Battery Basics

How batteries work and the effects of lead sulfate

How Do Lead Acid Batteries Work?

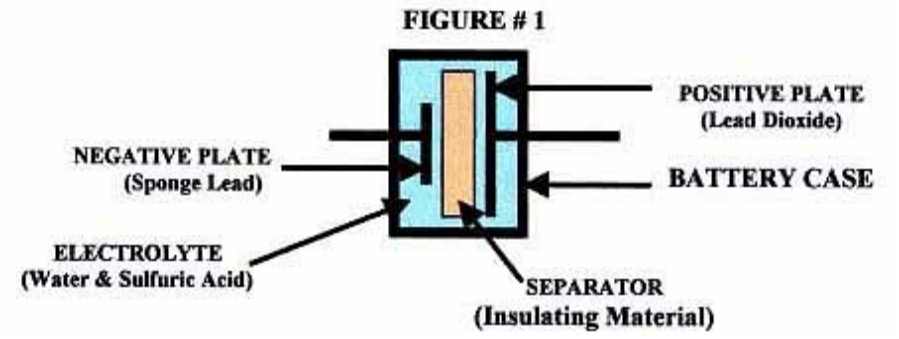
Lead Acid batteries have changed little since the 1880's although improvements in materials and manufacturing methods continue to bring improvements in energy density, life and reliability. All lead acid batteries consist of flat lead plates immersed in a pool of electrolyte. Regular water addition is required for most types of lead acid batteries although low-maintenance types come with excess electrolyte calculated to compensate for water loss during a normal lifetime.

Battery Construction

Lead acid batteries used in the RV and Marine Industries usually consist of several 6-volt batteries in series, or a several 8 or 12-volt batteries. These batteries are constructed of several single cells connected in series each cell produces approximately 2.1 volts. A six-volt battery has three single cells, which when fully charged produce an output voltage of 6.3 volts. A eight-volt battery has 4 single cells in series producing a fully charged output voltage of 8.4 volts. A twelve-volt battery has six single cells in series producing a fully charged output voltage of 12.6 volts.

A battery cell consists of two lead plates a positive plate covered with a paste of lead dioxide and a negative made of sponge lead, with an insulating material (separator) in between. The plates are enclosed in a plastic battery case and then submersed in an electrolyte consisting of water and sulfuric acid (see figure # 1). Each cell is capable of storing 2.1 volts.

FIGURE # 1



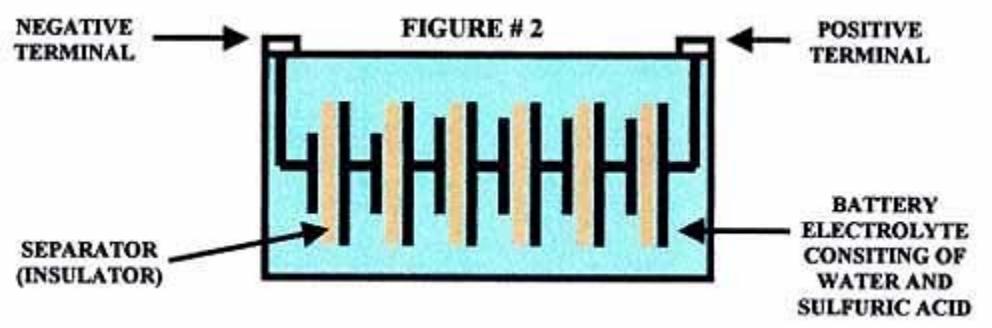
In order for lead acid cell to produce a voltage, it must first receive a (forming) charge voltage of at least 2.1-volts/cell from a charger. Lead acid batteries do not generate voltage on their own; they only store a charge from another source. This is the reason lead acid batteries are called storage batteries, because they only store a charge. The size of the battery plates and amount of electrolyte determines the amount of charge lead acid batteries can store. The size of this storage capacity is described as the amp hour (AH) rating of a battery.

Example: A typical 12-volt battery used in a RV or marine craft has a rating 125 AH, which means it can supply 10 amps of current for 12.5 hours or 20-amps of current for a period of 6.25 hours. Lead acid bat-

teries can be connected in parallel to increase the total AH capacity. Like in a Golf Cart where there can be 4 to 6 in parallel.

