous [Home] [Top] Next>>>

17. WHY WON'T MY ENGINE START?

Last Updated on July 11, 2004

Finding the reason why your engine will not start can be a very frustrating problem. The battery and starter motor's principal job is to start the engine. While the engine is running, the alternator, voltage regulator and battery all work together to provide stable source of power for your vehicle and to recharge the battery. **All** of these components, including the wiring and wiring connections, **must** be in good working order to start and operate your engine.

Assuming you have the battery's plates covered with electrolyte, sufficient fuel, the engine and ignition system are in good working order, and the electrolyte is not frozen, the following is a list of four simple instructions on how to troubleshoot the problem and isolate the source:

1. If there are **no lights or other strange electrical problems**, CHECK the wiring, battery terminal mating surfaces, inside the positive GM style side battery cable terminal with multiple cables, and grounding strap between the engine and chassis for **corrosion** or oxidation. Clean each end to bare metal. Loose, bad or corroded connections are very common causes. If good, then

2. RECHARGE and TEST the **battery** for latent damage and TEST the **charging system**. If good, then

3. Test the **starter**. Burned solenoid contacts, worn starter motor brushes or loose starter bolts are common problems for older vehicles.

4. If the problem continues or the battery drains overnight, TEST for excessive **parasitic** (ignition key off) **drain**.

*Some auto parts or battery stores in the United States and Canada, like Auto Zone, Sears, Wal-Mart, Pep Boys, etc., will test your battery, charging system and starter for **free**.* Simple stuff, like corrosion, bad or loose cable connections, loose alternator belt, loose starter bolts, or a dead battery, can cause your car not start. If the problem is not corrected, take your vehicle to a good auto electric shop is highly recommended.

<<<Previous [Home] [Top] Next>>>

18. WHERE CAN I FIND MORE INFORMATION ON BATTERIES?

Last Updated on July 11, 2004

Additional information on car and deep cycle batteries maybe found on the Web server at http://www.batteryfaq.org. For example, there is a frequently updated list list containing hyperlinks to lead-acid battery manufacturer's sites, battery brand names, and private labeling information. There are also two lists with hyperlinks to battery related product information and references about lead-acid batteries, for example, charging systems, regulators, isolators, test and monitoring systems, associations, books, magazines, history, directories, etc.

Most of the battery manufacturers have a Battery FAQ posted on their web sites in addition to product information, specifications and charging voltages and procedures. Web addresses will often change, so you can use an Internet search tool like http://www.google.com/ or http://www.yahoo.com/ to locate the new addresses. These search tools are very effective in finding specific topics as well.

I will be happy to try and answer your lead-acid battery and charging questions. However, over 80% of the questions I receive have already been answered in the information posted on this Web site, so please check first. Some of the e-mails I receive do not have a valid return address, so please inclose a valid "reply to" e-mail address in your message and subject that will not be blocked by your spam filter or firewall. For comments, suggestions or questions, please email Bill Darden at info@batteryfaq.org.

I highly recommend that you hyperlink to http://www.batteryfaq.org rather than republishing this document because this information will be revised periodically to keep up with the advancements in batteries and the changing resources. Revisions will be indicated with a more recent date or higher version number. These documents are in the public domain and can be freely reproduced or distributed without permission.

<<<Previous [Home] [Top] Next>>>

Specs

Ampere Hour Capacity

Maximum Ampere Hour capacity available during the time interval of:											
Battery	20	15	12	10	8	7	6	5	3	2	1
Type	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs
12 VOLT DEEP CYCLE BATTERIES											
U1-HC	35	33	32	31	30	30	29	28	26	25	23
22NF-HC	60	57	56	55	53	52	51	50	47	45	41
22F-HC	65	61	59	56	54	53	51	49	44	41	36
78-HC	70	67	65	63	61	60	59	57	53	50	46
24TM	85	79	76	73	69	67	65	62	56	51	44
27TM	105	98	93	89	84	81	78	75	66	60	51
27TMX	120	113	108	104	100	97	94	91	82	75	66
31TMX	130	123	117	113	109	106	103	99	90	83	73
16TF-HC	120	117	114	112	110	109	107	105	101	97	91
EV-145	145	138	133	128	124	121	118	114	105	98	87
8D-HC	240	223	212	202	192	186	176	171	151	137	115
US 185	195	187	174	167	159	155	150	144	129	118	101
US 185HC	215	200	196	185	181	174	169	163	146	135	118
BIG JOE	107	101	97	94	91	89	86	84	76	71	63
6 VOLT DEEP CYCLE BATTERIES											
1-HC	95	90	87	84	81	80	78	75	69	65	58
US 2000	210	197	188	181	173	168	163	157	141	129	112

US 2200	225	207	197	190	181	176	171	164	147	136	117
US 125	235	220	212	207	200	196	191	186	172	162	145
US 145	245	234	227	221	214	209	205	199	185	174	157
US 250	250	240	233	227	220	216	211	206	192	181	165
US 250HC	275	272	258	250	242	237	233	227	212	200	172
US 305	305	298	276	266	260	252	246	241	219	206	177
US 305HC	335	322	310	301	290	284	277	270	250	228	196
L16	375	355	342	327	312	308	298	284	258	238	204
L16 HC	415	395	373	358	342	329	323	311	278	257	244
8 VOLT DEEP CYCLE BATTERIES											
US 8V GC	165	157	151	147	141	138	135	131	120	112	100
11-4-1	142	138	136	134	131	130	129	127	121	117	111
13-4-1	155	150	147	144	142	140	138	136	130	125	117
15-4-1	190	182	176	172	168	165	161	157	148	139	119
17-4-1	215	206	200	193	187	183	179	174	162	152	137
19-4-1	240	231	224	218	212	208	204	200	186	176	161

U. S. Battery Manufacturing Co.
1675 Sampson Ave.
Corona, CA 92879
(800) 695-0945
(951) 371-8090
Fax (951) 371-4671

U. S. Battery Manufacturing Co.
653 Industrial Park Dr.
Evans, GA 30809
(706) 868-0532
Fax (706) 860-9342

U.S. Battery Manufacturing Co.
1895 Tobacco Road
Augusta, GA 30906
(800) 522-0945
(706) 790-0218
(706) 772-7756 Fax

Email Us: Information
Techsupport@usbattery.com
Sales: West Midwest
Southeast Northeast
Export

Uve's Battery Page

Flooded Battery Chart

Model	Volts	Weight (lbs)	lngth	width	height	20 hour (ah)	rsrv cpcty	cost	Cycles (80%)
SCS225	12	66				135	225	$85	
DEKA 8G27	12	62.5							
T-105	6	61	10.38	7.13	11.19	225	447	$55	733
T-125	6	66	10.38	7.13	11.19	235	488	$80	650
T-145	6	71	10.38	7.13	11.5	244	530	$95	625
T-875	8	63	10.38	7.13	11.19	150	295	$102	
T-890	8	69	10.38	7.13	11.19	165	340	$122	
US 8VGC	8	64.5	10.38	7.13	11.9	165	318	$50	
5SHP	12	86	13.56	6.75	11.5	165	272	$220	
Everready DC27-850	12	55	12.5	6.75	9.5	120	180	$55	
Douglas 31EV	12	66	13	6.81	10.17	135	200		

Sealed Battery Chart

Model	Volts	Weight (lbs)	length	width	height	20 hour (ah)	rsrv cpcty	cost	Cycles (80%)
Optima D750S	12	44.9	10.0	6.8	7.8	65	125	$130	220
Optima D750U	12	46.1	10.0	6.8	7.8	65	125	$119	220
Optima Group 31	12	72	13.0	6.8	9.5	100	190	$140	
Concorde GPC-1234	12	23	7.68	5.15	7.22	33	50	$58	
Concorde GPC-1248	12	32	9.41	5.45	9.35	48	84	$85	
Concorde GPC-1260	12	43	10.2	6.6	9.35	60	106	$102	
Concorde GPC-1272	12	50	11.82	6.6	9.35	72	114	$114	
Concorde GPC-1280	12	53	10.2	6.6	9.35	80	149	$118	
Concorde GPC-1285	12	61				85	159	$138	
Concorde GPC-1295	12	63	11.82	6.6	9.35	95	176	$152	
Concorde GPC-12105	12	68	12.95	6.75	9.25	105	190	$166	
Concorde GPC-4D	12	130	20.73	8.66	10.27	210	380	$301	
Concorde GPC-8D	12	158	20.62	10.95	10.17	255	561	$376	
Concorde GPC-6180	6	55	10.4	7.11	10.91	180	317	$145	
Exide Orbital 34XCD	12	38	10.175	7	7.44	50	95	$98	
Hawker Genesis G12V38Ah10VP	12	32.9	7.75	6.5	6.69	46	66		500

