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WHITE PAPER

Lead or Lithium: Batteries for Marine and RV/Caravan use

Understanding battery technology, why batteries fail and preventative maintenance will give you the confidence to know what battery to buy, why and when to buy it and how to look after it.

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 related maintenance and associated expenses are always on the mind of people who rely on batteries to power their adventures and lifestyle. This topic can be daunting when we consider modern engine technologies, and the ever-growing use of electronics, computers and accessories that people want to run when anchoring out or camping.

Developing a strong understanding of battery technology, how batteries interact and fit-in with the components of the electrical system, combined with simple preventative maintenance practices, can help identify battery problems early, and will prevent costly battery-related breakdowns.

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Executive Summary

The Problem

In modern Marine vessels and RV/Caravans there are four main contributors to battery failure.

First, to help save fuel and reduce emissions, anti-idle legislation is becoming the norm. New engine technologies for engine propelled vessels and vehicles are becoming the norm. Anti-idle legislation is also preventing engine idling everywhere from dockside to marine and land parks and many places in between. Rules and regulations are starting to limit the use of standby generators in some jurisdictions causing many to install solar panels as the main secondary charging source when AC power is not available.

New engine technologies deploy a range of sophisticated fuel management and engine monitoring electronics and computers. When combined with new and always on "key-off" parasitic loads, long periods between manufacture and final purchase from a dealer and the potential for long storage periods between use that are all typical in the Marine, and RV/Caravan industry, starting batteries are constantly being operated in a Partial State of Charge condition (PSoC).

Parasitic loads on starting batteries now easily reach 75 to 100 milliamps. A 100-milliamp draw will discharge a new and fully charged (most are not new or fully charged) 100AH battery to the point where it may not be guaranteed to start the engine (50% DOD) in 20 days. (100 milliamps x 24hrs = 2.4amps / 100 x 50% = 50Ah divided by 2.4amps = 20.8 days) Or 70% DOD in 30 days. Even a large 400AH diesel engine starting battery bank would be discharged to 50% DOD within 90 days and once again 90 days between use is not uncommon in the Marine, and RV/Caravan market.

Second, the PSoC phenomena prematurely killing starter batteries is also quietly ravaging the house-load battery banks installed in Marine vessels and RV/Caravans. The number of always-on parasitic loads that require electricity is growing as everything becomes digital and interactive. Even while underway and being assisted by the main engine or tow vehicle engine alternator house-load battery banks are supporting DC and AC (thru inverter) loads (some that are high surge) and are at the heart of massive electrical and electronics systems. Here are just a few of the systems running on electricity that are now common in Marine and RV/Caravan applications:

Engine fuel system controls, running lights, cruise control and auto-pilots, wireless control systems of all kinds, remote keyless locks, vehicle brakes, vessel thrusters, anchor motors, power windows, instruments and heads-up information displays, power and heated windows and mirrors, navigations systems, monitoring for a variety of safety control systems, systems, emergency braking or collision avoidance assist, lane departure and radar awareness systems, USB charging, Bluetooth, speakers and subwoofers, entertainment systems, remote cameras and anti-theft alarm system, fire suppression systems, anti-idle electronics, Wi-Fi and Bluetooth, laptops and phone chargers, refrigerators, freezers, stoves, ovens, microwaves, laundry, toilets, black water and grey water treatment systems, water heating and water making systems, HVAC support and more.

Third, heat kills batteries. Marine vessels and RV/Caravans are not going to stop traveling or parking in extreme environments and they certainly won't decrease their demanding electrical loads when exposed to extreme temperatures. They can't prevent from being required to function for hours at a time and for the most part they can't feasibly change course to immediately travel through or locate to more moderate climates. While cold temperatures will affect your batteries available capacity, cold temperatures do not cause accelerated battery failure. High operating temperatures however significantly affect battery life. No matter the technology and no matter the fancy brochure that may suggest otherwise, the inconvenient truth is exposed by science and physics. It's the law* that dictates that for every 10°F increase in temperature above 77°F/25°C, the chemical reaction inside your battery will approximately double cutting battery life in half. It is this same Law that explains why as temperatures drop your battery's available capacity drops along with it as the chemical reaction inside your battery decreases.

Keeping batteries cool will work to reduce the related electrochemical reactions that accelerate premature capacity loss and battery failure. Eliminating or mitigating the high temperature exposure of battery compartments in engine rooms or even making sure to shade them from the sun will save you money and should be a high priority for owners and builders. Lead or Lithium, no matter the battery technology, Heat Kills all Batteries! Even if you install isolator switches at all of your batteries to interrupt any parasitic draws the high temperatures that many Marine and RV/Caravan batteries are stored in will accelerated the batteries self discharge rate during storage periods. So, if the batteries you are using have an average self discharge rate of 5% per month at 20°C/68°F that rate will jump to 10% per month at 25°C/77°F. Depending upon technology, high-quality flooded deep-cycle batteries – like golf cart batteries - can have an average monthly self-discharge of 5% to 8% at room temperature. High-quality Sealed valve regulated AGM or GEL batteries will average 2% to 3% per month and lithium solutions will also have about a 2% to 3% self discharge rate. For lithium solutions this rate can increase depending upon the sophistication – or lack there of – of the battery management system (BMS).

