Ensuring Lead-Acid Battery Performance with Pulse Technology

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ABSTRACT

Basic lead-acid battery technology has remained virtually unchanged for almost 100 years. Although improvements have been made in chemistry and construction, the common causes that promote battery failure have remained the same. These causes are the result of sulfation buildup on the battery plates. The most effective solution to this problem has proven to be pulse technology.

Pulse technology helps eliminate battery failure in the following ways:

- Prevents sulfation buildup.
- Prevents physical degradation of the battery plates.
- Increases battery service life dramatically

As a result, productivity is improved, replacement and other battery-related expenses are avoided, and unnecessary negative environmental impact is averted.

INTRODUCTION

Experts predict lead-acid batteries will be the primary source of battery power well into the next century. The problem is that most batteries can barely handle the overwhelming demands of today's technologically advanced vehicles, let alone those of the future. It is interesting to note that there is actually enough reactive material in lead-acid batteries to keep them operating reliably for eight to ten years or even more, but, in most cases they don't. The average life of a battery, depending on usage, is six to 48 months. But according to a recent study, only 30% of all batteries actually reach the 48-month point.

This short life span is due to a series of problems caused by sulfation buildup on the battery plates. The most effective solution to these problems is a patented method called pulse technology.

First patented in 1989, pulse technology has been helping to enhance battery performance. With this technology, it is possible for a battery to have greater discharge capacity, accept a charge faster and ultimately last considerably longer. This improved productivity can help reduce costly battery replacement and other battery-related expenses. Plus, unnecessary negative environmental impact can also be averted.

HOW A BATTERY WORKS

To understand pulse technology and the benefits it provides, let's begin with a general review of what a battery is and how it works. According to the *Battery Council International Service Manual*, 11th Edition: "A storage battery is an electrochemical device by definition. It stores chemical energy which can be released as electrical energy upon demand. The three main functions of an automotive battery are to: 1) Supply power to the starter and ignition system so the engine can be cranked and started; 2) Supply extra power necessary when the vehicle's electrical load requirements exceed supply from the charging system; and 3) Act as a voltage stabilizer in the electrical system smoothing out or reducing high (transient voltages) which occur in the vehicle's electrical system.

"When two unlike materials, lead dioxide (PbO2) [positive plate] and sponge lead (Pb) [negative plate] are immersed in sulfuric acid (H2SO4) [electrolyte] they create a battery. Electrical energy is produced by the chemical reaction between the different materials and the electrolyte.

"During the discharge cycle, the lead dioxide (Pb02) in the active material of the positive plate combines with the sulfate (SO4) of the electrolyte to form lead sulfate (PbSO4) in the positive plate. At the same time, the lead (Pb) from the negative active material combines with sulfate (SO4) of the electrolyte to form lead sulfate (PbS04) in the negative plate. During discharge, the active material of both plates is being converted to lead sulfate (PbS04). A discharged battery can be recharged by passing electrical current through it in the opposite direction of the discharge.

"During the charge cycle, the chemical reactions that take place are basically the reverse of those that occur during discharge. The lead sulfate (PbSO4) in both plates is split into its original form of lead (Pb) and sulfate (SO4). The water is split into hydrogen (H) and oxygen (O). As the sulfate leaves the plates it combines with the hydrogen and is restored to electrolyte (H2SO4)."

Basically, lead-acid batteries work on a principal of energy being stored as ions during the charging cycle then transferred from the ions to the lead plates during the discharge cycle. During this energy transfer process, the sulfate (SO4) of the electrolyte reacts with both the positive and negative lead plates. At this point, a small

portion of the sulfate does not return to solution as it should, thereby creating sulfation buildup on the plates. This buildup is a physical phenomena of the electrochemical reaction that takes place within a lead acid battery. It is also a major contributing cause of battery failure.