Hawker Genesis G12V70Ah10EP	12	58	13.02	6.62	7.68	72	180	$200	500
Hawker Odyssey PC1200	12	38.2	7.87	6.66	6.8	40	78		
Hawker Odyssey PC1700	12	60.9	13.02	6.62	6.93	65	142		
Hawker Odyssey PC2150	12	75	13	6.8	9.4	88	200		

NiMH Battery Chart

Model	Volts	Weight (lbs)	lngth	width	height	20 hour (ah)	rsrv cpcty	cost	Cycles (80%)
Ovonic (85ah)	12	35	16.1	3	4	112	200		800
Ovonic (150ah)	12	49.5	15.16	4.1	8.54	185	384		800

LiPoly Battery Chart

Model	Volts	Weight (lbs)	lngth	width	height	20 hour (ah)	rsrv cpcty	cost	Cycles (80%)
mid term	12	21	12.5	6.75	9.5	70	140	$266	600
long term	12	19.5	12.5	6.75	9.5	145	309	$177	1000
VL Module	10.65	17.6	7.5	4.9	9.5	100	216	$177	1500

Note: Battery prices are the lowest price I have been informed of for that battery. These battery prices are not from a specific distributor or even taken at the same time.

---

use one of the following methods to calculate peukert's values:

Time 1: (min)

Rate 1: (amps)

Time 2: (min)

Rate 2: (amps)

or

20 hour capacity: (ah)

reserve capacity: 25 (min)

enter 20 hour capacity and reserve capacity

Peukert's exponent:

Peukert capacity: (ah)

All of the calculations in this section require peukert's exponent.

time: hours

amps:

amp hours: (ah)

given time period

given amps

More Battery Pages

- Technical Battery Information

Battery Frequently Asked Questions

What should I look at when deciding which battery to use?

> You should be looking for a low Puekert's number when selecting batteries for you car. A high puekert's number means the battery will not last very long and will have a large voltage sag. I would not use any battery which has a Puekert's number of greater than 1.23.

If I want to have a lot of range, which battery should I use?

> Range mainly depends on the weight of the batteries you have in your car.

If I want to have an inexpensive low maintenance battery, which battery should I use?

> I would suggest one of the concorde batteries as an inexpensive low maintenance battery. These batteries however can not take the abuse (high currents) that the optima or hawker batteries can.

If I want a high performance car, which battery should I use?

> I would suggest the optima or hawker battery for a high performance car.

If I want an inexpensive moderate-low range car, which battery should I use?

> I would suggest the T105 battery for an inexpensive moderate-low range car

If I want an inexpensive moderate range low voltage car, which battery should I use?

I would suggest the T105 or T125 battery for an inexpensive moderate range low voltage car

Why is the Peukert's number important when deciding on a battery

The Peukert's number is important because it tells you the internal resistance of the battery. A battery may have a high 20 hour amp-hr rating, but a high Peukert's number. At the currents needed for EVs, this may not be a good battery because the amp-hr rating at a 1 hour rate or 1/2 hour rate can be a lot less then a battery with a lower 20 amp-hr lower Peukert's number. When deciding on a battery, use the calculator on this page to calculate the the 1 hour or 1/2 hour amp-hr rating. This will give a better indication of the range you can expect.

Are there any precuations which need to be taken for sealed batteries?

A sealed battery must not be over charged. If you over charge a sealed battery you will greatly shorten it's life. You can use battery regulators to keep this from happening.

What is cell reversal?

Cell reversal is when a cell in the battery has the opposite value. This usually happens when a cell is charged in the incorrect direction as when the cell is completely discharged and current is still being drawn from the battery.

How do you fix a cell reversal?

Put a resister across the battery over night to completely drain the battery. Then charge the battery with a low current.

How much current can I draw from the battery without damaging the battery?

This depends on the battery and how long you draw the high current. In general, the lower the Peukert's number the high the current you can draw from the battery without damaging the battery.

How do I charge my flooded batteries?

Charge batteries at what ever current until they reach 2.4 v per cell +/- .003v per degree C difference from 25 degrees. The higher the temerature the lower the voltage. Once the batteries reach 2.4v +/-, Keep the batteries at this voltage until the current goes to 2% of 20ah rating. So my 120ah batteries should be charge until the current drops below 2.4 amps. Equalizing should be done about once a week when the batteries are new or very old, once a month during the normal life of the battery. To equalize, charge the batteries at 2% of 20ah rating until voltage stops rising. Make sure you keep track of the water level in the battery while equalizing. Equalizing will use water!

How do I charge my AGM batteries?

Battery Charger: (Constant Voltage) 13,8 to 15,0 volts, 10 amps maximum, 8-10 hours approximate.
Float Charge: 13,2 to 13,8 volts, 1 amp maximum current.
Rapid Recharge: (Constant voltage charger) Maximum voltage 15,6 volts. No current limit as long as temperature remains below 51 degrees C. Charge until current drops below 1 amp. Recharge time will vary according to temperature and charger characteristics. When using Constant Voltage chargers, amperage will taper down as the battery becomes recharged. When amperage drops below 1 amp, the battery will be close to a full state of charge.
Cyclic application or series string applications (CV/CC) only: Constant Voltage with Constant Current finish: 14,7 volts, temperature < 51 degrees C, no current limits. When current falls below 1 amp, finish with 2 amp constant current 1 hour.

If you want to download a comma separated battery table, which you can load into a spreadsheet or other program click here

---

If you have any information to fill in my chart or have other batteries you want to add to the chart, please email me at uve_rick@netzero.net

---

Ev Page
Home Page

This site visited by 001488 people as of May 30 2004.

Lead Acid Battery Desulfation Pulse Generator

Some help and information for builders

***NEW:* Parts kits available, now with peak reading option**

(Last update Sept 20 '02)

This ever growing page is intended to provide builders of the battery desulfator circuit, as shown in Home Power Magazine, issue number 77, with additional information. (Here is the original article, PDF format.)

Please note that due to time constraints, I am not able to answer desulfator related questions any longer. I would ask all those needing further assistance to please submit your questions to the desulfator BBS. Thanks for your understanding.

The volume of email has made it clear that a few more details are needed. This circuit has been duplicated by many around the world. (Africa, India, Indonesia.....) Anyone with soldering skills can build the unit. There are many reports of successful battery reclaimation after more than a year of testing, so it can be safely said that this technique is valid. While there are a number of commercial units available now, this circuit represents the lowest cost way to rejuvenate tired batteries. I have included complete technical details so that anyone with typical electronics skills can adapt or modify the circuit to their specific needs.

