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WHITE PAPER

Preventative Battery Maintenance for Commercial Vehicle Fleets

Preventing costly no-start situations to reduce battery-related breakdowns

ABOUT THE AUTHOR

Darwin Sauer is the CEO and founder of Discover Battery, and CEO and Chairman of the Board of Discover MIXTECH Manufacturing Co. Ltd. He is a visionary, innovator and entrepreneur with over 35 years of experience in the industry, and the driving force behind Discover's MIXTECH lineup of batteries and the acquisition of the MIXTECH plant in Korea.

Introduction

Battery expense is increasing as a percentage of commercial fleet maintenance expense as a result of decreased life expectancy of batteries in commercial vehicles. Fuel saving technologies, reduced emissions mandates and the ever-growing use of electronics, computers and accessories in vehicles have increased electrical demand on batteries causing no-start situations and battery-related breakdowns in commercial fleets.

Developing a solid preventive maintenance program where batteries are tracked by vehicle, crossed checked with its regular route schedule, and are checked on a regular basis can help identify battery problems early, will prevent costly no-start situations and reduce battery-related breakdowns.

Executive Summary

The Problem

In today's commercial vehicles, there are two main contributors to decreased life expectancy of batteries. First, to help save fuel and reduce emissions, start-stop engine technology and anti-idle legislation is becoming the norm across the transportation industry. Start-stop engines automatically shut off when the vehicle is at idle and restart when the driver's foot leaves the brake pedal. Anti-idle legislation prevents engine idling during stops for pick-ups, drop-offs and at truck stops and rest areas saving fuel and reducing emissions. Engine starts can surpass in a year what they used to be in a lifetime.

Second, electronics and computers are employed in greater and greater numbers in vehicles today than ever before. The number of vehicle systems that require electricity is growing. Even while driving and being supported by the engine's alternator, batteries are at the heart of massive electrical and electronics systems and must pass electricity to many devices. Here are just a few of the systems running on electricity that are now common in commercial vehicles:

Start-stop electronics, daytime running lights, cruise control, climate control, remote keyless power door locks, ABS brakes, power windows, instruments and information displays, electric mirrors, tire pressure monitoring systems, traction control systems, emergency braking assist, pre-collision safety systems, post-collision safety systems, lane departure warning systems, automated driving systems, USB charging, Bluetooth, speakers and subwoofers, entertainment systems, remote anti-theft alarm system, refrigerators, anti-idle HVAC support, CPAP machines and more.

The combination of these two factors produces a powerful third problem for today's batteries. In a start-stop vehicle, while stopped, the energy needed to power all of the electrical loads is provided by the battery without the assistance of the engine's alternator. This drains the battery, even during short stops. Once restarted, the alternators are required to recharge the battery very quickly, a phenomenon known as micro-cycling of the battery. In longer duration anti-idle situations batteries are being constantly deeply cycled.

Given these three attacks on batteries, it is not surprising that battery life expectancy has decreased. Battery related commercial fleet costs have increased - in more ways than you may have imagined - as vehicles have evolved which requires commercial fleet maintenance practises to evolve too.

The Solution

An improved understanding of how batteries work and fail and how emerging battery technologies and improved maintenance practices can be utilised to reverse the trend of reduced battery life and increased costs related to premature battery failures.

To lower battery costs for your commercial fleet, you should employ these steps:

- **Step 1**: Chose batteries with the capacity and technology best suited for the job.
- **Step 2**: Eliminate or reduce acid stratification to save fuel and maintenance related costs.
- **Step 3**: Install proven technology that helps to maintain and recover battery health.
- **Step 4**: Charge batteries regularly to increase battery life.
- **Step 5**: Avoid prolonged use of "engine-off" electrical loads.

Why it Happens: Battery Life Expectancy Declining

Historical Development of the Modern Lead-Acid Battery
Since the beginning of the 20th century when gasoline and diesel internal combustion engine technology emerged, vehicles have continued to electrify processes to improve reliability, comfort and safety. Manual cranking became unnecessary with the introduction of the starter motor and magnetic ignition was replaced by battery ignition that required an electric generator and a rechargeable battery. Soon electric headlights and windshield wipers were added.