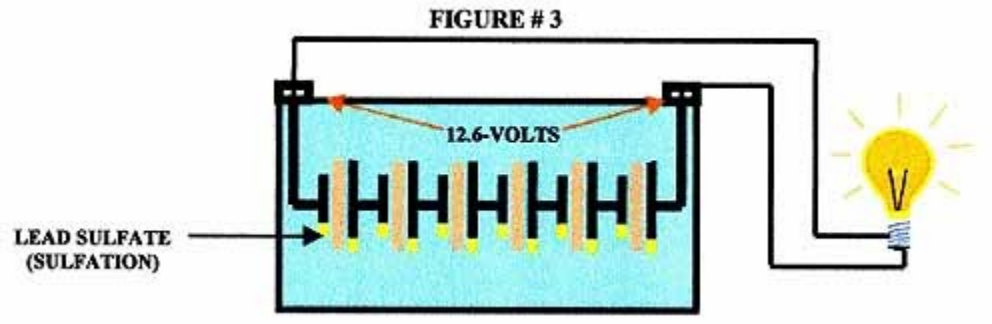
AH = Amp Hour, A = Amperage Amps/AH = hours 10/125=12.5

In figure # 2 below, six single 2.1-volt cells have been connected in series to make the typical 12-volt battery, which when fully charged will produce a total voltage of 12.6-volts.



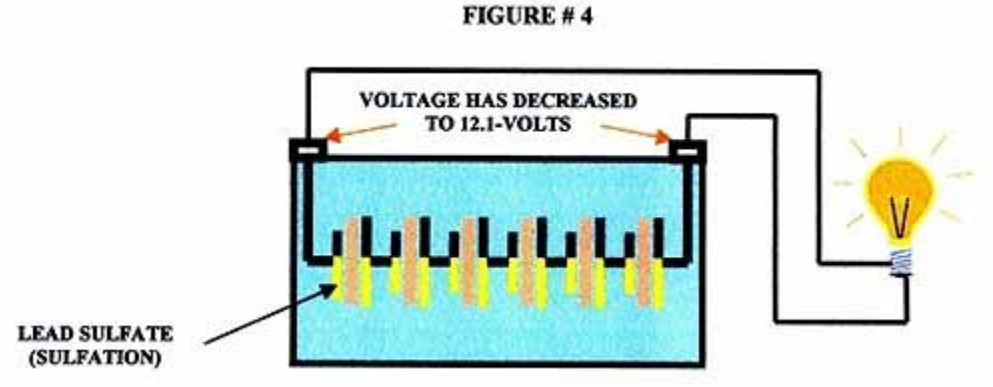
Lead Acid Batter Discharge Cycle

Fully charged battery provides electricity to a light bulb.



In figure # 3, above a fully charged battery is connected to a load (light bulb) and the chemical reaction between sulfuric acid and the lead plates produces the electricity to light the bulb. This chemical reaction also begins to coat both positive and negative plates with a substance called lead sulfate also known as sulfation (shown as a yellow build-up on plates). This build-up of lead sulfate is normal during a discharge cycle. As the battery continues to discharge, lead sulfate coats more and more of the plates and battery voltage begins to decrease from fully charged state of 12.6-volts (figure # 4).

FIGURE # 4

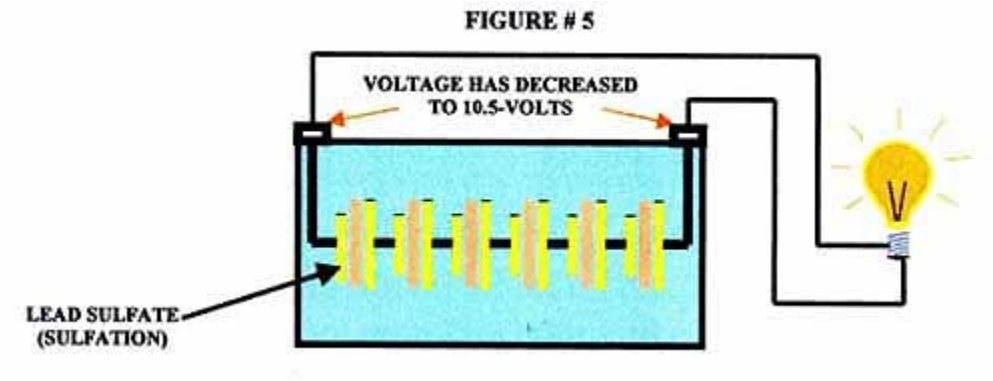


Discharging battery.