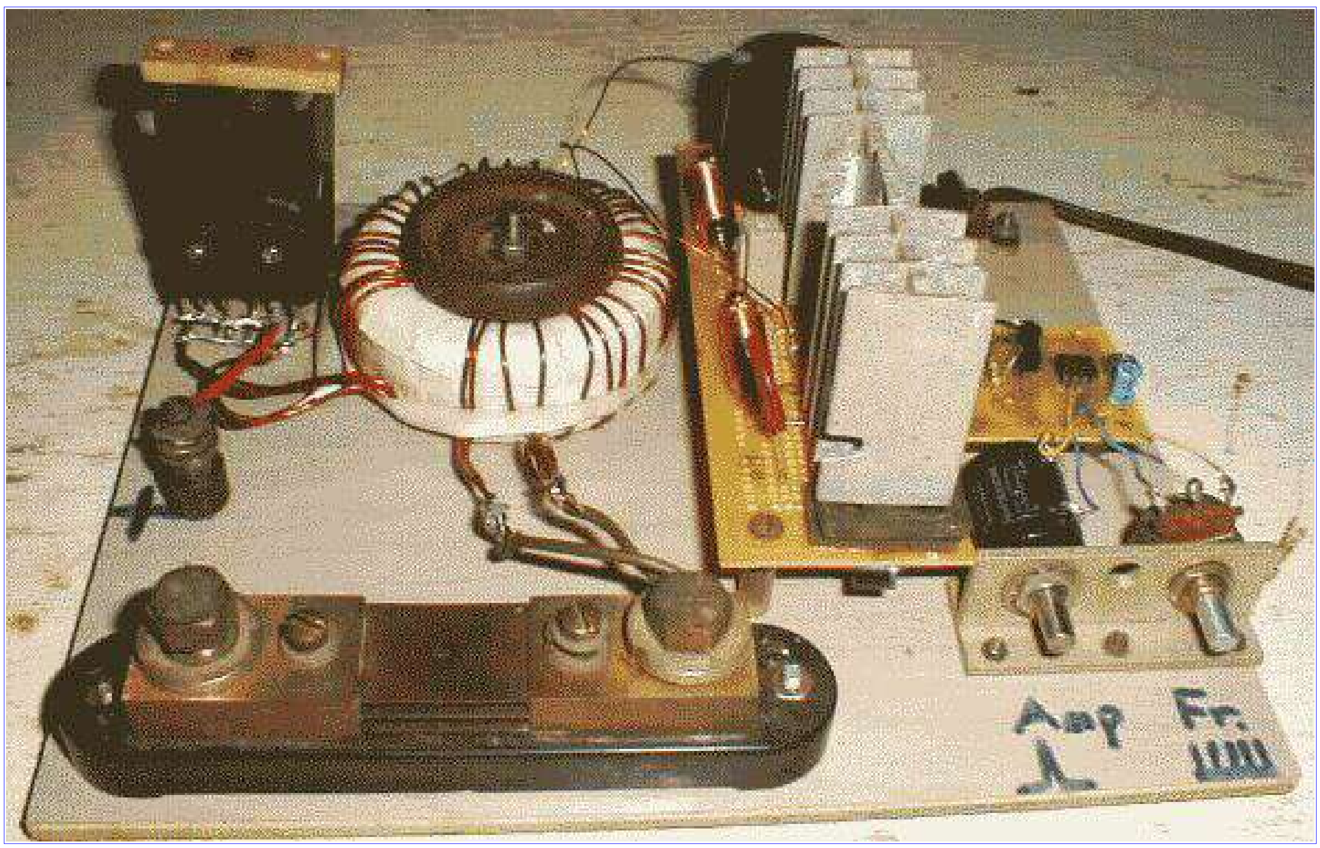
The main concern I have in presenting this information is to keep as many recoverable batteries in service as possible. Most batteries are discarded prematurely, due to sulfation rather than having reached their cycle limit. This represents a huge waste, and a potential resource. It is hoped that many tons of batteries can be kept out of the world's dumps by this simple technique.

- To start with, take a look at this short note on lead acid battery chemistry and the sulfation process.
- Don Denhardt has assembled a gallery of dissected batteries, showing their internal anatomy.
- **Here is a patent worth reviewing:** Patent #3,963,976 (www.uspto.gov) shows that high peak current is essential to overcome electrolyte stratification.
- Here are a few hints, suggestions, and procedures for reclaiming old batteries.

There are now several versions available, tailored to specific needs:

[The original, low power version,](#) suitable for most solar systems, vehicle starter maintenance, and gradual battery reclaimation. There are several flavors of this circuit.

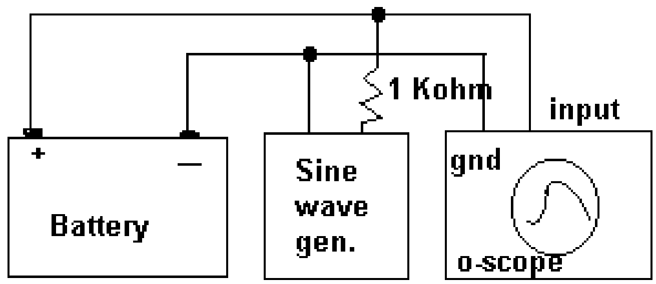
[The high power version,](#) for large battery reclaimation, electric vehicle maintenance, high voltage systems, and low level charging. Under development.



The following provides some supplemental info and links for those interested in theoretical aspects and additional help:

A few words about the "several megahertz resonance" that is mentioned in the original article. One of the most frequent questions is about the fact that the drive frequency is at 1 khz, but the resulting vibrations in the battery are at several MHz. Go back over the part in the article about the "plucked string". This is a very common situation in all systems with a resonant frequency. A disturbance of any sort will tend to create vibrations at the resonance. The megahertz range vibrations are over very quickly, ie they are a damped oscillation. The pulser circuit does not drive these frequencies, any more than a finger nail drives a guitar string at its pitch.

One can see them readily using an oscilliscope, but some care is required to get the triggering just right. A better way to see the fact that batteries have a high frequency resonance is to use a sweep generator, as in the diagram:



Vary the sine wave source over a range of one to ten megahertz, and look for the peak in the response, showing electrolyte resonance.

In the original article, I put forth an idea of what might be happening in the battery to cause this resonant frequency, and guessed that it was occuring in the electrolyte itself. An email from battery expert Heinz Wenzl, in Germany, said this:

> *The next question in my quest to understand this is the following: Given the same battery type there are small deviations of resonant frequency which are no measurement artefact. Now under normal conditions (i.e. the battery not being deep-deep discharged with an acid density close to one), there are always a lot of hydrogen and sulfate ions around which can create a plasma type charge distribution. A change of the frequency could be linked to the electrolyte density which is related to the state-of-charge (I have found no real correlation here), the viscosity (this I would imagine would be linked to the IR spectrum of molecular vibrations), the current exchange density (linked to state-of-charge and surface area and catalytic properties, etc.) and to .... some others. But gut feeling would tell me, that all these effects should be small compared to the plasma properties themselves. In which case, all lead acid batteries with flooded electrolyte should have the same resonance and NiCd a different one.*
>
> *What makes you think that the plasma condition is associated with the electrolyte and not with the solid material? Some lead minerals, e.g. PZT are piezoelectric and the few Mhz are really in that range of effects!*

So my original guess about what may be going on was not very close to the mark. Nevertheless, the resonance is very much there, and it helps to create conditions of high peak voltage (ringing) that are favorable to the process of desulfation.

Does this really work ?

The results are coming in. Here are some typical comments:

- *Hello Alastair, I would like to thank you for such a neat product. I have reclaimed several batteries now that were junk. I have gathered up as many more as I can find and have them connected to an Air 403 for charging and running of the desulfator. Free batteries and free power, doesn't get much better than this. I have built several other desulfators for other people to use ..... thanks again for such a fantastic project. Ed Goddard Castle Dale, Utah.*
- *I am pleased with the performance. Yours works faster than the $90 Pulse Tech unit I've had 3 years. George Ficklen Newport News, Va.*

- *I can actually see etching into the sulfate crystals on top of the cells. Eric Wiggins. Thames, N.Z.*
- *It looks as though this little device saved me $60.00. The white deposits have all but disappeared on the plates. Scott Sisson. Portland, Or.*

A number of comments on the message board have been about battery testing. Here is a response from Geoge Aumann:

> *Using a resisitive load to measure battery condition is a standard method. For each battery type a standard load is defined, and if the voltage under load drops below a certain level, the battery is bad or in need of recharging. For small batteries this load can be typical, like a 5 Ohm load for a AA Alkaline drops the voltage at end-of-life to 1.0 Volts. Using a load across the battery (for a few milliseconds) is used by laptop computers to assess the charge status of the battery.*
>
> *For big batteries the "standard" load resistor may get to be very small. However, given the availbility of good and fairly cheap(under $40) 3 1/2 digit digital volt meters, it is not necessary (or safe) to draw a big current spike out of the battery to measure its internal impedance. For my Dynasty UPS12-310 High output battery I use a 1 Ohm 1% 20 watt resistor shunted with a bar directly to the battery terminals. The resulting drop across the 1 Ohm resistor is eazy to measure with the voltmeter set to the 200 mV scale.*
>
> *A fully charged 12.6 volt lead-acid battery will have an internal resistance of about 0.01 ohms. My Dynasty UPS12-310 high output battery is spec'd at 0.0033 Ohm. Determine the internal resistance of the battery by measuring the terminal voltage with open circuit, V, and then the voltage drop across an accurately known resistive load R, voltage DV. The internal impedance of the battery, Ri, is then given by Ri= DV * R / V.*
>
> *Example: V=12.60 volts and DV= 81 mV Volt using a 1 Ohm 1% 20 watt Ohmite resistor. Ri= 0.081* 1.0 / 12.6 = 0.0064 Ohm.*
>
> *The power dissipated in the resisitor is V*V / R = 12.52 * 12.52 = 158 watt. The resistor will get warm very quicky. If this experiment is not finished quickly, the temperature increase will change the resistance. This will make the measurement inaccurate and will burn your fingers).*
>
> *Somebody on the email suggested pulling 200A, presumably using a 0.062 Ohm resistor. Pulling that much power (200 * 12.6 = 2.5KW!) has to be done fast indeed. Batteries of this size can be very dangerous.*

If you would like to communicate with others in this project, or to ask questions not answered by the above material, please try the
desulfator bulletin board.