PROBLEM: BATTERY FAILURE DUE TO SULFATION BUILDUP

Theoretically, when a charge is applied to a battery, lead sulfates absorb the charging energy as the change from crystalline lead sulfate to sulfuric acid, a liquid compound. In practice, however, some sulfate crystals do not return to the solution, but remain attached to the plates and eventually build up and become crystallized. In time the buildup of the crystalline lead sulfate covers so much of the plate that the battery loses its ability to accept or release energy.

According to the BCI Manual, page 58: "Since the battery is essentially a chemical 'device,' its charging properties are often altered by chemical changes in the battery itself. Sulfation, for example, while normal, may be a major problem if it is allowed to become excessive. Since sulfation is likely to occur whenever batteries are neglected for long periods of time, it can occur in new batteries in stock as well as used ones. A battery that is severely sulfated will not accept an adequate charge rate from the generator and will eventually become discharged...If they (batteries) are not kept in a satisfactory state of charge, they will become sulfated and lose the ability to accept a charge at normal vehicle charging voltages."

Page 56 states that "...charge voltage is affected by temperature, electrolyte concentration, plate area in contact with the electrolyte, age of battery, electrolyte impurities, state of charge and gassing. Plates that have lead sulfate that has become hard and crystalline (sulfation buildup) cause internal resistance of the battery to increase."

This buildup of sulfate crystals is a contributing factor in over 80% of all lead-acid battery failures. The rate and extent of accumulation and hardness of the crystal formation is a product of time, state of charge in the battery and usage cycle of the stored energy.

Sulfation buildup can become extremely troublesome to battery operation. While the sulfation process will occur sooner or later, it also can be accelerated through a variety of events including but not limited to:

1) Extended shelf storage prior to installation. Sulfation buildup begins almost the moment battery acid is added to a battery, so as new batteries sit in storage or on a store shelf, they will quickly become sulfated. This means a battery could literally fail soon after it is installed in a vehicle, even though it is "new".

2) Extended period of inactivity of a vehicle.

3) Corrosion of the battery terminal which increases resistance in the charge cycle, thus developing an undercharge situation.

4) Maintaining a state of discharge.

5) Temperature. For example, when the ambient temperature rises, the rate of sulfation can double for every 10° increase in temperature. That means that if the outside temperature goes from 75° to 95°, sulfation can occur 400% faster than normal.

   Cold conditions can cause the vehicle's fluids to thicken. This means it will take even more power to start the vehicle, so the battery has to discharge even further and the result is a faster buildup of sulfates on the lead plates.

   Also, keep in mind that the battery's electrolyte can actually freeze if the battery is in an advanced state of discharge, and this could damage the lead plates. At 1.270 specific gravity (100% charged), it will freeze at -83° F; at 1.200 it will freeze at -17° F; and at 1.140 (completely discharged), it will freeze at only 8° F.

6) An undercharging situation where the battery is maintained at less than maximum voltages, such as on frequently-used vehicles that stop and go constantly. According to the BCI Manual: "...it is possible for a vehicle to develop an undercharged battery if it is constantly driven at slow speeds and idled for long periods, as in heavy traffic and combined with high electrical load conditions."

   Since the vehicle is moving at slower speeds or idling, the alternator is not charging at an optimum rate. The result is a battery that is not fully charged even though the vehicle is running all day. And since it isn't fully charged, it will begin to sulfate. A vicious cycle is then created because the more the battery sulfates, the less energy it will accept and the battery will be undercharged even more. Ultimately, it too will die.

While sulfation is a necessary part of the energy transfer process, the buildup of sulfation becomes problematic, not the sulfation itself. And the problem is much more severe than most people realize. This is because the buildup of sulfation also plays a contributing role in a majority of the other common causes of battery failure, including:

1) Buckled plates. Sulfate buildup weakens the plates to a point where the batteries must be overcharged to accept energy. The overcharging could then overheat and warp — or "buckle" — the plates.

2) Plate disintegration due to the collapse of the grid mesh, also weakened by overcharging. And stratification of the electrolyte

3) Short circuits. Because of the additional internal resistance created due to the sulfation, plates may buckle, contacting other plates to create a short or breaking the frames that support the plate.