The combination of these three factors produces the very powerful fourth problem of Marine and RV/Caravan batteries always being cycled and used in a partial state of charge. While being used

at anchor or camping all of the energy needed to power all of the electrical loads is provided by the battery bank without the assistance of the engine's alternator. This drains the battery, even during short stops. Once the engine(s) is started, the alternators are required to recharge the battery very quickly in a phenomenon known as micro-cycling of the battery. In longer duration anti-idle situations, at anchor or during camping, batteries are being constantly deeply cycled and, even where solar panels have been installed to assist, alternators rarely are capable of fully charging their lead-acid batteries even after hours of engine run time.

The inconvenient truth is that most users simply do not understand what is really required in time and charging sources to actually fully charge their batteries. For example, the *old practice* of running up the engines for 45 minutes on a regular basis is still a good practice but cannot be relied upon to do anything more than surface charge the battery, and will not fully charge the battery in these applications.

Even when solar panels are used to help maintain batteries:

1. The battery constantly operates in a PSOC
2. The battery seldomly is ever fully charged
3. The battery is constantly cycled
4. The battery is exposed to extreme temperatures
5. The battery is left standing for long periods of time, and
6. The batteries have no counter measures against acid stratification, the #1 cause of premature capacity loss and failure

Countermeasures against acid stratification are:

- Flooded batteries with internal acid mixing technology installed
- AGM or GEL batteries built with internal acid immobilization technology
- Externally added battery sustaining technologies
- Regular charging of all batteries with high-quality multi-stage chargers
- Changing to lithium battery technology that does not suffer from acid stratification

The Solution

An improved understanding of how batteries work and fail, and how emerging battery technologies and improved maintenance practices can be utilised to prevent premature capacity loss and premature battery failure.

To lower your battery cost, you should try to employ these steps:

- **Step 1:** Chose batteries with the capacity and technology best suited for the job
- **Step 2:** Don't use the same battery to do more than one job. Install battery separators with the ability to combine different battery banks in emergencies
- **Step 3:** Install battery isolators that can interrupt all non-emergency parasitic draws and electrical loads when not in use
- **Step 4:** Eliminate or reduce acid stratification to save fuel and reduce battery related expenses.
- **Step 5:** Install proven technology that helps maintain and recover battery health.
- **Step 6:** Charge batteries r with remote chargers regularly to increase battery life.
- **Step 7:** Avoid prolonged use of "charging system-off" electrical loads.

For Marine/RV/Caravan battery owners, sulfation caused by acid stratification can pose a problem. While at the dock or otherwise plugged into and AC power source, the inverter/charger is supporting the electrical loads so it is assumed that the batteries are "good-to-go", but once away from the dock or camping the inconvenient truth of the false state of charge given off by a sulfated battery becomes apparent in short battery run times, more generator hours, inefficient solar panel charge efficiency and more main engine operation where alternators are used as a charging source.

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How batteries work and fail

Acid Stratification: A Lead-Acid Battery Serial Killer

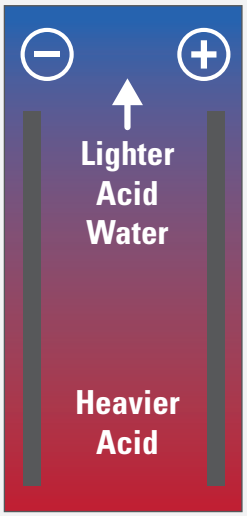
High cyclic demands of Marine and RV/Caravan parasitic electrical loads and electronic fuel systems of modern engines, combined with long periods between use and natural lead-acid battery electrochemical processes, accelerate the #1 cause of premature capacity loss and battery failure: acid stratification.

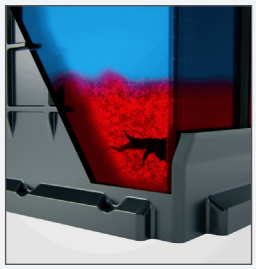
What is Acid Stratification?

Acid stratification happens naturally in all lead-acid batteries. The fluid in a battery is called electrolyte. Electrolyte is a mixture of sulphuric acid and water. The sulfuric acid in your battery's electrolyte is – depending upon battery type - 25% to 33% heavier than the weight of the same volume of water. Sulphuric acid is fundamental to the electrochemical charge and discharge process in a lead-acid battery (see electrochemical process image below).

Acid stratification happens as gravity acts upon the heavier acid in the battery's electrolyte causing it to separate from the water and assemble at the bottom of the battery's cell creating an area of very high specific gravity electrolyte.

- High Specific Gravity (more acid than water) = Higher Voltage
- Higher Voltage = Higher Pressure (Voltage is Pressure)
- Higher Pressure = Higher Heat
- Higher Heat = Higher Plate Corrosion
- Higher Plate Corrosion = More Active Material Shedding
- More Active Material Shedding = Loss of Capacity and battery failure
- HEAT KILLS BATTERIES by ACCELERATING BATTERY PLATE CORROSION!