Some relevant links:

Commercial Desulfators from Solar-Electric.com
Technical details on why pulse charging is good.
This shows that Ni Cads are similarly benefitted
Here is an email exchange on battery testing techniques.
A Battery Tester by Megger
http://www.btechinc.com/ Another battery tester.
http://www.powerdesigners.com/InfoWeb/design_center/Appnotes_Archive/A2615.shtm Further Battery testing info.
http://www.batterybes.com/ Commercial desulfator.
http://www.innovativeenergy.com/index.htm Another commercial desulfator.
http://www.van-haandel-1.myweb.nl/Download.html An article in Dutch about a desulfator with some interesting features. See page 2 for the schematic. Here is a translation to English of the most important details.http://users.pandora.be/vandenberghe.jef/battery/

Back to Aquarian Homepage

Visitors since April 2, 2002:

Some Technical Details on Lead Acid Batteries

The Chemistry of Sulfation, and Why Pulsing Helps

Return to Desufator Help Page   Return to Aquarian Electronics Homepage

---

Here is a basic look at the chemistry of conventional lead-acid batteries under charge and discharge. This data is taken from the technical manual for Power Sonic batteries. The manual is worth looking at in its own right: Click here for the PDF.

```
The basic electrochemical reaction equation in a lead-acid battery can be written as
follows:

Pb + 2H2SO4 + PbO2      <---- Charging        + PbSO4 + 2H2O + PbSO4
                      Discharging---->

Or, in words:


porous lead      +    sulfuric acid   +    porous lead dioxide
active material        electrolyte         active material
negative plate                             positive plate


                 ^    charging   ^
 Becomes         ----------------
                 V discharging V


lead sulfate     +      water         +    lead sulfate
active material       electrolyte          active material
negative plate                             positive plate
```

Discharge

During the discharge portion of the reaction, lead dioxide (positive plate) and lead (negative plate) react with sulfuric acid to create lead sulfate, water and energy.

Charge

During the recharge phase of the reaction, the cycle is reversed: the lead sulfate and water are electro-chemically converted to lead, lead oxide and sulfuric acid by an external electrical charging source.

This is how things work when the battery is new and clean. There are several effects that come in as the battery is used. One is the process called sulfation, which is of central concern to this effort. Here is Richard Perez, from Home Power magazine #29, page 44:

> *The biggest problem in lead-acid cells is sulfation due to chronic undercharging. Here the sulfate ions have entered into deep bonds with the lead on the cell's plates. The sulfate ions can bond with the lead at three successively deeper energy levels. Level One is the bond we use when we normally charge and discharge the cell. After a month or so at Level One, some of the bonds form Level Two bonds which require more electric power to break. After several months of being at Level Two bond, the sulfate ions really cozy up to the lead and form Level Three bonds. Level Three bonds are not accessible electrically. No amount of recharging will break Level Three bonds. The longer the lead sulfate bond stays at a level the more likely it is to form a closer*

acquaintance and enter the next deeper level. This is why it is so important to fully, regularly, and completely, recharge lead-acid cells.

> ***Equalization Charges***
>
> *If the loss in capacity is due to Level Two bonding, then a repeated series of equalizing charges will break the Level Two bonds. Under equalization the Level Two bonds will first be transformed into Level One bonds, and then the sulfate ion can be kicked loose of the lead entirely and reenter the electrolyte solution. If your lead-acid cells have lost capacity, then a regime of equalizing charges is the first procedure to try. An equalization charge is a controlled overcharge of an already fully recharged cell. First recharge the cell and then continue to charge the cell at a C/20 rate for five to seven hours. During equalization charges, the cell voltage will become very high, about 2.7 VDC per cell. This overcharge contains the necessary power to break the Level Two bonds and force them to Level One. Once they reach Level One, the bond is easily broken and the sulfate ions reenter into solution in the electrolyte.*

In the above, the Level One, Two, or Three bonds refer to progressively larger and insoluable crystals of lead sulfate. Like most crystal formation, it is a slow process. So the question is, How could pulse charging affect this situation? According to conventional wisdom, not at all. Here is the party line, from a product applications manager at Trojan Battery Co. on pulsing:

> ***The active material in the positive electrode....is lead dioxide. This molecule is a relative of rust, it is a corrosion product. When you charge a lead acid battery, one of the things you attempt to accomplish is the repair or reformation of the corrosion layer of the positive plate. If you don't properly charge the battery, the corrosion layer begins to break down in the acid environment and the voltage characteristic of the battery changes for the worse.***
>
> ***Pulse charging does not influence or improve the corrosion layer of the positive electrode and therefore, does not permanently or properly improve the performance of the battery. It is only through the electrochemical process of corroding the positive electrode that you optimize the battery's performance. To properly corrode the positive electrode the battery voltage has to reach and then excced the gassing potential of the battery. In a deep cycle battery, not gassing the cells will result in stratified electrolyte, ineffective corrosion of the positive plate, reduced performance and shortened life.***

My opinions on the matter, subject to further learning are:

- ***that pulsing does affect the Level Two bonds by constantly applying an overpotential above the gassing point, at a kilohertz rate. Thus, even if the battery is not fully charged, it keeps the Level One bonds from turning into Level Two bonds. Since the process is slow and continuous, it does not liberate significant amounts of gasses, as they are able to dissolve into the electrolyte.***
- ***that pulsing can also affect the Level Three bonds by virtue of the high rise time of the pulses. Since the Level Three bond crystals are insoluable and electrically inactive to DC current, they act as a dielectric. This forms a capacitive connection between the deeper layer of the plate and the electrolyte that will pass transients of current with low impedance. This then allows for enough energy to be transferred to the material to allow for the slow breaking apart of the crystals.***
- ***The main factors are: fast rise time, high peak amperage, and moderate repetition rate.***

There are a number of other factors that can degrade batteries, to site a few:

- ***Cycling of the battery causes "shedding", or loss of material from the plates. If you see a battery that has reached its limit, you might find chunks of lead on the bottom of the cell, and actual holes in the plates. Nothing's to be done in this case. Excessive charge rate will also cause this to occur.***
- ***Electrolyte stratification occurs when the batteries do not receive sufficient charge rate to cause bubbles to rise and stir the liquid. The heavier electrolyte sinks to the bottom of the cell. This renders the lower portion of the plates inactive, and that is where sulfation gets started. Some large batteries use pumps to force the electrolyte to turn over. While pulsing can repair the harm done from prolonged stratification, it does not alleviate the situation. Only sufficiently high charge rate for the size of the battery will cause the needed convection currents. As one pulse charging patent states, (US Patent #3,963,976) high peak amperage is needed to overcome this factor.***
- ***Electrolyte contamination happens everytime a (dirty) hydrometer is inserted in the cells, or less than good distilled water is used. This can lead to a mineral layer on the plates, which might be removed by pulsing, or by EDTA.***
- ***Shorted cells can be caused by sulfation. It seems that the crystal formation expands and warps the plate material.***

This can cause the case to bulge, or to push adjacent plates together. If you are lucky, desulfation can relieve this situation, but I have not seen it myself.

Return to Desufator Help Page ***Return to Aquarian Electronics Homepage***

Desulfator Frequently Asked Questions

Return to Desufator Help Page   Return to Aquarian Electronics Homepage

---

Q: What is battery sulfation and why does it cause battery failure ?

A: Each time a battery is discharged some of the sulfuric acid in the electrolyte is converted to lead sulfate crystals which form on the plates. These crystals interfere with the chemical reaction neccessary for proper battery operation. When the battery is recharged MOST (but not all) the sulfates are reconverted back into sulfuric acid. This is why a discharged battery will have a low Specific Gravity (SG) reading. Over time the sulfates which are not reconstituted as acid form stubborn patches of large crystal growths that will grow and eventually choke the life out of a lead acid battery. These crystal growths if not stopped will act like ice expanding the cases (bulges), breaking the plates and plate and cell interconnects and causing shorts.

Q: Why does a battery die when it sits ?

A: All lead acid batteries will self discharge forming sulfates in the process. The degree of self discharge will depend on temperature, plate chemistry, and how clean the battery is and how it is stored.

Q: Is there any truth to storing a battery on the ground being a bad idea ?