Larger engines with higher cranking requirements and further electrification saw system voltages double from 6V positive-ground to 12V negative-ground (and some 24V systems) in the 1960s. Generators changed to higher efficiency alternators and batteries began to standardise around the current 12V design.

Batteries continued to improve with mechanical (grid, separator, case, cover and terminal) and electrochemical (lead alloys, active material additives and electrolyte) enhancements. Low or maintenance-free calcium plate alloys largely replaced water consuming antimony alloys and that led to the introduction of flooded sealed and maintenance free transportation batteries in the 1970s. Battery design changes throughout the 80s and 90s largely kept pace with growing maintenance, reliability and performance demands as well as original equipment manufacturers' demands for component weight reductions.

Batteries transitioned from being purchased "mostly" on the basis of their capacity in Amp Hour ("AH") or minutes of reserve capacity ("RC") to being marketed mainly on the basis of their cold cranking ("CCA") ratings. In total, the lead-acid starting battery has survived over one hundred years of cost reducing manufacturing advancements as well as radical performance transformation.

As of 2020, vehicle evolution has accelerated, and the electrical demands are still being handled by essentially the same power supply system that has been used since the 70s. The lead-acid battery is once again being challenged to transform. For the first time in 100 years, the average battery life of lead-acid batteries is declining.

More Electricity, More Problems
The number of vehicle systems that require electricity is growing. Even while driving and being supported by the engine's alternator, batteries are at the heart of massive electrical and electronics systems and must pass electricity to many devices. Here are just a few of the systems running on electricity that are now common in vehicles:

Start-stop electronics, daytime running lights, cruise control, climate control, remote keyless power door locks, ABS brakes, power windows, instruments and information displays, electric mirrors, tire pressure monitoring systems, traction control systems, emergency braking assist, pre-collision safety systems, post-collision safety systems, lane departure warning systems, automated driving systems, USB charging, Bluetooth, speakers and subwoofers, entertainment systems, remote anti-theft alarm system, refrigerators, anti-idle HVAC support, CPAP machines and more.

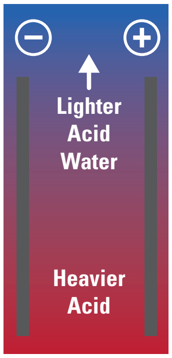
Start-stop engine technology and anti-idle legislation have placed a dramatically higher demand on batteries. Due to combining start-stop systems with the increasing number of electrical systems in vehicles, today's batteries suffer from parasitic electrical loads and frequent charge and discharge cycle demand.

Parasitic electrical loads are an excessive electrical load on the system that happens after the vehicle is turned off. This happens because modern vehicle electronics are always on like clocks, security cameras, Bluetooth, radio antennas, and more. Frequent charge and discharge cycles (also called "high cyclic demand" or "high-cycling"), occurs when a battery must be recharged frequently because it is always being drained. In a start-stop application, batteries can both be deeply discharged ("deep-cycled") and shallowly discharged ("micro-cycled") at various times, depending on the length of time the engine is off and the number of electrical systems that are running in the vehicle. These factors combine so that today's batteries are almost always operating in a partial state of charge ("PSOC").

While engine starting power expressed as cold-cranking amps ("CCA") became the dominate measure of the starting battery in the last century, with the increase of electrical systems in vehicles, the key performance metric is now swinging back to battery capacity expressed in amp hours ("AH") or reserve capacity ("RC"). Battery designers are also adding mechanical and electrochemical breakthroughs aimed at eliminating acid stratification to improve and sustain cycle life and dynamic charge acceptance ("DCA") in batteries that are almost always being used in a PSOC condition.

Acid Stratification: A Lead-Acid Battery Serial Killer
High cyclic demand and parasitic electrical loads brought about by the use of start-stop technologies, increased electrical systems, and the frequent PSOC operation of batteries in modern vehicles combine to accelerate the #1 cause of declining battery life expectancy: Acid Stratification.

Acid stratification is accelerated if (1) the battery operates in PSOC conditions, (2) the battery seldom receives a full charge, (3) the battery is constantly cycled, (4) the battery is used or exposed to extreme temperatures, and (5) the battery is left standing for long periods of time. All of these can contribute to battery failure.