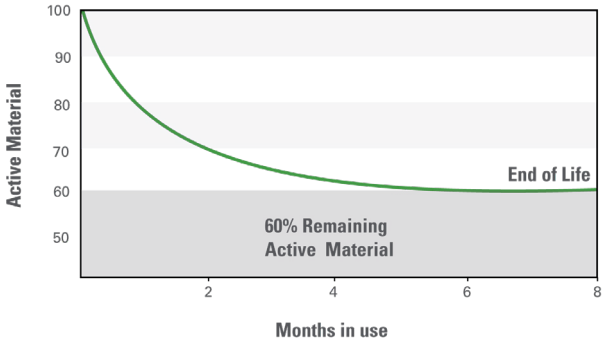




Effects of Acid Stratification?

- 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 now rendered inactive and is no longer capable of supporting discharge activity. 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 below)

"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.

- The stratified acid at the lower half of the cell focuses discharge activity at the lower half of the cell causing the bottom part of the plate to do most of the work and even work overtime. While the bottom part of the plate gets excessively discharged, the top part of the plate receives most of the charging activity.
- Since electrical current moves more easily through water (top part of the cell) than it does through acid (bottom part of the cell), charging current and its related heat is concentrated at the upper part of the plate causing accelerated corrosion of the plates grid wires. The plates grid wires are the pathways along which cranking current or electrical load currents travel. This corrosion dramatically lowers the battery's current delivery capability such as it needed to support starter cranking power ("CCA") or the amps to efficiently support other electrical loads. As a result, acid stratification can cause a battery's dynamic charge acceptance ("DCA") to decline by 50% to 70% within six months of installation, increasing alternator wear and decreasing solar panel or generator charge efficiency.

- Stratified acid promotes increased internal resistance, lower conductivity and the accumulation of sulfation on the lower part of the positive plate, further and sulfation over the total area of the negative plate, 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 volt meters and modern engine computer systems. So, a battery may appear fully charged but only provide low "CCA" and "AH"/"RC" support. This leads to inefficient use of charger sources, such as alternators and generators, causing excessive wear and tear and increased fuel consumption.

For Marine and RV/Caravan battery owners sulfation caused by acid stratification can pose a very inconvenient truth. While at the dock or otherwise plugged into shore power, the inverter/charger is supporting the electrical loads so it is assumed that the batteries are "good-to-go", but once away from the dock or dry camping the false state of charge becomes apparent in short battery run times, longer generator runs, inefficient solar panel charge efficiency and more main engine hours where alternators are used as the charging source.

Acid stratification is accelerated if:

1. The battery constantly operates in a PSOC
2. The battery seldomly is every fully charged
3. The battery is constantly cycled
4. The battery is exposed to extreme temperatures
5. The battery is left standing for long periods of time, and
6. The batteries have no counter measures against Acid Stratification, the #1 cause of premature capacity loss and failure

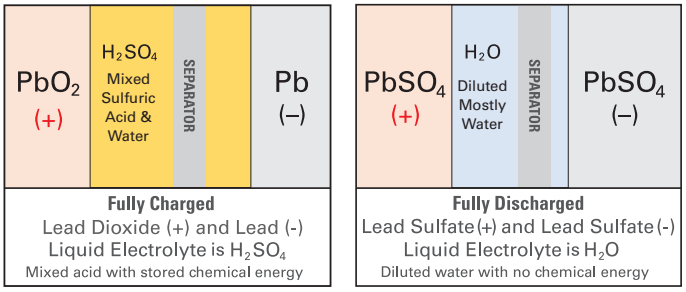
Countermeasures against acid stratification are:

- Flooded batteries with acid mixing technology installed
- AGM or GEL batteries built with internal acid immobilization technology
- Externally added battery sustaining technologies
- Regular charging of all batteries with high-quality multi-stage chargers
- Changing to lithium battery technology that does not suffer from Acid Stratification

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

The discharge and charge process first cause the expansion, then contraction of the positive **(+)** active material. Expansion occurs in the plane (height and width) of the plate as the grid is pushed/ stretched by corrosion processes (heating and cooling) over time, and in its thickness as the plates active material is forced to expand to accommodate the lead sulfate ("$PbSO_4$") with each discharge.

The illustration below represents the electrochemical reactions in the battery charge and discharge process.



The volume increase of the positive **(+)** lead dioxide ("PbO_2") plate during discharge and 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 reverses the reaction and restores the positive plate to almost its original volume but, because of acid stratification the volume increase is over-concentrated to the lower part of the plate and step-by-step, the positive grid grows and the active material begins to shed and soften. By contrast, the negative plate does not suffer as much from permanent expansion over time because lead ("Pb") is softer and more pliable than lead dioxide ("PbO_2").

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. An old battery should simply be replaced.

If we did a tear down analysis of a newer battery showing low capacity signs, 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.