4) Shedding of active materials. Overcharging the plates to counteract the sulfation buildup will cause materials to fall from the plates in small chunks.

In the past, a battery suffering from sulfation buildup was considered useless and beyond recovery. But now, with pulse technology, this problem can be eliminated.

SOLUTION: PULSE TECHNOLOGY ELIMINATES SULFATION BUILDUP

In August 1990, when engineers at the Stennis Space Center evaluated a crude electronic device, they discovered that the pulsed power it utilized "will prevent sulfate accumulation on battery plates maintaining peak performance". Based on this report, patent numbers (4871959, 5084664, 5276393, 5491399 and 5592068) were assigned to the circuit and an associated group of products.

The patented process these products use is called pulse technology. It's main purpose is to prevent sulfation buildup. Also, in most cases where crystallization has already taken place on the battery plates, the technology will dissolve the crystal and enable the sulfates to free themselves from the crystal formation and become active electrolyte again.

Pulse technology eliminates sulfation buildup by introducing a dc pulse into the battery that strictly controls the rise time, pulse width and resonant frequency. The pulse required to accomplish this effect must also have a carefully controlled shape and amplitude.

As a result, the individual sulfate ions are freed from the crystal and are now ready to be charged and returned to solution to form an active electrolyte again. The entire process requires very low energy input to the battery, primarily because each molecule is being individually energized enough to dissolve and liquefy the sulfur crystals. This low energy also means the pulsing action will never damage the battery itself.

The technology works with any size and any voltage lead-acid battery. This includes not only maintenance-free, antimony, hybrid, calcium plate designs, but also valve-regulated lead-acid batteries including gel cell and absorbed glass mat battery technology.

By eliminating the sulfate buildup from the plates and returning it to the electrolyte, the battery will perform at 100% efficiency all the time. This in turn provides a great number of benefits for vehicles and equipment that were never available before the technology was invented.

BENEFITS OF PULSE TECHNOLOGY

The principal benefit of pulse technology is to ensure battery performance dramatically by keeping battery plates free of sulfation buildup. With clean plates, an unobstructed transfer of energy will occur so the battery will accept a full charge and release all its stored energy. As a result, many benefits will take place:

1) Increased battery efficiency. By keeping the battery plates free of sulfation buildup and keeping the sulfates within the electrolyte in an active state, battery efficiency will be increased to 100%. Continued use of pulse technology will also keep crystallized sulfates from reforming on the plates. This means batteries will continue to operate at peak efficiency as long as the technology is used. Also, by using pulse technology to keep the plates in optimum condition, it will help reduce the damage caused by vibration, typical in off-road or heavy equipment use.

2) Greater utility value. By maintaining batteries in peak condition, a vehicle alternator does not have to work as hard at recharging once the vehicle has started. Since the battery will accept a charge more readily and faster, alternator life should be extended. Plus, by maintaining available cranking amps in the battery, there will be more energy going to the vehicle starter. The engine will turn over faster, so your starter should also last longer. Additional performance and life extension of key components to the vehicle electrical system simply allow the vehicle to be utilized more with fewer repairs and their associated expenses. Adding additional loads such as GPS systems and other advance technology systems to vehicles will only continue to burden existing electrical systems.

3) Extended battery life. With the use of pulse technology, the "usable" life of a battery is easily extended. Optimizing battery life within any application can be related primarily to three factors, as reported to the BCI Annual Meeting, April 14, 1997, by Dr. Patrick T. Moseley of The Advanced Lead-Acid Battery Consortium. Their conclusions stated: "We believe that the optimum life of a battery depends primarily on three factors related to: an appropriate recharge regime, the maintenance of adequate compression on the active material and, probably, the preservation of a high surface area form of the active material."

   Pulse technology can be included in any electrical system to address two of the three above factors directly. It enhances a battery's ability to accept charge thereby maximizing "an appropriate charge regime." Secondly, by returning sulfation buildup into active electrolyte, pulse technology ensures the "preservation of a high surface area form of the active material." Both accomplishments lead directly to optimum battery life.