Battery Failure Mode: Positive Plate Active Material Softening/ Shedding & Corrosion

The discharge and charge process cause first the expansion, then contraction of the positive **(+)** active material. Expansion occurs both in the plane (height and width) of the plate as the grid is pushed/stretched by corrosion processes over time and in thickness of the plate as the active material is forced to expand to accommodate the lead sulfate ("$PbSO_4$") with each discharge. The above image represents the chemical process in the battery charge and discharge process. The volume increase of the positive **(+)** lead dioxide ("PbO_2") plate during transformation to positive **(+)** lead sulfate ("$PbSO_4$") can be greater than 90%. The volume increase of the negative (-) lead ("Pb") plate during transformation to negative **(-)** lead sulfate ("$PbSO_4$") can be greater than 160%. Recharging restores most of the lead dioxide in the positive plate to almost its original size, but, step-by-step, the positive plate will grow. By contrast, the negative plate does not expand over time because lead ("Pb") is softer than lead dioxide ("PbO_2").

PbO_2 (+)	H_2SO_4 Mixed Water and Sulfuric Acid	Pb (–)

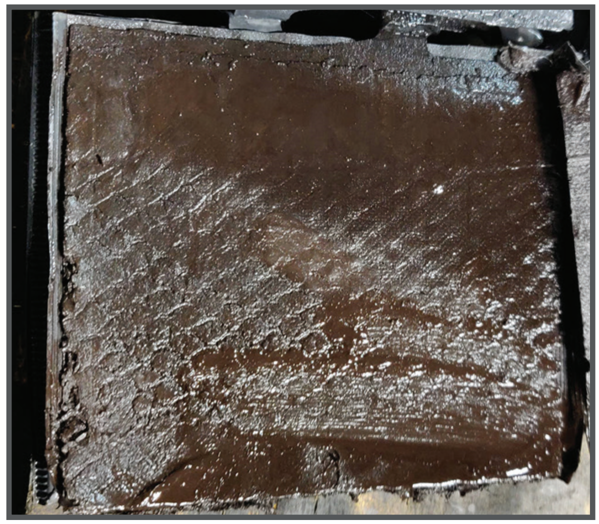
Fully Charged
Lead Oxide (+) and Lead (-)
Liquid Electrolyte (H_2SO_4)
Mixed Acid with Stored Chemical Energy

$PbSO_4$ (+)	H_2SO_4 Diluted Mostly Water	$PbSO_4$ (–)

Fully Discharged
Lead Sulfate (+) and Lead Sulfate (-)
Liquid Electrolyte (H_2SO_4)
Mostly Water with No Chemical Energy

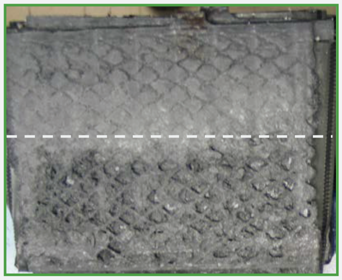
Progressive expansion and contraction of the positive plate as the battery is cycled causes an ever-increasing amount of the active material to be lost ("shedding") from the grid/plate wires (a process called "corrosion"). This change in the active material mass manifests itself as a loss of battery capacity as expressed in Amp Hour ("AH") or Reserve Capacity ("RC").

Positive plate softening (active material appears muddy) will happen before shedding if the battery is regularly undercharged. In the field, a "new" battery that presents itself as being low on capacity can often be conditioned using an external charger and successfully put back into service. However, if we did a tear down analysis of that battery, we would observe positive plates that appear to be in good shape but the active material looks to be softening and muddy. In a battery suffering from acid stratification, the muddy appearance may be concentrated on the bottom of the plate. Muddy positive plates are usually accompanied by negative plates that show signs of sulfation.



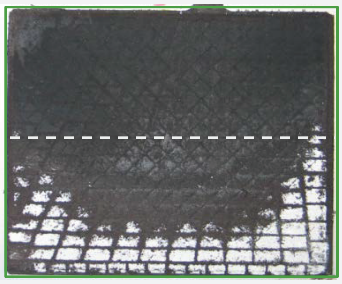
Since grid wires are the current collectors upon which electrical current is delivered to the starter (Cold Cranking Amps or CCA), corrosion decreases the electrical performance of the battery. In a corroded battery, much of the current gets lost to resistance (in the form of heat) as the grid wires become exposed and/or disconnected from the active materials. The mechanical integrity of the plate is broken down as the structural integrity of the active material breaks down into individual crystallites that eventually break their bond with the grid wires and shed from the plate's active material mass within the grid/plate. The result is grid wires become exposed to accelerated corrosive activity during charge. And over time, these conditions cause the battery to fail.

