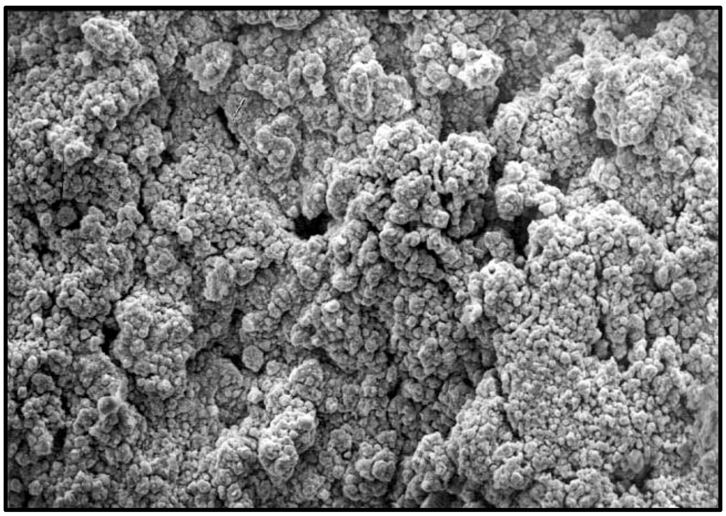
Tech Notes

Sulfation:
The Natural Enemy of Every Lead-Acid Battery

Lead-Acid Battery Basics

A lead acid battery consists of a plastic case containing one or more cells. Each cell is made up of 2 plates, one made from sponge lead (Pb), and the other from a paste of litharge (PbO), red lead (Pb3O4), lead sulfate (PbSO4), and sulfuric acid (H2SO4) mixed with certain proprietary binders and expanders. During the forming process most of these ingredients are converted to a coating of lead dioxide on tiny strands of metallic lead. The sponge lead metal forms the negative battery terminal, and the lead dioxide paste forms the positive terminal. The cells are filled with diluted sulfuric acid (H2SO4) having a range of specific gravities depending on the particular application. Typical SLI batteries, for example, have a specific gravity of 1.275 - 1.285. Each cell, when connected to a load at room temperature, produces electrical current at approximately 2 volts per cell. A 12 volt battery, for example, consists of 6 cells connected in series. The photomicrograph below (550X) shows the surface of a new, fully charged, sponge lead battery plate.



Photomicrograph I (550x magnification)
Active, New Lead Sponge Battery Plate.

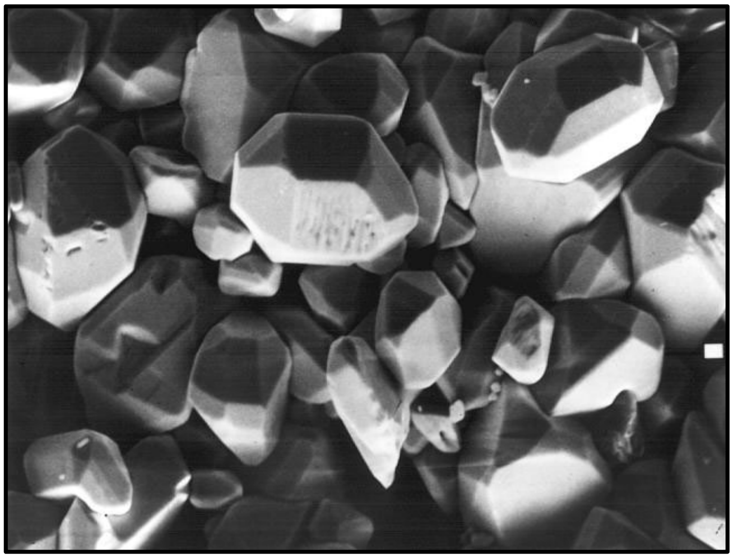
Lead-acid batteries generate electricity through the double sulfate chemical reaction shown below. When a battery discharges, lead and lead dioxide, which are the active materials on a battery's plates, react with the sulfuric acid in the electrolyte to generate electrical current. A finely divided, amorphous form of lead sulfate (PbSO4) is produced.

$$Pb + PbO_2 + 2H_2SO_4 \rightleftharpoons \text{electricity} + 2PbSO_4 + 2H_2O$$

During charging, the amorphous lead sulfate is easily converted back to lead, lead dioxide, and sulfuric acid, in essence returning the battery to its former state. Unfortunately, there is no "perfect machine", and with repeated use, the ability of a battery to reach a full charge diminishes.