A: Yes, When stored on the ground the battery will assume the same temperature as the ground. When warmer moist air comes in contact with the battery case, moisture can condense out (like an iced drink in the summer) and increase the amount of self discharge across the top of the case (between the posts). To see this in action take a voltmeter and attach one lead to a post and drag the other lead across the top. You will note an increasing voltage as the probe heads to the other post. To reduce this aspect of self discharge always store batteries on a shelf or on some form of insulation.

Q: How long does it take to desulfate a battery ?

A: That would depend on the degree of sulfation, how clean the tops of the battery is (another route of self-discharge paths), plate chemistry, temperature of the battery and size of the battery. Generally speaking gell cell batts will respond in a week, car starter batteries in a month or so, deep discharge depends on its condition.

Q: How does this pulser compare with commercial units ?

A: All reports received to date suggest this design works faster than what is commercially available.

Q: How much current does this circuit draw ?

A: Normally from 0.040 to 0.050 Amps

Q: Do I need to use a battery charger with this circuit ?

A: Not if the batteries are being charged on a daily basis such as in service in a photovoltaic system or car starter battery

Q: Can I install the 12V pulser permanently in my battery charger ?

A: NO! Unconnected battery chargers (not connected to a battery) can put out peak voltages 20V or higher. If the pulser is permanently installed in the charger AND the charger is energized AND not connected to a battery, C1 will charge up to a damaging voltage to the 555.

Q: Is there any way to permanently install a pulser in a battery charger ?

A: Yes. Parallel C1 with a 15V rated Zener diode, banded end to positive.

Q: Does the pulser affect other equipment connected to the battery ?

A: Quite possibly. While the typical unfiltered battery charger is not a problem, some other types of loads, such as inverters, might shunt away some of the pulser's output. In such a case, place a choke in series with one of the inverter leads to keep the high frequency spikes from traveling further. This can be a simple ferrite toroid with one or two turns through it, or a few ferrite beads placed over the wire.

Q: Will this circuit work on a 6V battery ?

A: The 12V pulser will pulse a 6V batt but will have it's pulse decreased by 1/3. OR use a 44K ohm resistor for R2. OR use two series connected 22K resistors for R2 with a shorting switch for one of them (this will give you a switch selectable 6/12V pulser. There is no need to change R3 as with 6V operation it only drops about 0.75V and leaves plenty of volts to run the 555 and trigger the FET.

Q: Are special tools needed to assemble the circuit ?

A: A grounded tip soldering pencil will be needed. A temperature controlled, grounded tip iron is best. Other nice to have things are a magnifying glass and miniature side cutters for trimming the soldered leads.

Q: Do I need special equipment to calibrate or test the circuit ?

A: No, if you are very careful not to zap the gate of the FET with static charges and you make sure all your wiring matches the schematic, it should fire up with no problems. The components listed provide for a healthy pulse with a nice safety margin.

Q: Is there a recommended order of building the circuit with checks ?

A: Yes, solder together the 555 section and insure you have a negative pulse at pin 3 before going on to the output stage (if you have a scope).

Q: Are there any tips for a better working pulser ?

A: Yes, solder the battery leads directly to the pulse producing components (C4 positive and D1 negative). Use 18Ga to 10Ga stranded for the pulser leads going to the battery (keep them as short as possible).

Q: What are the best pulser leads to use ?

A: 10Ga stranded virtually eliminates the impedance losses in the connecting cabling.

Q: Can the pulser be custom tuned or adjusted ?

A: Yes, by using pots for R1 and R2. Initially set R1 (1Meg pot) for max R, R2 (50K pot) for min. Adjust R2 (increasing R) for a peak pulse out. Adjust R1 (decreasing R) for a PRF that does not heat up L1 or C4 too bad. NOTE: it will take 1/2 hour or so to see the effects of heat gain in L1 and C4. Try to do this calibration at the highest voltage the circuit will see (15V equalization in PV systems, 14.7V in automotive systems).

Q: Should I do anything the first time I fire it up ?

A: Yes, connect the neg pulser lead to batt. While holding the metal tab of Q1 and D1 between three fingers (for a heat sensor), briefly connect the pos pulser lead for one second. If you do not detect any heat from Q1 and D1 connect for 2 seconds and so on until it can be connected for 10 seconds without detectable heat.

Q: How do I know it is working ?

A: . The best indication that the circuit as a whole is working is the slight 1kHz tone, and the good spark that it makes when connected or disconnected from the battery terminals. You can also hold an AM radio near L1 or drop a kitchen magnet on L1.

Q:Can additional (parallel) stages be driven from the same 555 timer ?

A:Yes, that should work just fine.

Q:Also would the 330 uH L3 inductor, if used in the 12V circuit instead of the 220uH inductor, provide a boost and a faster reclamation rate of the battery ?

A:Less, actually, as it stands. The peak current is as much a function of the ohmic resistance of the coil. If you want to increase the peak current, it would be also necessary to change the R1/R2 ratio, using trim pots, to increase the 50 microsecond pulse slightly. Use a .1 ohm current shunt and a scope to take a look at the current pulse wave form. Watch out for over heating in the inductors if you set the current too high. Look at the output of the 555 pin 3. You want to see a narrow, negative going pulse of 50 usec, at a rep rate of 1 khz. Use a 1 Meg pot for R1, and a 50 kohm for R2. Use the adjustment procedure described above.

Q: My FET, inductors or diode got red hot. What is wrong ?

A: You connected the pulser with reversed polarities, FET is in backwards, the gate is isolated (not connected to pin 3 of the 555). FET is shorted. Diode is in backwards. Wrong combination of timing components (R1, R2, C2) leading to a Pulse Repitition Frequency (PRF) that is too high or a pulse width (pin 3 output) that is too long. Bad C1 will cause ringing in the pulse when it is supposed to shut the FET off.

Q: Is there a schematic to be able to use N Channel FET's ?

A: Yes, look for the link on the Help page for the schematic variants.

Q: Does this work on NiCads ?

A: Yes, NiCads suffer the same crystal growth problems that are fixed with pulsing.

I would be interested in any feedback or corrections to the above : kalepa at shaka dot com

---

Back to Aquarian Homepage

ELECTRICAL AND PARASITIC LOAD TROUBLESHOOTING

Parasitic load problems don't have to be draining - on the technician, that is. Every so often, we tend to long for the days when life was simpler. Things are a little more sophisticated today when approaching an electrical problem that robs the battery of its power. Gone are the days when "just gimme a test light and a jumper wire; I'll fix 'er" technology applied. Armed with some proper test equipment, an understanding of vehicle systems and some solid knowledge of electrical theory, the process becomes less of a mystery. Whether you're working on a 1931 Model A or the most electronically advanced vehicle on the road today, the same basic procedures apply. First, don't get intimidated or frustrated by the type of vehicle or problem you're facing. Sure, the electrical system on the Model A was simpler and just looking at the schematic for that car was a confidence builder - not much to it. But keep this in mind: many times on today's vehicles it's actually easier to diagnose the problem than it is to actually physically repair the problem. Sometimes the greater challenge is just getting to the culprit component or problem area.

In this article, we'll explore some testing methods for various electrical problems including the elusive parasitic drains. You'll see how sometimes just through logical thinking, you can diagnose some problems without even raising the hood and we'll share some "tricks, tips and traps" of parasitic load troubleshooting.

First, how about a quick review of some basic electrical terms? I know, I know - been there, done that, right? Just let me cover a few basics to refresh your memory and if you haven't taken your fairly new DVOM out of the box recently, now is a good time to get the operator's manual out and reacquaint yourself with it. While you're at it, be sure to check what the meter's capabilities and limitations are. And if you are in the market for one, don't "undersell" yourself. There is nothing worse than making an investment in a tool, just to find out it can't do what you need it to do. If you are not sure, consult someone who can help you out that is knowledgeable in diagnostic tools and equipment.

First, let's take a look at some simple meter hook ups for some basic troubleshooting tests.

Testing for Voltage

First, connect the clip end of the test light to a good ground. Of course if you are using a voltmeter, connect the negative test lead to ground. Now touch the test light probe to your desired test point. Naturally, if the test light illuminates, there is voltage present. That's good for a quick test, but can you tell how much voltage there is just by looking at how bright the bulb is? Of course not (although I've heard some say they can), which is why the voltmeter is preferred when exact information is required. I'm getting ahead of myself by asking this next question: How many system draws or parasitic load problems have you successfully diagnosed with the use of a test light placed in series between the battery terminal and the cable end? Remember the Model A? You got away with it on earlier cats, with good results I might add, but you probably won't experience the same with a current vehicle. I'll explain why later.