In an acid stratified battery, shedding and corrosion and sulfation happen much faster at the bottom of the plate leading to earlier battery failure. What's more, modern vehicle batteries that operate in a PSOC condition, that seldom receive a full charge, and/or are constantly deeply cycled or micro-cycled combine with acid stratification to accelerate shedding and corrosion. For this reason and others, average battery life is declining for the first time since the beginning of the 20th century.

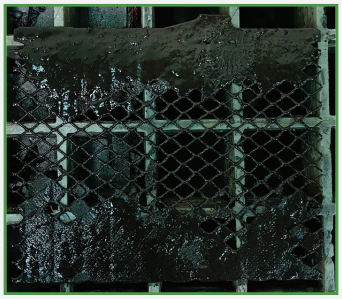


Shedding

Softening



Sulfation



Battery Failure Mode: Battery Dry Out and Thermal Run-away

When a battery is charged, evaporation occurs which reduces the volume of electrolyte solution (Water + Sulphuric Acid) inside the battery. It is mostly the water volume that is lost in this process. A vicious cycle is created as lower volumes of electrolyte (now with higher acid to water ratios) increase internal resistance causing excessive heating during charge and that causes a further increase in water loss through evaporation. At some point in this incremental process, the water volume depletes (battery dry-out) to the point where a battery's growing internal resistance, combined with the corrosion processes described earlier, causes so much heat during charge that a thermal run-away event can occur, such as battery fires or melting.

Battery dry-out and the chance for thermal run-away are accelerated by acid stratification. What's more, modern vehicle batteries that operate in a PSOC condition, that seldom receive a full charge, and/or are constantly deeply cycled or micro-cycled combine with acid stratification to supercharge battery dry-out conditions and increase the likelihood of thermal run-away. For this reason and others, average battery life is declining for the first time since the beginning of the 20th century.

Battery Failure Mode: Negative Plate Sulfation

When a lead acid battery is left to self-discharge (in storage or installed but seldomly used), or is exposed to excess and repeated high-rate charging (such as is the case with Start-stop vehicles), a point can be reached where the reaction at the negative plate that should convert the lead back to active material ($PbSO_4$ back to Pb) can not accommodate all of the charging current. In this case, the excess electrical current escapes and causes hydrolysis, where water is divided into hydrogen and oxygen which escape as evaporation.

This inefficient charge-acceptance occurs almost exclusively at the negative plate where the surface area of the active material is much lower than that of the positive plate. This negative accumulates lead sulfate (sulfation) on the negative plate. This sulfation of the negative plate will cause battery performance to incrementally decline and will result in premature battery failure.

A battery with highly sulfated negative plates will eventually only accept a surface charge, resulting in false positive high state of charge readings. In this condition, a battery may appear fully charged but have very low capacity as expressed in Amp Hour (AH) or Reserve Capacity (RC). This false state of charge reading tricks modern vehicle charging systems into thinking the battery is more charged than it is and leads to 1) batteries always being in a PSOC condition, and 2) increased alternator wear and fuel consumption.

Negative plate sulfation is accelerated by acid stratification. What's more, modern vehicle batteries experience the sulfation effects even more dramatically when they suffer from acid stratification while operating in a PSOC condition, seldom receive a full charge, and/or are constantly being deeply cycled or micro-cycled. For this reason and others, average battery life is declining for the first time since the beginning of the 20th century.

Battery Failure Mode: Undercharging

If either the negative or positive plate is continually undercharged, a premature decline in capacity will occur because of sulfation. Undercharging is on the rise across the world in vehicles of every type. Undercharging can be caused by defective charging or persistent PSOC operation. Defective charging can happen as a result of faulty equipment or as a result of some of the other battery failure modes discussed in this document. PSOC operation is a growing trend due to the growing number of vehicle systems that rely on the battery to properly function and the deep and micro-cycling that occurs in start-stop vehicles.