   The United States Air Force Management Equipment and Evaluation Program reports similar findings. Their findings were specific to the use of pulse technology stating: "This evaluation indicates that many batteries previously condemned could be reclaimed if pulse technology were used extensively; assuming there is no internal damage to battery, i.e.: plates, etc." The report goes on to state: "In conclusion, pulse technology worked by removing sulfation from the battery plates as the manufacturer claimed. It is unknown exactly how long a battery will last with pulse technology connected, but it is estimated at least eight to 10 years of life can be added."

   By minimizing sulfation buildup and thereby producing less resistance through the charge and discharge cycles throughout the "usable" life of a

battery, the battery's life can be enhanced considerably.

4) Economic impact. Although the lead-acid battery is not excessively expensive, its cost goes up dramatically when you include the cost of downtime, disposal and labor hours. Imagine how many of these costs will be reduced or even eliminated by simply extending battery life and increasing battery efficiency.

   A recent government study has detailed a return on investment as high as 24-to-1 with the use of pulse technology. An additional benefit of pulse technology, as reported in the U.S. Army's *Ft. Hood Battery Management Task Force Final Report* dated Sept. 30, 1994, is: "...a critical advantage of pulse technology (but one that cannot be monetarily measured) is the improved confidence in, and improved readiness of the equipment".

   Greater charge acceptance and discharge capacity also means reduced electrical expense. With a battery pack accepting more energy while discharging longer, an electric car for example can have a range 50% further with a faster, more efficient, less expensive charge cycle.

5) Environmental impact. After the tire, the battery is the most expensive and difficult product to dispose of safely. Yet, it is estimated that over 80% of the batteries being discarded every year are only suffering from lead plates that are clogged with sulfate crystals. Imagine the contamination that prematurely dumping battery lead and sulfuric acid across the nation can cause. Then realize what difference the implementation of pulse technology can make. By extending battery life and improving battery efficiency, the number of batteries being prematurely discarded can be reduced considerably, and the potential environmental damage can be avoided.

   The Environmental Protection Agency (EPA) estimates that approximately 80% of all dead lead-acid batteries are currently recycled. Unfortunately, the remaining percentage of dead batteries is not properly recycled and are dumped improperly in ditches, landfills and other sensitive areas. Although battery manufacturers are making more of the battery's components more recyclable than ever, it doesn't help if the batteries are not delivered to the correct recycling center. Curtailing misdiagnosis of battery failure and thereby keeping the battery in service through the incorporation of pulse technology becomes a tremendous benefit to our environment.

EVALUATION AND VALIDATION OF PULSE TECHNOLOGY

Since 1989, government agencies, commercial users and individuals have installed, evaluated and proven the benefits of pulse technology. Initial results regarding pulse technology dating back to August of 1990 at Stennis Space Center related the potentials of the technology. They stated, "The pulsed power will prevent sulfate accumulation on battery plates maintaining peak performance."

Conclusions from The United States Air Force Management Equipment and Evaluation Program echo the above. They state "the use of pulse technology virtually eliminated chronic battery/charging system problems. There was a direct correlation between the use of pulse technology and a reduction in labor and materials cost associated with battery/charging system maintenance. However, to get full benefit of this technology, the product has to be used full time. This should result in: reduction in battery handling fees now being charged, reduction in hazardous waste disposal handling and reduction in hazardous waste disposal costs."

In July 1996 an independent test was conducted by Ohkura Corporation, of Japan. The goal of the test was to prove the effectiveness and value of pulse technology. To document the visual results, they built a clear Lexan battery and photographed the lead plates. On July 6, a battery with deeply sulfated plates (see Figure 1) was completely discharged. The discharge time was 800 seconds. A pulse technology product was then mounted on the battery and allowed to pulse the plates through the cycling process. On July 24 the battery was tested again. This time, the plates were completely clean (see Figure 2) and the battery discharged over 2000 seconds. The conclusion was: By using Pulse technology and removing sulfate buildup on the plates, the discharge capacity of the battery increased two-and-a-half times in only 18 days.