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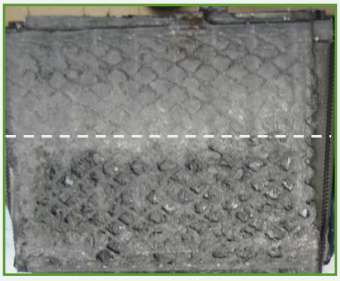
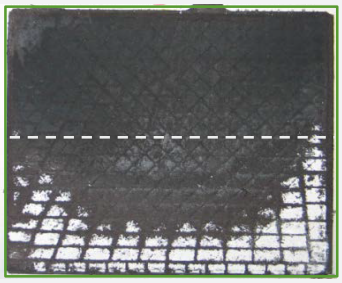


Shedding

Softening



Sulfation

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").

Since grid wires are the current pathways upon which electrical current is delivered to the starter (Cold Cranking Amps or CCA), or the pathways for electrical charge and discharge loads (current flow in Amps), 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 sulfation happen much faster at the bottom of the plate and corrosion happens faster at the top of the plate. All of the affects of acid stratification lead to premature capacity loss and early battery failure. All negative activity across the plates in a lead-acid battery are accelerated by acid stratification. The corrosion process described above can eventually manifests itself externally with mossy green/white material around the positive terminal. With age, and when viewed closely, the positive terminal bushing may also appear to be lifting out of the case.

As the positive plates heat and cool and continually expand and contract during the electrochemical discharge and charge process the positive plate groups are forced to expand putting upward pressure on the positive terminal to the point where the bond can be broken allowing gas and in extreme cases electrolyte to escape around the bushing to interact with the terminal and cable ends. In a flooded type battery this corrosive mess can also result from excess gasses escaping from the battery vents during charge.

This type of corrosive gassing is present during an equalization charge (flooded batteries only) where the voltage is driven higher for a period of time to generate bubbling within the electrolyte to cause it to mix to reverse acid stratification.

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Marine and RV/Caravan batteries often operate in a Partial State of Charge (PSOC) and may seldom receive a full charge, they are constantly deeply cycled (>50% DoD) and often left for long periods of time between use. All of these contribute to battery failure.

Battery Failure Mode: Battery Dry-Out and Thermal Runaway

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 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. Marine and RV/Caravan batteries operate in extreme temperatures, often in a Partial State of Charge (PSOC) condition and may seldom receive a full and complete charge. They are constantly deeply cycled (>50% DoD) and often left for long periods of time between use. These activities combine with the inevitable process of acid stratification to supercharge battery dry-out conditions and increase the likelihood of thermal run-away. For these reasons and others, batteries fail in Marine and RV/Caravan and applications.

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 repeated high-rate charging (such as is the case for a sulfated battery giving off a false State of Charge) 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 reaction accumulates lead sulfate (sulfation) onto the surface of the negative plate. This sulfation 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 will actually have very low capacity as expressed in Amp Hour (AH) or Reserve Capacity (RC). This false state of charge reading tricks modern charging systems into thinking the battery is more charged than it actually is which in turn leads to batteries always being in a PSOC condition, and more importantly increases alternator wear and fuel consumption in systems were the alternator is the charging source. Negative plate sulfation also decreases the charge efficiency of solar panels and generators and increases generator fuel consumption.

For Marine and RV/Caravan batteries this can pose a very inconvenient truth. While at the dock or otherwise plugged into shore power, the inverter/charger is supporting the electrical loads so it is assumed that the batteries are "good-to-go", but once away from the dock or dry camping the false state of charge indicative of battery sulfation becomes apparent in short runtimes.

Negative plate sulfation is accelerated by acid stratification. Marine and RV/Caravan batteries often operate in a Partial State of Charge (PSOC) condition and may seldom receive a full and complete charge, and they are constantly deeply cycled (>50% DoD) and often left for long periods of time between use. These reasons, combined with the inevitable process of acid stratification, accelerate premature capacity loss and battery failure.

Battery Failure Mode: Undercharging

If either the negative or positive plate is continually undercharged, a premature decline in capacity will occur because of sulfation. Permanent 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. Undercharging 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 most Marine and RV/Caravan applications.

On top of that, battery failure due to undercharging is accelerated by the affects of acid stratification. For this reason, and others discussed in this document, it is not surprising that there is a growing trend of battery related inconveniences and frustrations on the part of Marine watercraft and RV/Caravan owners, and dealers.

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The #1 killer of lead-acid batteries is acid stratification. THAT'S BAD, WE FIXED THAT!

Reversing the trend: Fixing battery related problems

It is possible to reverse the trend of declining battery life expectancy, premature capacity loss, and 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 and reduce all of the other related 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 the battery to store more energy, charging sources to work 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 it can support.