On-top of all of that, battery failure due to undercharging is accelerated by the affects of acid stratification. For this reason and the others discussed in this document, it is not surprising that average battery life is declining for the first time since the beginning of the 20th century.

Reversing the Trend: Fixing Modern Battery Problems

It is possible to reverse the trend of declining battery life expectancy and increased vehicle fleet maintenance costs related to batteries and battery failures. To accomplish this, first we must eliminate or, at a minimum, reduce acid stratification. If you can win against acid stratification, you can improve a battery's active material utilization, slow the phenomena of the 4 battery failure modes discussed in this document, and prevent premature loss of performance and life.

Eliminating acid stratification helps to sustain a battery's dynamic charge acceptance ("DCA"). In turn, high DCA allows more energy to be stored, alternators to work more efficiently and batteries to support electrical loads for longer periods of "no-alternator" operation. The better a battery's DCA, the more efficiently the batteries active materials are utilized and the greater the number of full capacity cycles and stop-start events it can support.

The following steps can be taken to fix the problems facing batteries in modern fleet vehicles and reduce costs associated with battery failures.

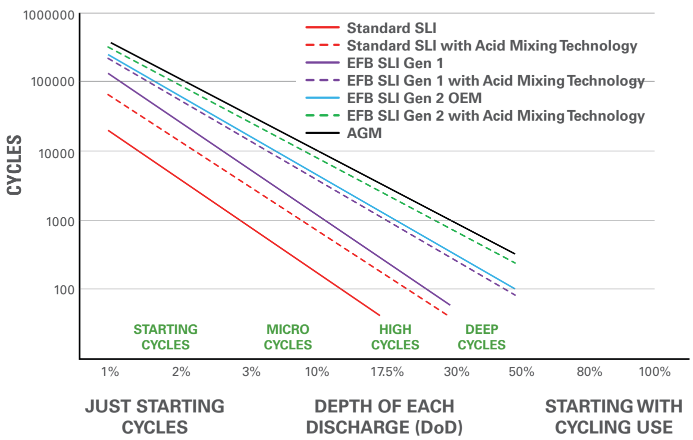
- **Step 1**: Chose batteries with the capacity and technology best suited for the job.
- **Step 2**: Eliminate or reduce acid stratification to save fuel and maintenance related costs.
- **Step 3**: Install proven technology that helps to maintain and recover battery health.
- **Step 4**: Charge batteries regularly to increase battery life.
- **Step 5**: Avoid prolonged use of "engine-off" electrical loads.

Choose the Right Battery Capacity and Technology

Avoid dreaded Monday morning no-starts by properly sizing the capacity of the battery to the real key-off electrical loads. Avoid premature battery failure by choosing the proper battery technology to match the frequency and duration of key-off or anti-idle loads.

Every cycle the battery will only recover to "very near" its original capacity if it is properly charged. Even if properly charged, a lead acid battery incrementally looses some of its original capacity with each successive discharge event. A standard starting battery can only be regularly discharged to <3% before it experiences negative consequences. A high-capacity (high RC or AH) extra heavy-duty battery with a deep cycle design can only regularly use a maximum of 30% of its rated capacity before causing incremental and permanent damage. Discharging a starting battery to 50% or lower depth of discharge will dramatically reduce battery life.

STARTING & CYCLING ABILITY OF TRANSPORTATION BATTERIES



The battery you choose needs to have the adequate specifications to support the job its being asked to do, and your maintenance supervisors and operators should be trained in best maintenance practices to protect this investment. Choose battery technology that includes:

- Counter measures against acid stratification by introducing acid mixing technology or acid immobilisation technology.
- Deep and micro-cycle capability through enhanced active material ratios, densities and alloys (less of a starting battery and more of a cycling battery).
- Fibre dividers that reinforce active material against shedding caused by acid stratification and vibration.
- Enhanced negative plate performance via increased carbon and/or other additives.
- Element bonding that protects against positive grid growth and vibration.

- Anchor bonding that protects against shock and vibration.
- Higher lead content using thicker or more plates as may be sufficient to secure the increased positive and negative plate active material for increased capacity (AH or RC) and cycle life, while maintaining enough surface area to produce adequate cold cranking performance (CCA).