Similar results have been achieved on deep cycle batteries. Table 1 details a discharge test conducted by Electric Car Distributors in Rancho Mirage, California on a set of deep-cycle batteries removed from a leased vehicle. After cycling the batteries three separate times to establish base-line performance, a pulse technology product was put in parallel to the charging circuit. The original baseline performance of approximately 47 minutes discharge time was enhanced to 49 minutes after only two days; 51 minutes after 4 days; 59 minutes after 9 days; 65 minutes after 23 days; 69 minutes after 29 days and 72 minutes after 32 days. The net increase of 24.4 minutes of discharge time represents a 51.8% greater discharge capability. This increase in battery performance easily becomes the difference between replacing these batteries and simply conditioning them for further use.

CONCLUSION

The potential to eliminate a major contributing cause of lead-acid battery failure quickly, safely and completely has been identified as pulse technology. This patented, proven technology is simple to apply and works with virtually every type of vehicle and equipment that uses a lead-acid battery. The technology helps to provide greater battery performance, increased battery life, reduced costs, and it can also have a huge positive impact on the environment.

Appendix

Ohkura Corporation Pulse technology Discharge Test Results

Below are photographs highlighting the results of a test conducted by a company in Japan.

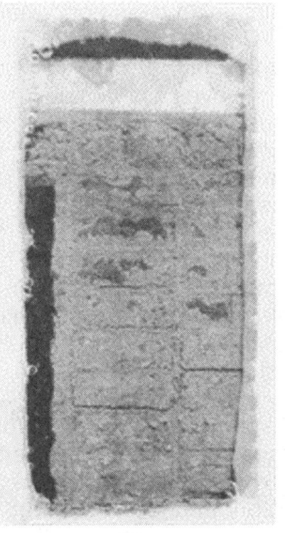

Figure 1: Battery plate with heavy sulfation buildup.

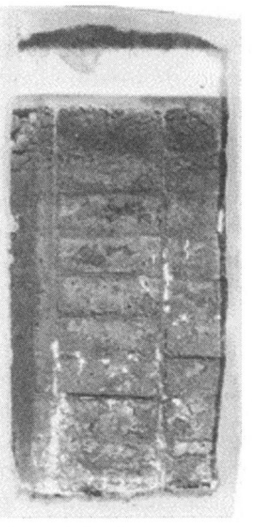

Figure 2: Same plate 18 days later. No sulfation buildup.

Electric Car Distributors Pulse technology Discharge Test Results

Below is a chart highlighting the results of a test conducted by a golf car and electric vehicle distributor in California.

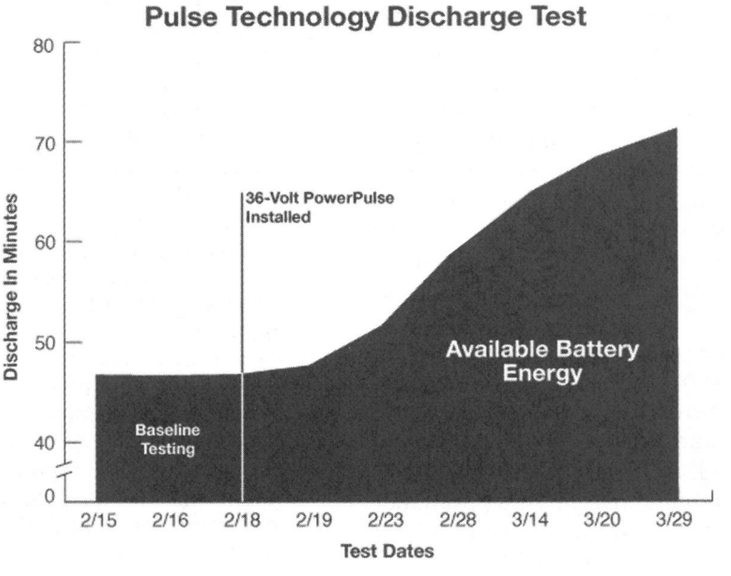

Table 1. Results from a discharge test conducted by Electric Car Distributors.