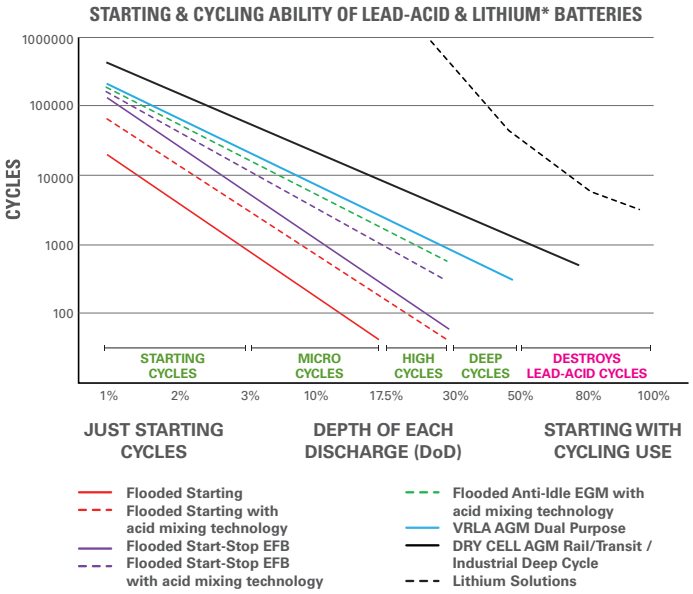
The following steps can be taken to fix the problems facing batteries in modern Marine and RV/Caravan applications, and to reduce costs associated with battery failure:

- **Step 1:** Chose a battery (batteries) sized with the capacity and technology best suited for the job.
- **Step 2:** Don't ask the same battery to do more than one job. Install battery separators with the ability to combine different battery banks in emergencies
- **Step 3:** Install battery isolators that can interrupt all parasitic draws and electrical loads when not in use.
- **Step 4:** Eliminate or reduce acid stratification to save fuel and reduce battery related expenses
- **Step 5:** Install proven technology that helps to maintain and recover battery health
- **Step 6:** Charge batteries regularly to increase battery life
- **Step 7:** Avoid prolonged use of "charging system-off" electrical loads.

Choose the Right Battery Capacity and Technology

Avoid frustration and inconvenience by properly sizing the capacity of the battery to the real electrical loads. Avoid premature battery failure by choosing the proper battery technology to match the frequency and duration of the loads.

Every cycle 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. High quality deep-cycle lead-acid batteries will maintain their original capacity for between 50 and 150 cycles before they begin to incrementally loose capacity. A standard starting battery can only be regularly discharged to <3% before it experiences negative consequences.



It is important to understand the large and parasitic loads that the battery is subject to. A high-capacity (high RC or AH) extra heavy-duty dual-purpose battery with a high cycle design can only regularly use a maximum of 30% of its rated capacity before causing incremental and permanent damage. A true deep-cycle battery should be installed when the battery is being sized with expected discharges of greater than 50% DOD.

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

- Countermeasures against acid stratification by introducing acid mixing technology, acid immobilization technology or high-quality OEM grade Lithium battery technology that does not suffer from acid stratification
- Deep and micro-cycle capability through enhanced active material ratios, densities and alloys (less of a starting battery and more of a cycling battery) or choosing safe and robust Lithium battery technology solutions that will dramatically increase battery life and charging source efficiency over even the highest quality lead-acid technologies

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- Lead-acid batteries with glass mat separators that increase cell compression and reinforce active material against shedding caused by acid stratification and vibration.
- Lead-acid batteries with enhanced negative plate (EFB Dual Purpose) performance via increased carbon and / or other additives that help to prevent negative plate sulfation
- Lead-acid batteries with element bonding that protects against positive grid growth and vibration
- Lead-acid batteries with anchor bonding that protects against shock and vibration or lithium battery solutions purpose-built with automotive grade mechanical designs
- 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).
- High quality lithium solutions can be engineered and purpose-built for either high temperature or low temperature operational excellence. Which do you need?

Do I need to do anything special when installing lead-acid batteries on or near water?

Installing batteries in marine applications (especially salt water) requires some special attention. The cables used should be marine approved and should be tinned copper. If you use any other type of cable, be prepared to spray or coat the cable ends and all other connections with silicone or another type of grease such as Vaseline. Use silicone lined heat shrink tubing to cover terminal connections to protect against corrosion. The main concern is obviously keeping the marine atmosphere away from any exposed terminals or connections.

Do not allow battery electrolyte to mix with salt water. Even small quantities of this combination will produce chlorine gas that can cause harm or death.

A word about acid mixing and acid Immobilization

Acid mixing technology uses components that mix the acid to equalise the acid's specific gravity evenly throughout the battery's cells. Acid immobilization technology uses absorbent glass-mat material or silicate Gel to absorb or suspend all of the acid to slow stratification in the battery's cell ("AGM" and "GEL" 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 or GEL batteries because acid mixing technology defeats acid stratification and acid immobilization technology slows (but does not fully stop) the stratifying effect of gravity on battery acid.

Can I use my Lithium battery for starting applications?

High-energy lithium batteries are design for deep-cycling and are "NOT" generally" suitable for starting use! You should be wary of claims made by companies selling lithium batteries as starting batteries or as dual-purpose starting/cycling batteries.