A word about acid mixing and acid Imobilisation

Acid mixing technology uses components that mix the acid to equalise the acid's specific gravity evenly throughout the battery's cells. Acid immobilsation technology uses absorbent glass-mat material to suspend acid to slow stratification in the battery's cell ("AGM" batteries). While the same electrochemical reactions take place, the negative consequences of acid stratification have been shown to be delayed in acid mixing and AGM batteries because acid mixing technology defeats acid stratification and acid immobilisation technology slows (but does not fully stop) the stratifying effect of gravity on battery acid.

Eliminate or Reduce Acid Stratification: ACID STRATIFICATION IS A KILLER!

Acid stratification happens naturally in all lead acid batteries and causes alternator wear and increased fuel costs. Technology-heavy, start-stop and anti-idle vehicle batteries experience accelerated acid stratification, increased alternator wear and fuel consumption. Acid stratification is application related and is not a battery defect, but the impacts of acid stratification put strain on alternators and represent the largest contributor to lead acid battery failure.

Eliminating/reducing acid stratification helps to sustain a battery's dynamic charge acceptance (DCA), improve active material utilization, and prevent premature loss of performance and life. Higher DCA allows more energy to be recovered and stored faster allowing alternators to work more efficiently and batteries to support electrical loads for longer periods of "no-alternator" operation. Efficient alternator operation lowers the alternator burden on an engine, improving fuel efficiency and lowering CO_2 emissions. The higher a battery's DCA, the more efficiently the battery's active materials are utilized and the greater the number of full capacity cycles and stop-start or anti-idle events it can support.

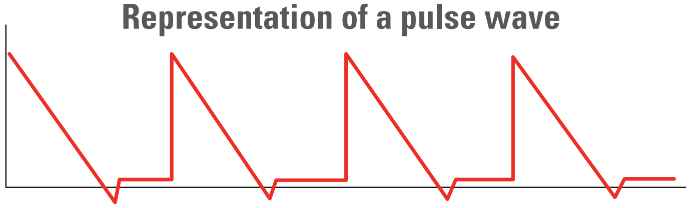
Typical lead acid batteries start with a high DCA but, this degrades rapidly because of the acid stratification and PSOC use, stabilizing within a few short months at around 30% to 50% of original specifications.

Install Cost Effective and Proven Battery Sustaining Technology!

Proven high-frequency pulse wave technology exists and work independently of the vehicle charging circuits. They are small and easy to install on a battery or battery bank. Once purchased, they are re-useable on one battery or battery bank after another as batteries are replaced. Pulse wave technology is also available in some chargers.

These devices promote a high-frequency pulse across a battery's plates, working to keep the plates clean of sulfation and helping to sustain battery capacity and dynamic charge acceptance (DCA).

Representation of a pulse wave



Utilising pulse wave technology along with proper charge maintenance practices is a proven cost reduction strategy. Charging with pulse wave technology has been proven to help discharged batteries recover allowing some batteries to be put back into service that might otherwise have been discarded.

High-Frequency Pulse Wave Conditioning used by Mack Trucks

MONTRÉAL (April 11, 2019). To maximize uptime and significantly extend the life of electrical charging system components, Mack Trucks today announced that it is making a battery refresher standard on all Mack® models. The battery refresher helps reduce and reverse the effects of sulfation, giving lead-acid batteries longer life and superior performance. Mack made the announcement during ExpoCam 2019 April 11-13 in Montréal.

"Sulfation is one of the top causes of lead-acid battery failure," said Roy Horton, Mack Trucks director of product strategy. "With the addition of the refresher, we can increase the life of a battery by up to two times and help prevent unplanned no-starts."

Sulfation occurs when sulfate crystals, a by product of normal battery operation, build up on the battery's lead plates. As more sulfate crystals build up, the battery loses its ability to accept energy and reach a full charge, shortening its life.

The refresher emits high-frequency pulses of energy to remove the sulfate crystals and allow the batteries to once again accept a full charge, resulting in significantly improved life and performance. In addition, fully charged batteries reduce the wear and tear experienced by other electrical system components, such as the alternator and starter, helping extend their service life.