In figure # 5 the battery is now fully discharged, the plates are almost completely covered with lead sulfate (sulfation) and voltage has dropped to 10.5-volts.

NOTE: Discharging a lead acid battery below 10.5 volts will severely damage it!

FIGURE # 5



Fully discharged battery.

Lead sulfate (sulfation) now coats most of the battery plates. Lead sulfate is a soft material, which can be reconverted back into lead and sulfuric acid, provided the discharged battery is immediately connected to a battery charger.

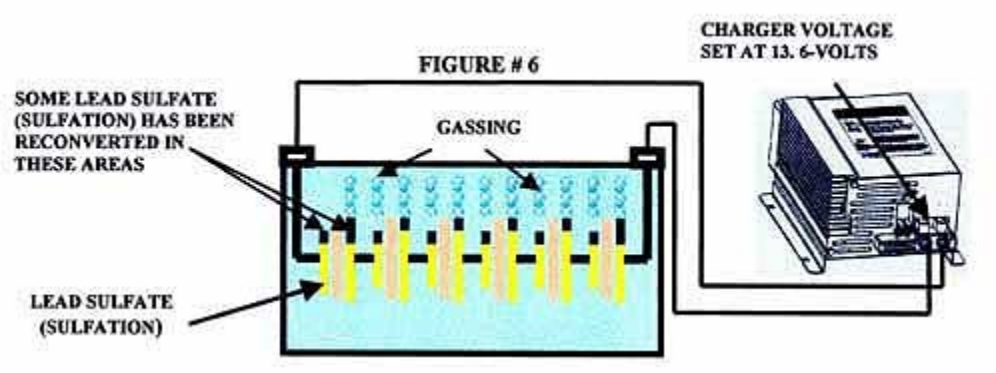
Note: If a lead acid battery is not immediately recharged, the lead sulfate will begin to form hard crystals, which cannot be reconverted by a standard fixed voltage (13.6 volts) battery converter/charger.

NOTE: Always recharge your RV or Marine battery as soon as possible to prevent loss of battery capacity due to the build-up of hard lead sulfate crystals!

Lead Acid Battery Recharge Cycle

The most important thing to understand about recharging lead acid batteries is that a converter/charger with a single fixed output voltage will not properly recharge or maintain your battery. Proper recharging and maintenance requires an intelligent charging system that can vary the charging voltage based on the state of charge and use of your RV or Marine battery. Progressive Dynamics has developed intelligent charging systems that solve battery problems and reduce battery maintenance.

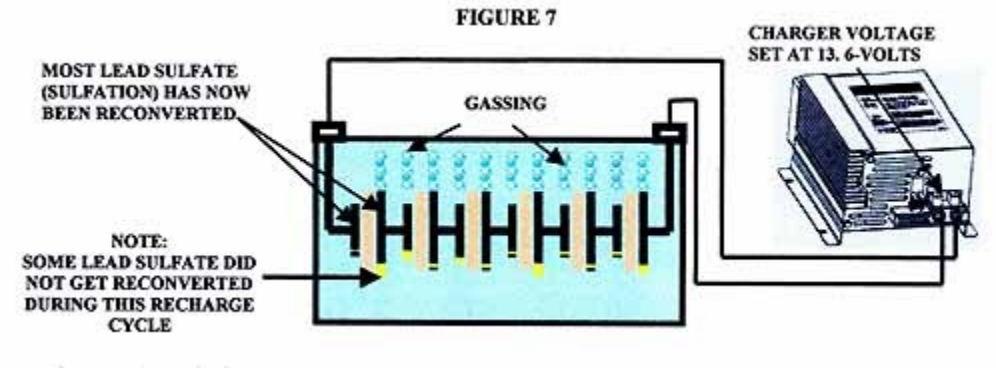
The discharged battery shown in figure # 6 on the next page is connected to a converter/charger with its output voltage set at 13.6-volts. In order to recharge a 12-volt lead acid battery with a fully charged terminal voltage of 12.6-volts, the charger voltage must be set at a higher voltage. Most converter/chargers on the market are set at approximately 13.6-volts. During the battery recharge cycle lead sulfate (sulfation) begins to reconvert to lead and sulfuric acid.