- It is "extremely" unlikely that any lithium battery offered for sale in the market as a "primary" starting battery will have the required safety certifications you should be looking for when making your buying decision! For lithium batteries to pass the required safety and performance certifications, stringent tests are performed on the battery's Battery Management System (BMS). The BMS is essentially an advanced protection system that prevents the battery from being operated outside of its safe limits.
- For a high-quality high-energy deep-cycle lithium battery to work as a starting battery the BMS high-current protection circuits would need to be switched off.
- Actual built-for-starting-purposes lithium batteries use "high-power" lithium cell technology. They are usually low capacity (30Ah to 50Ah) batteries that can be discharged at 20-30 times the their rated capacity. When installed they are normally in places that are not exposed to high temperatures (trunk or under a seat).
- No matter what anyone tries to tell you, high-power lithium technology is not suitable for deep-cycle applications. High-power lithium technology does not handle high temperatures well, and high-power lithium technology does not provide the long life expected of advanced technology buyers in deep-cycle applications.
- A low-quality lithium battery offered as a starting battery might only have a protection circuit (PCS) that does not even try to protect from over current events. Do not buy this battery!
- Robust high-quality, high-energy and deep-cycle lithium technology degrades quickly if discharged at high C Rates (current) such as is required by a starting battery.
- High C Rate high-power Lithium technologies (10xC or 20xC) degrade quickly at the high temperatures typical of under the hood or engine room installations, and they do not have the high-cycle life that deep-cycle high-energy battery buyers are looking for.
- Without highly engineered electronic operating controls, such as in OEM automotive applications, High C Rate lithium technologies are not safe enough for use in most applications. When used in OEM applications, sophisticated temperature management systems are included.
- If you wish to use your high-quality high-energy deep-cycle lithium battery for starting, confirm the peak starting current (peak starter draw) is less than the peak surge current rating of the lithium batteries BMS. If you confirm this to be true, you are good to go. NEVER DISABLE A LITHIUM BATTERIES BMS PROTECTION CIRCUITS.
- Do not consider using the lithium battery as your primary starting battery if you have large or hard starting engines.
- Do not consider using the lithium battery as your primary starting battery if it will be operating at high temperatures.

WARRANTY. To avoid damage to your vehicle or vessels alternator and potentially other equipment on the electrical circuit, you need to take special precautions if you intend to install the lithium battery in the vehicle or vessels electrical system and intend to charge it with the vehicles alternator.

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

Acid stratification happens naturally in all lead-acid batteries and dramatically affects charging efficiency. Acid stratification causes engine alternator wear and increased fuel costs in all types of gas or diesel engine supported charging sources such as main engine alternators or back-up generators. Highly equipped Marine, RV/ Caravan and Tiny Home batteries experience accelerated acid stratification. Acid stratification is application related and is not a battery defect, but the impacts of acid stratification put strain on charging sources and represent the largest contributor to lead-acid battery failure.

Eliminating or reducing acid stratification helps to sustain a lead-acid battery's dynamic charge acceptance (DCA), improve its active material utilization, and prevent premature loss of performance and life. Higher DCA allows more energy to be recovered and stored faster allowing charging sources to work more efficiently and batteries to support electrical loads for longer periods of "no-charge source" operation. Efficient alternator operation lowers the alternator burden on an engine, improving fuel efficiency and lowering CO2 emissions. Generators are designed to work under a full-load and are not efficient if they are often free-wheeling.

Solar panels are not as efficient as alternators, generators or AC charge sources so it is really important that the batteries charge efficiency is maintained as high as possible (internal resistance is as low as possible) when being charged by solar panels. 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 it can support.

Typical lead-acid batteries start with a high DCA but, this degrades rapidly because of acid stratification and PSOC use, stabilizing within a few short months at around 30% to 50% of original specifications. Lithium solutions can have a charge efficiency of over 99% at low charge/discharge rates. Depending upon the age and technology of the lead-acid battery, lithium batteries can be 60% to 70% more efficient, will reduce main engine and generator operating hours and require fewer solar panels versus lead-acid batteries.

Flooded lead-acid starting batteries. They are the most popular lead-acid battery type for gasoline inboard and outboard motors. Heavy-duty commercial flooded batteries are required for larger higher compression gasoline or diesel engines. They should be of a sealed maintenance free design to avoid acid spilling through the vents, are often operated under the most extreme temperature conditions and must be able to consistently deliver high cold cranking amps (CCA). Flooded starting battery failure is most commonly caused by the affects of acid stratification in combination with long storage periods, extreme temperatures and destructive vibration. Starting batteries are not designed for regular discharges of more than 1% to 3% DOD.

MIXTECH EMX Marine/RV Starting batteries combine patented MIXTECH technology with expanded metal grids and advanced active materials to produce a superior starting battery that uses the natural movement of the vessel or vehicle to keep the acid throughout the battery in constant circulation as a countermeasure against acid stratification, the #1 cause of performance loss and battery failure.