Continuity Test

Make sure you disconnect the battery first and then connect one lead of a self-powered test light. Or if you prefer, an ohmmeter to one end of the circuit that you need to test. Attach the other end of the self-powered test light or ohmmeter to the other end of the circuit you are testing. If the light illuminates, there is a complete circuit or continuity. But once again, if you need exact results of just how good the continuity is, the ohmmeter will give an exact resistance reading. Perhaps corrosion is beginning to affect the operation of a particular component. The test light will glow if there is continuity, but how bright is good? At least specific measurements can be obtained with the ohmmeter and then be compared to actual specs or known good parts.

Voltage Drop Test

This particular test is one of the most revealing tests in your "toolbox of tricks." This check is to see how much voltage is being lost in a circuit, either through the conductor, connection, switch or component. Using a voltmeter, connect the positive lead to the connector or wire end that is closest to the battery. Then connect the negative lead to the other end of the wire, connection or component being tested. Now activate the circuit. Voltage drop tests are live, dynamic readings. The voltage drop test can be used on virtually any circuit or component. From large starter motor cables to small computer circuits, the voltage drop test can help you locate resistance type problems. The proof is in the reading. Depending on the item being tested, you can expect readings well below one volt - sometimes one or two tenths of a volt. Lower is better. Check with manufacturers specifications for the component or circuit you are testing. Remember, a component or connection may appear to look all right, but sometimes the oxidation or corrosion is not detectable visually. Test, don't guess.

Short to Ground Test

Depending where in the circuit this problem is, this may be a very easy draw to locate. Or, it may just be affecting the operation of a component. For this test, remove the fuse and connect a test light or voltmeter in its place. Power up the circuit and start moving the wire(s) and connectors beginning near the fuse block and working back. Keep moving onward at about 6- to 12-inch intervals while observing the test light or voltmeter. Also keep an eye out for telltale signs of evidence of shorting as you move down the wiring. When the test light glows or the voltmeter shows a reading, there is a problem near that point.

Using a Short Finder

A short finder is designed to "pulse" the current through the circuit. Here's what you do: Remove the blown fuse and leave the battery connected. Connect the short finder in place of the fuse and close all switches (in series) associated with the circuit that you are testing. As the short finder pulses the current to the short, there is a magnetic field traveling along the circuit wiring between the fuse block and wherever the short is located. Like before, start at the fuse block, this time using an inductive ammeter and slowly move the meter along the wiring. The meter can even show current pulses through sheet metal and body trim. When you move past the point of the short, the meter will stop reading. You now have isolated the general area of the short.

Load Testing

Okay, now that we've covered some other basic electrical problem tests, let's take a look at the seemingly mysterious problem of parasitic load problems. Knowing how to test for them is probably the most important part of the test sequence.

First, a typical draw (non-parasidic) test. This can be rather obvious. A trunk light that stays on or an accessory that is inadvertently left on, etc., will usually take the battery down in a relatively short time. To locate the problem area, you can simply connect an ammeter to either battery cable (negative preferred) and observe the meter as you deactivate or open one circuit at a time, usually at the fuse block. Remember, some meters have an inductive clamp that does not require the circuit to be opened for the meter to be connected. Other meters require series connections. Make sure the ammeter is set to an appropriate scale so that the ampere reading from the draw can be interpreted. Also, be sure that the interior light is not on due to the door that you have open! Look for the obvious.

Now, (depending on the meter) if you are using an inductive type ammeter connection, the amp draw reading may be too small to be accurately read or detected, so you may have to use a 10X multiplier. You may have one that came as an accessory to your shop's volt/amp tester or they're available as a separate item. In a pinch, you could make one in a few minutes. All you need is a soda can and some wire. Leave about a 12-inch lead-in wire, then begin to wrap the wire around the soda can 10 times. Be sure to wrap it snugly, then leave another 12-inch piece when you are done wrapping. Slide the soda can out of the loop of wire you just created and use electrical tape to secure it. Wrap the electrical tape around the loop in several places so it doesn't unravel. You should have a loop of wire with a foot of wire hanging out each end. Attach test clips to the ends and you're ready to go. Especially helpful on the lower amperage current draws, the 10X multiplier actually makes the reading on the ammeter, well, 10 times greater. So, if you had only a one amp draw, depending on the meter, it may be difficult to read. But connecting the 10X multiplier in series with the negative battery cable, then connecting your inductive ammeter clamp around the loop, it will increase the reading, i.e. one amp will read as 10 amps. Oh, by the way, don't get trapped into a false sense of accuracy or security by using a test light for a draw test. It probably would be okay on the Model A, but...

Parasitic Loads

Ever since computers and other electronic devices that require some sort of memory started to make their appearance, we have seen more things that can draw the battery down. Back in the early days, the battery would just simply discharge over a long period of time. Now, with today's systems, it has a little help in loosing its power. So much help in fact, that if a late model vehicle (with a fair amount of electronic goodies) is going to be parked for even a short period of time, it's recommended that the battery be disconnected.

Some recommendations I have read or heard about suggest if the vehicle is sitting over three weeks, the battery should be disconnected. Do your customers know this? Have you been looking at a "problem" that's inherent to that particular vehicle that's not really a problem at all? But yes, there are some problems that do crop up that cause a higher-than normal draw that may not level the battery overnight, but in a few days time. These lower, parasitic type draws need instruments that can read in lower values and procedures that won't damage your meter or give you wrong readings. I'll give you some guidelines to follow regarding procedures and specifications. The maximum acceptable battery draw on a typical later model vehicle is 50 milliamps, or for you digital folks, .050 amps. Now, several things determine this specification. Some systems should be lower, while others are allowed to be higher. It depends greatly on the type and amount of accessories on the vehicle. A word of diagnostic caution: Some systems may appear to have a parasitic load for a while after the ignition is turned off. Be aware of this fact and the system you are working on. This time out period may be as long as 15 to 20 minutes and is considered normal.

Testing Parasific Loads

First, you'll end up interrupting power to the vehicle when you disconnect the battery to connect your ammeter, which is capable of measuring in milliamps. Keep in mind when doing this, the timer circuits have been momentarily interrupted by the removal of the battery (negative) cable. Watch what could happen next. Because they no longer are being powered, they lose the existing charge they had prior to you disconnecting the battery cable. With me so far? So guess what happens when you connect your DVOM to the battery terminal, then on to the battery cable, thus completing the circuit? The timer circuits will want to recharge through your meter, drawing current through it that exceeds the meter's capability. What then? The protection fuse in the meter blows, but the digital display may still, however, display numbers - all zeros. This may be interpreted as no load present. The safeguard is to properly connect your meter.

Here's how:

Make sure the ignition switch and all accessories are off. Don't forget the obvious things like the doors, trunk and underhood lamps are off, too. Next, disconnect the battery cable and install a 12-volt test light or a jumper wire between the battery terminal and the battery cable. If you're using the test light, it will light brightly, then should dim in a second or so.

Quick Tip:

If the test light goes out, usually there is not enough of a current draw to keep that bulb lit, meaning there is probably less than a 500 mA draw. Or, as mentioned, you can use a jumper wire to do the re-connection between the cable and battery. The purpose? To protect your meter. If the meter is used to complete the circuit once the cable is disconnected from the battery, all the current required by those seemingly harmless little silicone things are going to pull too much through your meter. Using the test light or jumper wire will "absorb' the surge, then once dissipated, disconnect the test light or jumper, so the current flows through the meter so you can read what's happening.

Got it? Okay, another warning. If you get the feeling you want to open a door or activate some other circuit during the test, protect your meter. Use the jumper wire and connect it parallel to your meter. Just remember, the timer and memory circuits and think about what's running through your meter, especially before activating any accessories or even opening a door. A meter with a 10 amp position should be used for this type of test. Once connected, observe how the draw decreases quickly and indicates that the memory and/or timer circuit(s) is (are) charging. Once this has stabilized, scale down the meter until the actual current draw is displayed. After you are stabilized with the connections and readings, begin to eliminate one circuit at a time until the reading drops to an acceptable level. Don't reactivate any circuit until you reconnect your jumper lead to protect your meter!

How Much is Too Much?

Again, various publications have a specification range anywhere between 25 to 75 milliamps (mA). Consider how many options are on the vehicle and just figure the more options the higher the allowable draw. Now enter the battery. A perfect case for "one size does not fit all!" It would stand to reason that the more option content of a vehicle, the higher the reserve capacity of the battery. Beware of smaller, economical batteries of a suspect vehicle. That bargain battery may turn out to be no bargain at all.