The Onset of Sulfation

As batteries are "cycled" through numerous charge and discharge sequences, particularly if the batteries are not charged fully, or are allowed to remain in a partially discharged stare for extended periods, the amorphous lead sulfate is converted to a very stable crystalline form. This process, called sulfation, is the primary cause of declining performance over time, and is ultimately the leading cause of battery failure. An extreme case of battery plate sulfation is shown in the following photomicrograph.



Photomicrograph 2 (550x)
Battery Plate Coated by Dense, Hardened, Crystalline Lead Sulfate. (Notice that no active lead sponge is visible.)

There are many causes of sulfation, including acid stratification, excessive battery discharge, chronic undercharging, infrequent use, and leaving batteries (even new batteries) in a discharged state for extended periods of time. Subjecting batteries to extended periods of float charging also accelerates sulfation.

Over time, and without exception, sulfation will reduce the performance and life of every lead-acid battery.

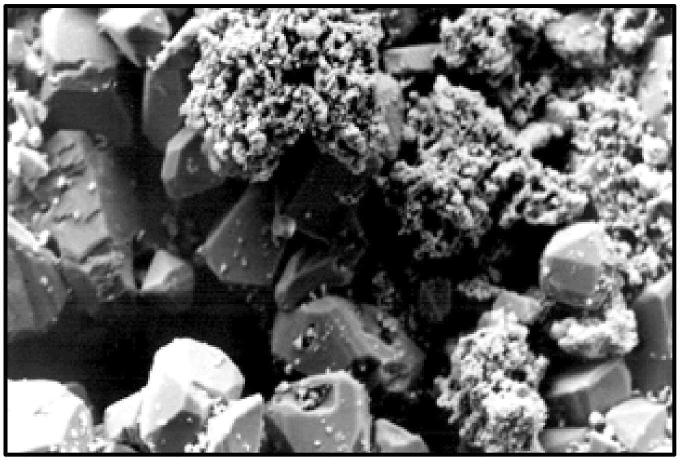
Symptoms of Sulfation
How can you tell if your battery is suffering from excessive sulfation? Higher temperatures are observed during both charging (since higher charge voltages are needed to overcome the higher internal cell resistance), and discharging (since a sulfated battery puts out a lower voltage, but power requirements remain the same so the current increases). The net result is that running times of battery powered equipment are shorter, electrolyte specific gravity decreases, CCA (cold cranking amps) output is reduced, and charge acceptance is slower and less efficient. Terminal corrosion also increases because the higher operating temperatures increase water loss and the generation of sulfuric acid mist.

Impact of Sulfation on Battery Performance
Hard sulfate, large lead sulfate crystals that do not decompose during charging, are non-conducting and dramatically increasing the electrical resistance of the battery. The crystalline lead sulfate coating also reduces the capacity of the battery, both by permanently reduce plate surface area, and also by separating the active material (lead and lead dioxide) from the electrochemical reaction sites. Thus, the rate at which current can be supplied (Cold Cranking Amp output, quantified by a CCA Test) is diminished significantly. As the lead sulfate crystals cover more of the surface area of the battery plates, load voltage, which correlates with battery storage capacity (amp-hours), and CCA (ability to deliver peak current) continue to decline.

The electrochemical driving force of a battery declines with decreasing temperature, so that in extreme cold, the energy available to start a vehicle is substantially less than at room temperature. In addition, the viscosity of the lubricating oil in the engine increase as temperature decreases, so more energy is required to start it. Sulfation exacerbates cold weather starting problems by further reducing the available energy in a battery. All of these factors combine to increase the rate of battery failures in cold weather.

Equalization Charging - Does it Really Help Reduce Sulfation?
Typical charging voltages cannot breakdown the crystalline lead sulfate buildup, so sulfation gradually gets worse, and the performance of the battery declines. Battery users believe they can reverse sulfation by "equalization charging", which raises peak charging voltages. It is possible that, depending on crystal particle size, some of lead sulfate is converted to sulfuric acid, but probably most of the 'benefit' comes from the physical separation of the crystalline coating due to the vigorous gassing which occurs at such elevated

voltages. Fresh plate surface is exposed at the expense of losing active material which simply falls to the bottom of the cell. Battery temperature increases dramatically during equalization charging. The higher charging temperature increases positive grid corrosion, water loss through gassing (the electrical conversion of water to hydrogen and oxygen, which can re-combine violently causing an explosion), and sulfuric acid ‘misting’ which, in turn, causes terminal corrosion. All of these phenomena reduce battery life significantly.