Enhanced flooded dual-purpose lead-acid batteries. To avoid acid spilling through the vents, the batteries should be sealed maintenance-free design, and must be able to consistently deliver reasonable cold cranking amps (CCA), operate in high and low temperatures and withstand vibration. When the engine is off, Reserve Capacity (RC) is required to support moderate parasitic loads and electric loads such as electronic equipment, radios, house lights, bilge pump, small inverters, etc. From low to high, dual-purpose batteries can be designed with micro-cycle (17.5%DOD) or high-cycle (30%DOD) life characteristics while still providing the cold cranking ability necessary to start engines. Flooded dual-purpose battery failure is most commonly caused by the affects of acid stratification in combination with long periods of inactivity, extreme temperatures and destructive vibration.

Typically, the higher the cycle life design, the lower the CCA rating will be in these batteries. A battery offered with high CCA, and high RC "and" long life cycles should be viewed with suspicion. To achieve long cycle life, the battery must be designed with thick grids and a lot of high-density active material which restricts the number of plates that can fit in the battery's cells. CCA is wholly the result of the total amount of plate surface area so fewer plates mean lower CCA

MIXTECH EFB Marine/RV Dual Purpose batteries combine the latest dual-purpose Enhanced Flooded battery (EFB) breakthroughs with MIXTECH acid mixing technology that uses the natural movement of the vessel or vehicle to keep the acid throughout the battery in constant circulation as a countermeasure against acid stratification.

Flooded Deep-cycle lead-acid batteries. These must be able to consistently deliver deep-cycle reserve capacity and operate in high and low temps and withstand vibration. These batteries require regular watering and maintenance, and without the purchase of special vent caps spillage through the cell filler vents cannot be prevented if the battery is moving. High quality flooded deep-cycle batteries have been around for a long time

and are an excellent deep-cycle (50% to 80% DOD) choice for stationary applications that are well ventilated and where the owner enjoys battery maintenance. To achieve reasonable life cycles manufacturers, recommend a maximum 30% to 50% allowable DOD for deep-cycle applications. Flooded deep-cycle battery failure is most commonly caused by the affects of acid stratification in combination with extended PSOC operation, long periods of inactivity, extreme temperatures, poor watering and maintenance practices and destructive vibration in mobile applications. Equalization charges are recommended to mitigate the affects of acid stratification in flooded deep-cycle batteries.

As the Lead to Lithium transition gains momentum, Discover is phasing out the production of flooded deep-cycle batteries.

VRLA AGM dual-purpose lead-acid batteries. For leisure Marine and RV/Caravan applications with reasonable CCA power and moderate energy demands. These batteries are safe sealed nonspillable maintenance-free and have a low self-discharge rate making them ideal for seasonal use applications. To achieve reasonable life expectations general purpose VRLA AGM batteries should not be installed in systems that will regularly be discharged to more than 30% DOD or periodically discharged to more than 50% DOD. VRLA AGM batteries are widely available in the market.

Discover branded VRLA AGM batteries are general purpose high-cycle batteries that can be used to provide adequate CCA and good RC power for accessories and electronics. Discover branded VRLA AGM dual purpose batteries are safe Sealed Nonspillable maintenance-free and have a low self-discharge rate. Discover VRLA AGM batteries incorporate acid immobilization technology as a countermeasure for acid stratification.

VRLA *DRY CELL* AGM or *GEL CELL* deep-cycle lead-acid batteries. These are heavy-duty batteries that dramatically outperform traditional flooded deep-cycle and general-purpose AGM, and Gel high-cycle batteries and an exceptional choice for deep-cycle applications, and can easily provide moderate starting performance. AGM and GEL deep-cycle batteries should be tolerant of a wide ambient temperature range, vibration and Partial State of Charge operation and be designed for regular discharges of more than 30% to 50%.

Discover VRLA ***DRY CELL Marine/RV*** and ***GEL CELL*** batteries are industrial deep-cycle traction batteries and a #1 trusted choice of OEM builders and vessel and vehicle owners around the world. Designed for regular discharges of 50% to 80% DOD, they are purpose-built with the highest quality flame arresting valves and independently tested and certified as safe, no-gas, no-spill, require no water, and are sealed and maintenance-free.

DRY CELL batteries can easily support dual-purpose starting performance particularly if more than one battery is installed in parallel which is most often the case. DRY CELL and GEL CELL batteries incorporate acid immobilization technology as a countermeasure for acid stratification.

Lithium Battery Solutions. Lithium cell technology represent a breakthrough for all-round improved performance and life versus lead-acid technology for deep-cycle and house load applications. The charge and discharge efficiency of lithium cell technology makes it feasible to rely on solar panels as a "meaningful" main charging source. For these reasons and others, the transition from Lead to Lithium is here to stay. But just as with all battery technology there are a wide range of Lithium cell technologies to be considered, each with there own more or less positive benefits for any one particular application. As important as it is to understand this new cell technology, it is equally important to understand the overall inherent quality of the finished battery product and the design philosophy of its builder. To be sure, there will be lithium batteries falling from the skies over the coming years as traders try to flood the market to take advantage of this new opportunity. Visit our website for more in-depth information on everything to do with lithium solutions.