Here's the simple formula to calculate the acceptable parasitic load a vehicle can have. First and fore-most, you must start with the proper battery in the vehicle. Regardless if it's OEM or not, look for the Reserve Capacity Rating in minutes.

You may have to reference a spec chart for some batteries that don't have that information printed on top of the battery. Once you have confirmed the proper battery and the Reserve Capacity in minutes, you're ready for the math. Multiply the RC minutes by 0.25 to give you a guideline, in milliamps, as to what the allowable parasitic load you could expect for that vehicle. For example, if the battery has an RC minute capacity of 100, you would multiply that by 0.25 to get 25 milliamps. Or, a battery with an RC minute rating of 160 x 0.25 = 40 mA.

Following these simple yet important procedures can take the mystery out of parasitic load diagnosis. The Model A had a long list of accessories to include such luxuries like headlamps, stop and tail lamp and even a dome light. Technology has made us keep current in our troubleshooting and diagnostic skills, all in the effort of the "creature features" we all enjoy now. Who would have thought?

Understanding Alternators -- an Overview

by Dan Masters, danmas@aol.com

ALTERNATOR WARNING LIGHT

"What does that little red light that says ALT mean when it comes on?" Very basically, it means that either the alternator output voltage is lower than the battery voltage, or the battery voltage is lower than the alternator output voltage. If the light gets dimmer as you rev up the engine, then you most likely have a problem with the alternator. If it gets brighter, then the battery is most likely bad.

That's all well and good, but just exactly what does all that mean? To get a good idea, it is first necessary to understand how an alternator works. You don't need an engineering degree, just a basic understanding of the general principles. Figure 1, below, is a block diagram, or a "functional" diagram, of an alternator, and its connections to the remainder of the automobile electrical system. Following the figure is a description of the various components that make up an alternator, and a description of how each operates to keep the battery charged in your car.

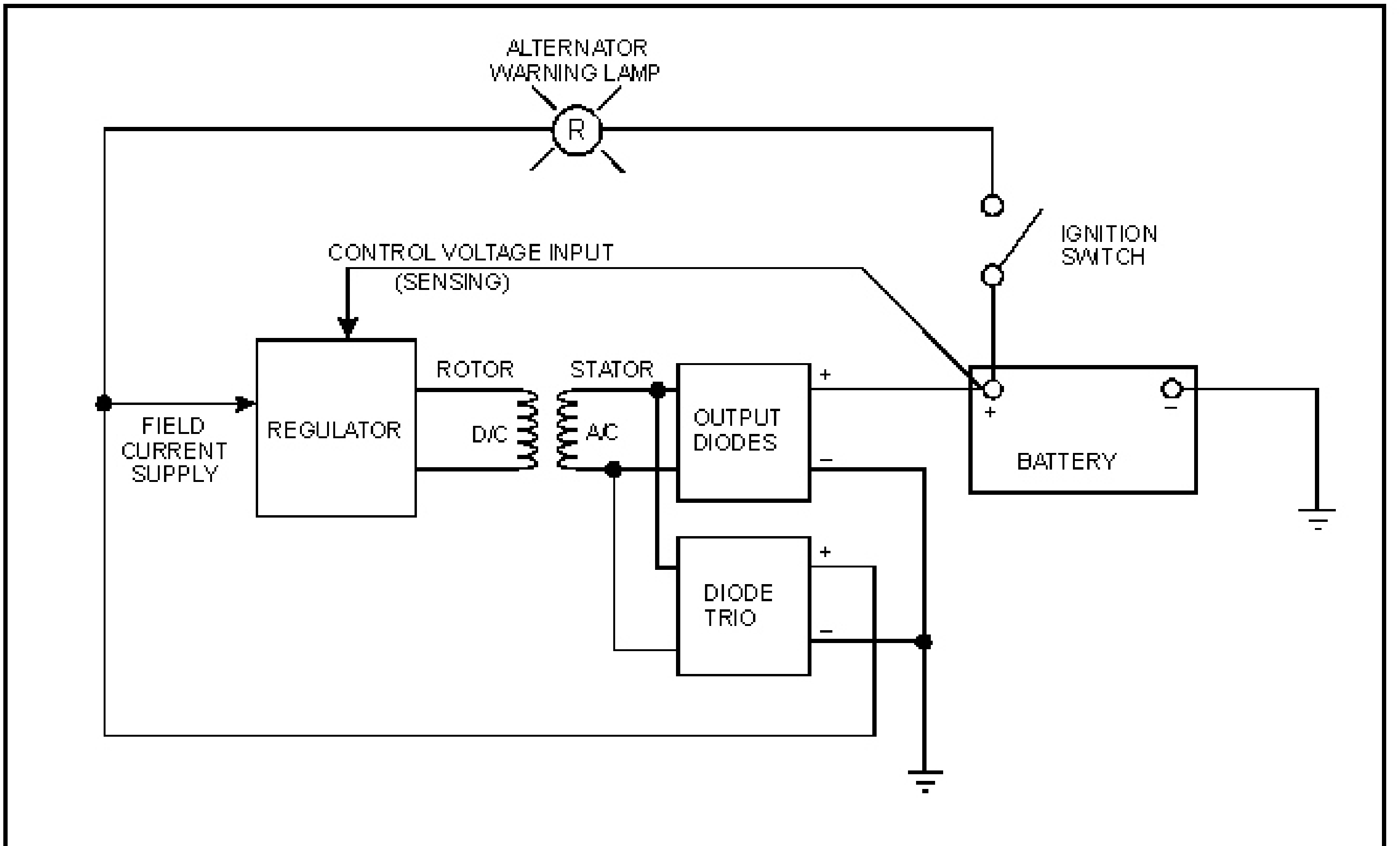


FIGURE I: ALTERNATOR FUNCTIONAL DIAGRAM

ALTERNATOR ROTOR

We'll start our tour of the alternator where it all starts in the alternator itself - at the alternator rotor. The rotor consists of a coil of wire wrapped around an iron core. Current through the wire coil - called "field" current - produces a magnetic field around the core. The strength of the field current determines the strength of the magnetic field. The field current is D/C, or direct current. In other words, the current flows in one direction only, and is supplied to the wire coil by a set of brushes and slip rings. The magnetic field produced has, as any magnet, a north and a south pole. The rotor is driven by the alternator pulley, rotating as the engine runs, hence the name "rotor."

STATOR

Surrounding the rotor is another set of coils, three in number, called the stator. The stator is fixed to the shell of the alternator, and does not turn. As the rotor turns within the stator windings, the magnetic field of the rotor sweeps through the stator windings, producing an electrical current in the windings. Because of the rotation of the rotor, an alternating current is produced. As, for example, the north pole of the magnetic field approaches one of the stator windings, there is little coupling taking place, and a weak current is produced, As the rotation continues, the magnetic field moves to the center of the winding, where maximum coupling takes place, and the induced current is at its peak. As the rotation continues to the point that the magnetic field is leaving the stator winding, the induced current is small. By this time, the south pole is approaching the winding, producing a weak current in the opposite direction. As this continues, the current produced in each winding plotted against the angle of rotation of the rotor has the form shown in figure 2. The three stator windings are spaced inside the alternator 120 degrees apart, producing three separate sets, or "phases," of output voltages, spaced 120 degrees apart, as shown in figure 3.