Discharged battery connected to a converter/charger.

During the recharging process as electricity flows through the water portion of the electrolyte and water, (H2O) is converted into its original elements, hydrogen and oxygen. These gasses are very flammable and the reason your RV or Marine batteries must be vented outside. Gassing causes water loss and therefore lead acid batteries need to have water added periodically. Sealed lead acid batteries contain most of these gasses allowing them to recombine into the electrolyte. If the battery is overcharged pressure from these gasses will cause relief caps to open and vent, resulting in some water loss. Most sealed batteries have extra electrolyte added during the manufacturing process to compensate for some water loss.

Note: Never use tap water to replenish the reservoirs in Lead Acid Batteries. Tap water includes minerals that is harmful to the battery plates and will reduce battery life and cause premature failure. Always use distilled or deionized water when replenishing the battery reservoirs.



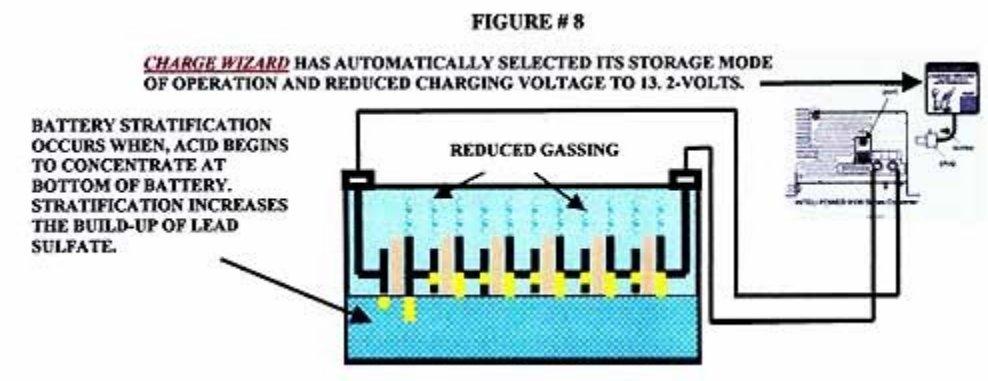
Fully recharged battery.

The battery shown in figure # 7 above has been fully recharged using a fixed charging voltage of 13.6-volts. Notice that some lead sulfate (sulfation) still remains on the plates. This build-up will continue after each recharging cycle and gradually the battery will begin to lose capacity to store a full charge and

eventually must be replaced. Lead sulfate build up is reduced if battery is given an Equalizing Charge once every 10 discharge cycles or at least once a month. An Equalizing Charge increases charging voltage to 14.4 volts or higher for a short period. This higher voltage causes gassing that equalizes (remixes) the electrolyte solution.

One disadvantage of recharging a lead acid battery at a fixed voltage of 13.6-volts is the recharge time is very long. A typical 125-AH RV or Marine battery will take approximately 80 hours to recharge at 13.6 volts. Increasing the charge voltage to 14.4-volts will reduce battery recharge time for a 125-AH battery to 3-4 hours. Once a battery reaches 90% of full charge, the voltage should be reduced from 14.4-volts to 13.6-volts to reduce gassing and water loss.

At a charging voltage of 13.2 volts, the converter/charger will maintain a full charge, reduce gassing and water loss. However, this lower voltage does not provide enough gassing to prevent a battery condition called Battery Stratification. Battery Stratification is caused by the fact that the electrolyte in the battery is a mixture of water and acid and, like all mixtures, one component, the acid, is heavier than water. Therefore, acid will begin to settle and concentrate at the bottom of the battery (see figure #8).



Battery stratification.