Photomicrograph 3 (550x)
Normally Charger Battery

Sulfation Affects More Than Just the Battery...

Sub-par batteries strain all electrical system components, shortening the life of starters, alternators, halogen lights, contacts, motor windings, brushes, and electronic components. Poor battery performance always results in more frequent and higher maintenance costs.

Sulfation also negatively affects battery charging. Increased resistance results in longer charging times, lower charging efficiencies, increased energy consumption, incomplete charging, and excessive heat generation (higher battery temperatures). Higher charging temperatures mean longer cool-down times for motive power batteries, and will also accelerate positive grid corrosion. Reduced battery capacity caused by sulfation means that more motive power batteries are required to keep battery powered equipment operating than would otherwise be required of sulfate-free batteries.

Increased maintenance and less efficient batteries ultimately result in one of the most expensive impacts to the bottom line, reduced labor and equipment productivity.

Canadus Battery Energizers - the Solution to the Sulfation Problem

To improve a battery’s performance and extend its life significantly, sulfation must be eliminated. Canadus Power Systems is the world’s leading supplier of the most effective desulfation technology. Its patented Canadus battery energizers revitalize and extend the useful life of lead-acid batteries by preventing and even reversing the sulfation process.

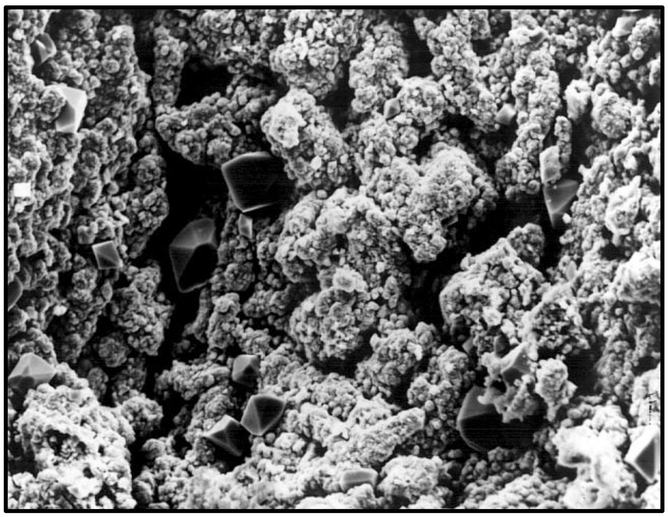
Canadus battery energizers connect to a battery or charging system and emit a high frequency electrical pulse that reverses the lead sulfate crystallization process. Hundreds of tests and actual field installations have shown that Canadus’ Advanced Desulfation Technology improves battery performance by eliminating sulfate buildup on older batteries, and preventing it from forming on new batteries.

Canadus battery energizers help maintain batteries in “like new” condition. Batteries operating at peak voltage absorb voltage spikes from the alternator and other equipment, and deliver clean, stable power, protecting the entire electrical system.

The photomicrograph (550X) shown below illustrates a battery plate which has been partially rejuvenated using a Canadus battery energizer. Note that fewer crystals are present, that many have ‘holes’ in them indicating that they are being driven from the plate surface.

Photomicrograph 4 (550x)
Partial Recovery of a Heavily Sulfated Plate Following the use of a Canadus Battery Energizer. (The size of the lead sulfate crystals is decreased, and the crystals are pitted as they dissolve.)

Complete rejuvenation of a sulfated battery using the Canadus battery energizer is illustrated in the following photomicrograph (550X). Note the similarity to a new battery plate



Photomicrograph 5 (550x)
Final Recovery of the Plate to Active Sponge Lead.

In Summary...

If sulfation is not treated, it will slowly and continuously reduce battery capacity, increase electrical resistance, reduce the operating voltage, and ultimately cause the battery to fail. Now, there is an answer to the normal battery “death spiral”. By uniquely delivering high frequency, crystal-destroying, high current pulsed energy[U1] to the battery, Canadus battery energizers deliver the energy necessary to destabilize hardened crystalline lead sulfate. Sulfuric acid is released boosting acid specific gravity and overall battery performance.

By eliminating or reversing sulfation with Canadus battery energizers, thousands of dollars can be saved in electrical system maintenance, battery replacement and energy costs, as well as the amount of working capital tied up in batteries. Moreover, worker and equipment productivity can improve dramatically.