Discover lithium solutions are purpose-built. From case, cover and terminal designs and layouts, to the choice of the most intrinsically safe cell chemistry for each and every application; from cell supplier audits to internal BMS Software and BMS hardware development; from independent destructive testing to outside safety certifications our Design for Excellence approach guarantees we purpose-build and match the right battery, with the right benefits and features to the right application. Just as with lead-acid battery technology there is no one size fits all lithium cell technology. Discover's Lithium solutions do not suffer from acid stratification. Discover's Lithium solutions:

1. Prefer to be operated in a Partial State of Charge condition
2. Suffer no negative consequences from rarely receiving a complete charge
3. Can be constantly cycled without negative consequences
4. Can operate at extreme temperatures (hot or cold with little capacity loss)
5. Because Discover's lithium solutions incorporate smart management technology they can be professionally integrated with inverters, chargers, charge controllers, generators, and solar panels to improve round trip efficiency (charge / discharge) by up to 67% versus lead-acid batteries. Smart Integration with remote keys, SoC gauges and more can making a good system great.

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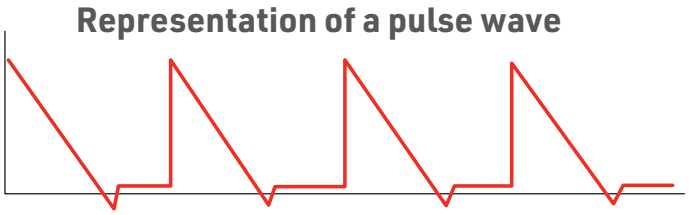
Discover 12V, 24V, 36V, and 48-volt lithium $LiFePO_4$ battery solutions for Marine and RV/Caravan applications can be paralleled to increase capacity. Discover lithium batteries can last a lifetime of up to 5000 to 6000 cycles when charged and discharged at .5C to 90% DoD and have an average life-time round-trip-efficiency (RTE) of >95%. Lithium battery RTE can be as much as 67% more efficient than lead requiring less generator time or less solar panels to charge. Lithium batteries can be opportunity charged and used constantly in a PSoC condition without negative consequences and do not need to be recharged to 100% State of Charge (SoC) after each discharge. In fact, battery life increases significantly if the battery is cycled between 15% and 85% SoC. With a correctly sized lithium battery charger with, or without integrated communications, batteries can be charged from 0-95% in as little as one hour without needing a cool down period. Discover ***Lithium PRO*** series models include Battery Management System (BMS) controlled internal heating for use in cold temperature environments. Discover's ***Lithium BLUE*** series Bluetooth app provides access to battery State of Charge, Voltage, Current, and temperature status.

Reversing the Trend: Install Cost Effective and Proven Battery Sustaining Technology!

Proven high-frequency pulse wave technology exists for use with lead-acid batteries 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-usable 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). Utilizing pulse wave technology along with proper charge maintenance practices is a proven way of eliminating premature capacity loss, battery failure and helps to reduce battery related costs. 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.

The Discover organization has deployed pulse wave technology around the world for decades and testify to you that this technology works. We are not sure about some of the products hitting the market recently as copycats but you are free to contact us for our definitive recommendation on product, we "know" has worked for us and our customers for decades.



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.

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

You should be checking and recharging batteries at least every three months in your Marine or RV/Caravan vessel or vehicle. If you are using them regularly you should do it more often when opportunities like overnight stops, weekend breaks, or when inspections/repairs are happening. Instituting a practise of top charging batteries (whenever possible) using an external charger if you need to, will not only reduce costs associated with premature battery failure but can also lead to reduced fuel consumption of 1.5% to 3% for your generators and main engines.

Buy a good multi-stage temperature compensating charger! 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. 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 Partial State of Charge 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 vessels or vehicles will typically only charge the bank up to 90% due to the 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 higher speeds mainly due to fan resistance. Combined, it is almost impossible for the alternator alone to fully charge batteries to eliminate Partial State of Charge conditions.

A generator is the combination of an engine with an electric generator (often an alternator) to generate electrical energy.

Generators are used in places without connection to a power grid, or as emergency power-supply. Proper sizing of diesel generators is critical to avoid low-load or a shortage of power. Generators are more efficient at full load. If batteries do not maintain a high level of dynamic charge acceptance generators will spend a lot of time running, causing component wear and increased fuel costs.

Conclusion

The added technology and features in modern Marine and RV/Caravan applications will continue to drive the need for advanced battery technology. Today more and more electrical and electronic loads are putting ever greater strain on the battery. Batteries represent the heartbeat of massive electrical systems that are always being called upon for more starting, more cycling, and to generally provide more power output.

As laid out in this paper, there are steps that Marine Watercraft and RV/Caravan owners can take to greatly reduce battery related inconveniences and frustrations but the first step is to:

Improve your understanding of how batteries work and fail and how emerging battery technologies and improved maintenance practices can reverse the trend of increased costs related to premature performance loss and battery failure.

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