This higher concentration of acid at the bottom of the battery causes additional build-up of lead sulfate (sulfation), which reduces battery storage capacity and battery life. In order to prevent Battery Stratification, an Equalization Charge (increasing charging voltage to 14.4-volts) must be applied periodically.

Answers to Common Questions about Batteries

Do lead acid batteries discharge when not in use?

All batteries, regardless of their chemistry, will self-discharge. The rate of self-discharge for lead acid batteries depends on the storage or operating temperature. At a temperature of 80 degrees F. a lead acid battery will self-discharge at a rate of approximately 4% a week. A battery with a 125-amp hour rating would self-discharge at a rate of approximately five amps per week. Keeping this in mind if a 125 AH battery is stored for four months (16 weeks) winter without being charged, it will loose 80 amps of its 125-amp capacity. It will also have severe sulfation, which causes additional loss of capacity. Keep your batteries charged while not in use!

Do lead acid batteries develop a memory?

Lead acid batteries do not develop any type of memory.

Do I need to completely discharge my lead acid battery before recharging it?

No, in fact you should never discharge your lead acid battery below 80% of its rated capacity. Discharging it below this point or 10.5 volts can damage it.

When do I need to perform an equalization charge?

Equalizing should be performed when a battery is first purchased (called a freshening charge) and on a regular basis (every 10 discharge cycles or at least once a month). Reduced performance can also be an indicator that an equalizing charge is needed.

What is an equalizing charge?

An equalizing charge for a 12 volt battery requires that it be charged with a voltage of at least 14.4 volts for a period of at least one hour once a month, or every 10 discharge cycles. An equalizing charge prevents battery stratification and reduces sulfation, the leading cause of battery failure.

When should I add water to my batteries?

How often you use and recharge your batteries will determine the frequency of watering. Also, using batteries in a hot climate will require more frequent watering. It is best to check your battery water level frequently and add distilled water when needed. Never add tap water to your battery. Tap water contains minerals that will reduce battery capacity and increase their self-discharge rate.

Warning - A brand new battery may have a low electrolyte level. Charge the battery first and then add water if needed. Adding water to a battery before charging may result in overflow of the electrolyte.

What is the proper electrolyte level?

Battery electrolyte levels should be just below the bottom of the vent well, about ½ - ¾ inch above the tops of the separators. Never let the electrolyte level to drop below the top of the plates.

Do I ever need to add acid to my battery?

Under normal operating conditions, you never need to add acid. Only distilled or deionized water should be added to achieve the recommended electrolyte levels.

Can my batteries freeze?

If your battery is partially discharged, the electrolyte in a lead acid battery may freeze. At a 40% state of charge, electrolyte will freeze if the temperature drops to approximately -16 degrees F. When a battery is fully charged the electrolyte will not freeze until the temperature drops to approximately -92 degrees F.

What are the most common mistakes made by owners of lead acid batteries?

Undercharging - Generally caused by not allowing the charger to restore the battery to full charge after use. Continuously operating a battery in a partial state of charge, or storing the battery in the discharged state results in the formation of lead sulfate (sulfation) on the plates. Sulfation reduces the performance of the battery and may cause premature battery failure.

Overcharging - Continuous-charging causes accelerated corrosion of the positive plates, excessive water consumption and in some cases, damaging temperatures within the battery. Lead acid batteries should be charged after each discharge of more the 50% of its rated capacity and during or after prolonged storage of 30 days or more.

Under-watering - In lead acid batteries water is lost during the charging process. If the electrolyte level drops below the tops of the plates, irreparable damage may occur. Check your battery water level frequently.

Over-watering - Excessive watering of a battery results in additional dilution of the electrolyte, resulting in reduced battery performance. Add water to your battery after it has been fully charged, never when the battery is partially discharged.

Can I reduce the need to add water to my battery by lowering the charging voltage to 13 volts or less?

Lowering the charging voltage will reduce the need to add water, but this will cause a condition known as battery stratification. Battery stratification is caused when the sulfuric acid in the electrolyte mixture separates from the water and begins to concentrate at the bottom of the battery.

This increased concentration of acid increases the formation of lead sulfate (sulfation). To prevent stratification, your battery should receive a periodic equalizing charge (increasing the charging voltage to 14.4 volts or above).