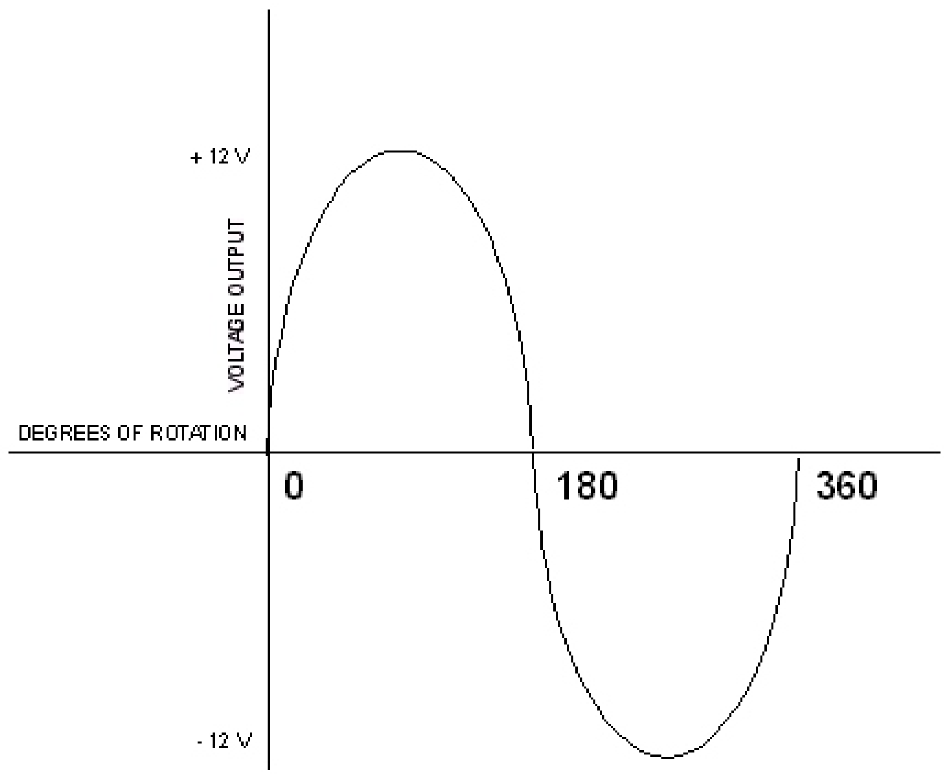


FIGURE 2: OUTPUT VOLTAGE vs DEGREES OF ROTATION

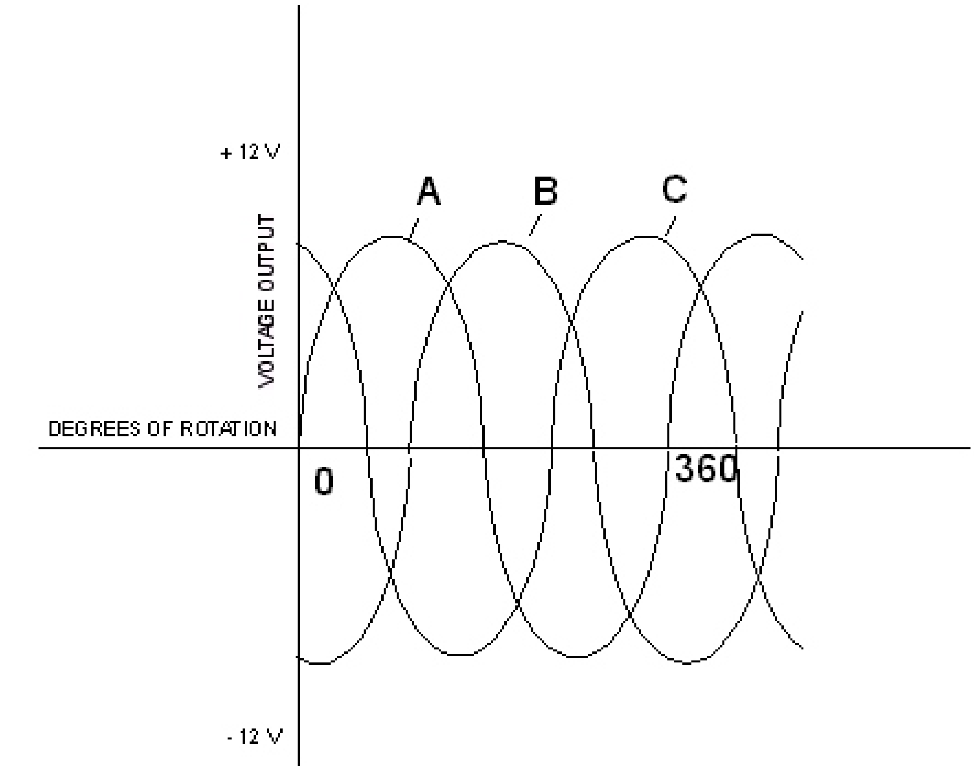


FIGURE 3: OUTPUT VOLTAGE vs DEGREES OF ROTATION

OUTPUT DIODES

A/C voltage is of little use in a D/C system, such as used in an automobile, so it has to be converted to D/C before it can be used. This conversion to D/C takes place in the "output diodes" and in the "diode trio." Diodes have the property of allowing current to flow in only one direction, while blocking current flow in the other direction. The output diodes consist of six diodes, one pair for each winding. One of the pair is for the negative half cycle, and the other for the positive half cycle. As a result of this diode rectification, the output of the alternator looks as shown in figure 4.

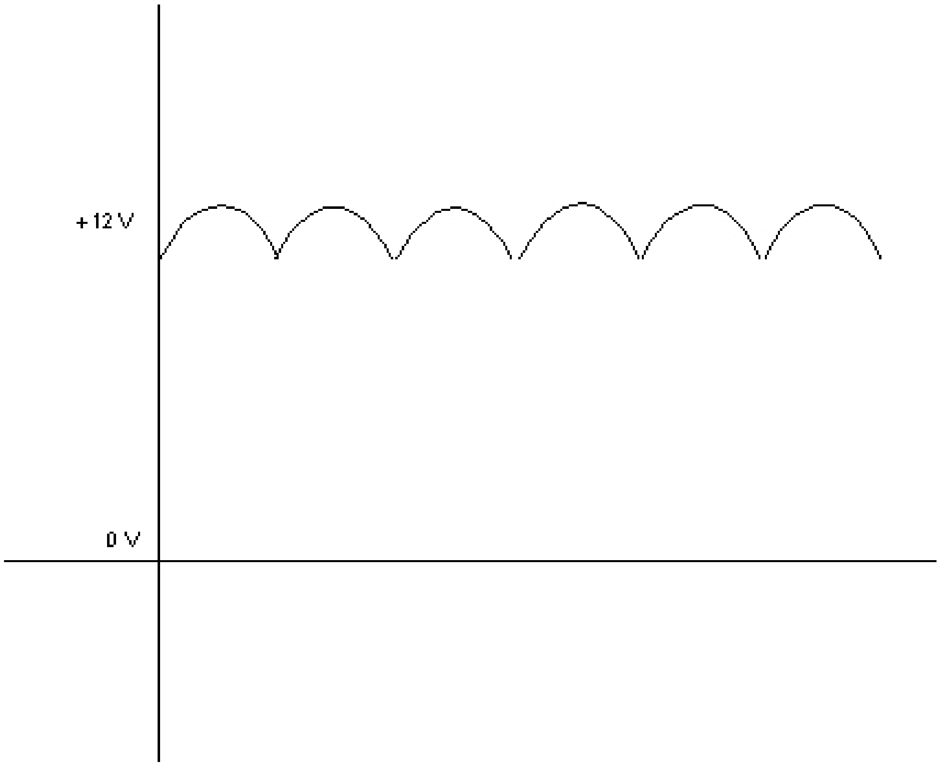


FIGURE 4: PULSED DC VOLTAGE

Surprisingly enough, the output of the alternator is not a pure D/C as one might expect, but a pulsating D/C. Because there are three windings, each with a positive and a negative half, by the time the voltage is passed through the diodes, there are six pulsations for each rotation of the rotor. This is close enough to D/C for most automotive components. Critical components, such as radios, have their own internal filtering circuits to further smooth out the waveform to a purer D/C.

DIODE TRIO

The diode trio consists, as the name suggests, of three diodes, one per phase, which provides field current to the alternator regulator. This output will be discussed in more detail later in the "field current supply" section.

REGULATOR

The regulator has two inputs and one output. The inputs are the field current supply and the control voltage input, and the output is the field current to the rotor. The regulator uses the control voltage input to control the amount of field current input that is allow to pass through to the rotor winding. If the battery voltage drops, the regulator senses this, by means of the connection to the battery, and allows more of the field current input to reach the rotor, which increases the magnetic field strength, which ultimately increases the voltage output of the alternator. Conversely, if the battery voltage goes up, less field current goes through the rotor windings, and the output voltage is reduced.

FIELD CURRENT SUPPLY

Field current supply is provided from two different sources - from the alternator itself, via the diode trio, and from the battery, via the alternator warning lamp. When you first get in the car and turn the key on, the engine is not running and the alternator is not spinning. At this time, the voltage/current source for the field current is from the battery, through the ignition switch, and through the warning lamp. After the engine is started, and the alternator is up to speed, the output of the diode trio is fed back to the regulator, and serves as a source of current for the field current. At this time, the alternator is self sustaining, and the battery is no longer needed to power the automobiles electrical system WARNING!!! This is theoretical only - in actual practice, the voltage surges resulting from disconnecting the battery can seriously damage the regulator circuitry. All alternator manufacturers strongly advise NOT doing this! This test will not prove the functionality of the alternator anyway, as the engine may still run with a weak alternator output.