Charge your batteries regularly to increase battery life and reduce operating costs

Your team should be checking and recharging batteries at least every 3-weeks. More when opportunities like overnight stops, weekend breaks, or vehicle inspections/repairs present themselves. Instituting a practise of top charging batteries - whenever possible - at least once every 3 weeks using an external charger will not only reduce costs associated with premature battery failure but can also lead to reduced fuel consumption of 1.5% to 3%.

Always use an external charger with charging output in amps =/>10% of the combined total RC or AH capacity rating of the batteries in the bank. A 12V battery bank of 4 x 100AH (total 400Ah) or 4 x 180RC (total 720RC) should use an intelligent temperature compensated 12V charger with a minimum 40-80 Amp output at 12V. If you having inverters in your vehicles to support additional loads, consider installing inverters that have internal chargers built in.

If possible, your staging/parking areas should install AC outlets where vehicles can access power to operate these external chargers. Your operators should be trained on how and why this is important. A good quality 12V-80A (960-watt) charger can easily be operated using a standard 110V AC wall outlet. Typical 110V outlets are capable of supporting a 1200-watt continuous draw.

Alternators, Fuel and PSOC Batteries

Every hour a 400-amp alternator is charging (not freewheeling) wastes almost 1 gallon of fuel. Alternator torque requires engines to produce 1 horsepower (HP) for every 25-amps of charging current produced. A 200-amp alternator requires about 8 HP and a 400-amp alternator will require 16 HP from the engine. Diesel engines require on average .06 Gal (.21Li) or .40 lbs (.18Kgs) of fuel per hour to generate 1Hp.

Alternators in technology-rich vehicles will typically only charge the bank up to 90% due to the vehicle's charge voltage regulation. The efficiency of standard alternators at medium speed is limited to 70-80% (at 77°F/25°C) by fan cooling loss, bearing loss, iron loss, copper loss, and the voltage drop in the diode bridges. This efficiency reduces dramatically at higher temperatures and at high speeds mainly due to fan resistance. Combined, even by working as hard as it can, it is almost impossible for the alternator alone to fully charge batteries to eliminate PSOC conditions.

Avoid Prolonged Use of added Electrical loads during "Engine-off" periods

Battery performance and service life is dramatically affected by the frequency and depth of battery discharge. Here are some common electrical loads for popular devices used in commercial vehicle fleets to support driver health and comfort:

- *Refrigerator at 5 amps*
- *Heating/AC at 19 amps*
- *Interior lighting at 4 amps*
- *Entertainment systems at 4 amps*
- *Sleep assist systems CPAP at 3 amps*

If these additional loads are used together for a period of 6 hours while your vehicle is parked, they will collectively consume 210Ah (35-amps per hour x 6 hours = 210 Amp hours) from the battery pack.

Conclusion

The added technology and features in our modern vehicles will continue to drive the need for advanced battery technology. Today's vehicles are equipped with new technologies putting more and more strain on the battery. A modern vehicle may have as many as 150 electrical features. That means your battery simply needs to do more starting, more cycling, and output more power.

As laid out in this paper, there are steps that that commercial fleets can incorporate to create an effective preventative maintenance program.

- **Identify your onboard electronics requirements** and speak to a battery expert at Discover Battery to ensure your fleet is buying and using the ideal batteries for your requirements.
- **Develop a solid preventive maintenance program** where batteries are tracked by vehicle and checked on a regular basis to identify battery problems early in order to prevent costly no-start situations and reduce battery-related breakdowns.
- In order to save fuel, reduce emissions, and remain compliant, take the time to **understand start-stop engine technology and your regional anti-idle legislation**.
- **Improve your understanding of how batteries work and fail** and how emerging battery technologies and improved maintenance practices can reverse the trend of reduced battery life and increased costs related to premature battery failure.

References

*1 Characterization of Dynamic Charge Acceptance for Lead-Acid Batteries in Micro-Hybrid Vehicles. Heide Budde-Meiwes*1, Dominik Schulte2, Julia Kowal1, Dirk Uwe Sauer1, Ralf Hecke3, Eckhard Karden4,1Electrochemical Energy Conversion and Storage Systems Group, Institute for Power and Electrical Drives (ISEA), RWTH Aachen University, Germany, Jägerstraße 17-19, 52066 Aachen, *batteries@isea.rwth-aachen.de*

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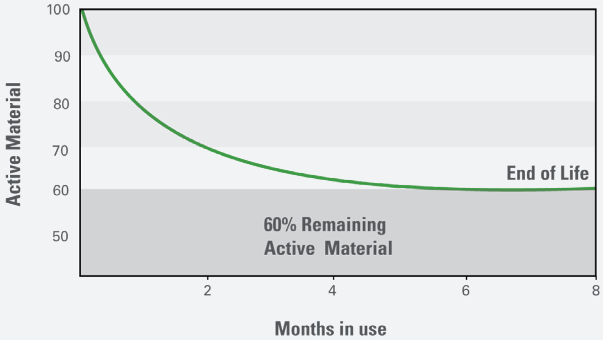
What is Acid Stratification?

Acid stratification happens naturally in lead-acid batteries. The fluid in a battery is called electrolyte. Electrolyte is a mixture of sulphuric acid and water. Acid is heavier than water and is fundamental to the electrochemical charge and discharge process in a lead acid battery. Acid stratification happens when the heavier acid in the battery's electrolyte separates from the water and assembles at the bottom of the battery's cell creating an area of very high specific gravity electrolyte.

Effects of Acid Stratification

- When acid stratifies (sinks to the bottom of the battery's cells) and the upper portion of the battery's plates are left subject to low specific gravity electrolyte (now mostly water), the upper portion of the plate is rendered inactive and is no longer capable of supporting discharge capacity. Under these conditions, the useful active material in the battery will be reduced by as much as 40% within six months of normal use, creating "dead lead" or "inactive active material." (See graph)
- The stratified acid at the bottom of the battery's cell focuses discharge activity to the bottom of the cell causing the bottom part of the plate to work overtime. While the bottom part of the plate gets excessively discharged, the top part of the plate receives most of the charging activity. As a result, acid stratification can cause a battery's dynamic charge acceptance ("DCA") to decline by 50% to 70% within 6 months of installation, increasing alternator wear and tear and decreasing fuel efficiency.
- Since electrical current moves more easily through water (top part of the cell) than it does through acid (bottom part of the cell), stratified acid concentrates charging current and charging heat at the upper part of the plate accelerating corrosion which dramatically lowers the battery's cranking power ("CCA").
- Stratified acid promotes increased internal resistance, lower conductivity and accelerated sulfation on the lower part of the plates, reducing the battery's dynamic charge acceptance ("DCA"). This means a sulfated battery will only accept a surface charge, resulting in false positive state of charge readings to vehicle computers and on battery testers. So, a battery may appear fully charged but only provide low "CCA" and "AH"/"RC."

"Modern electrical systems and a large number of cycles accelerate losses in nominal capacity in the lead/acid battery." Acid Stratification causes a new battery to lose 40% of its capacity within months!



Source: Varta/JCI Advanced Lead Acid Battery Convention - Boston, Massachusetts - 2006.

About Discover Battery

What began as a regional battery distribution business in 1949 has evolved into a global engineering and manufacturing company providing leading edge technology to the transportation, motive power, and energy storage industries through the best knowledge-based distribution and service organizations on the planet. Along with highly engineered industry leading power electronics features, Discover PURPOSE BUILD award winning patented technology and over 70 years of applications history into the design and production of high value power solutions that matter to people who rely on batteries to work, live or get away.

About MIXTECH

MIXTECH is an award winning patented German technology built into every Discover MIXTECH battery that uses the vehicle's natural movement to continuously mix the electrolyte inside to eliminate acid stratification. The battery maintains uniform specific gravity (acid density) throughout. Eliminating acid stratification improves active material utilization, sustains Dynamic Charge Acceptance and cycle life and prevents premature loss of performance and life.

MIXTECH batteries maintain dynamic charge acceptance (DCA) up to 3 times greater than conventional, EFB or AGM batteries when used in severe duty and partial state of charge (PSOC) use. Higher DCA allows more energy to be recovered and stored faster allowing the battery to support electrical loads for longer periods of "no-alternator" operation. This saves fuel! Fuel savings are also secured because the stop-start function in many cars can also be better utilized if the battery maintains its DCA and is able to recover and store more current.

Innovative Battery Solutions

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