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THE SWITCH:

Why Equipment Manufacturers Are Ditching Lead-acid Batteries for Smart Lithium Solutions

If you're reading this white paper, you're probably sold on the value of battery power, but you may be navigating a host of choices when it comes to what type of battery makes the most sense for your application. Do you turn to the familiar power source of lead-acid that gets the job done but can be cumbersome due to its weight, high internal resistance and it's connectivity limitations? Or do you invest in a lighter, more intelligent Lithium-Ion battery that can provide superior performance over the lifetime of your equipment?

The answer may seem simple at first but it's one original equipment manufacturers (OEMs) across industries are grappling with as they balance cost and performance factors against the growing demand for electrified equipment. To help OEMs navigate this choice, we're taking a deeper look at lead-acid versus Lithium-Ion and why smart Lithium-Ion batteries ultimately win as a durable and sustainable power source that works across a range of applications.

This white paper will explore everything you need to know about making the switch from lead-acid to smart Lithium-Ion, including:

- Battery Life & Usable Power
- Maintenance
- Discharge Cycle
- Safety Features
- Advantages of a Battery Management System

LEAD-ACID BATTERIES ARE DURABLE. BUT ARE THEY "DUMB?"

Lead-acid batteries have long been a go-to choice for OEMs due to their low cost and high surge currents. Sometimes referred to as "dumb batteries," lead-acid batteries don't require sophisticated electronics to function and tend to be less expensive upfront. They can also tolerate a lot, from short-circuiting to "dirty" power. While these lead-acid advantages are obvious and compelling, OEMs need to be aware of the technology's limitations and where Lithium-Ion outperforms its lead-acid counterpart.

BATTERY LIFE AND USABLE POWER

When comparing the overall battery life of a lead acid battery to a Lithium-Ion battery, Lithium-Ion has a much larger usable range in terms of capacity. After 500 cycles, a lead-acid battery is down to about 80% capacity. It takes 2,000 cycles before a Lithium-Ion battery is at the same 80% capacity.[1] Another way to look at this difference in capacity is that Lithium-Ion offers a much longer lifespan and faster, more efficient charging over the life of the battery. This creates an opportunity for OEMs looking to make the switch from lead-acid to Lithium-Ion to get more usable power by switching to a battery that is lighter and packed with more power in a smaller footprint. When switching to Lithium-Ion, OEMs may be surprised to learn that they don't need the same rated capacity [Ah] of Lithium-Ion as they do with lead-acid in order to provide enough power and runtime to meet their application's requirements.

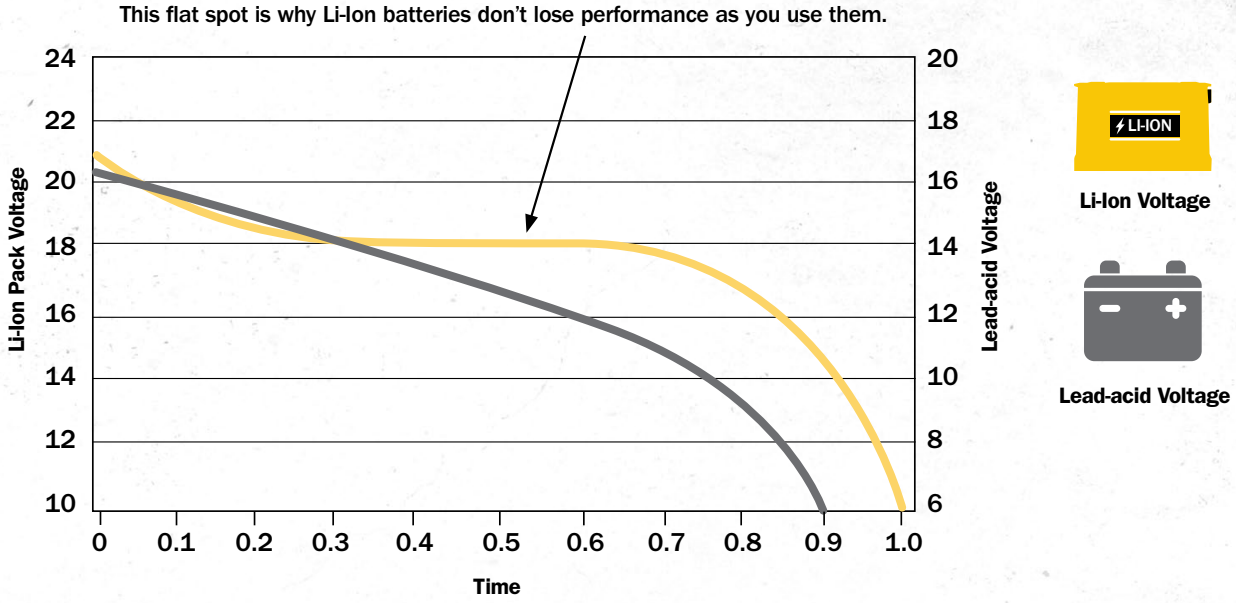
MAINTENANCE

A common advantage often associated with electrified equipment is the low-to-no maintenance that's needed. However, a lot of that depends on the type of battery being used. There is more room for error with lead-acid battery maintenance. One way lead-acid battery maintenance significantly differs from Lithium-Ion battery maintenance is that lead-acid batteries sometimes have to be "watered." The plates in some lead-acid batteries need to be continuously soaked in a liquid mixture of sulfuric acid and water to operate correctly. Over time, the water portion of the mixture will need to be replenished. Overwatering can significantly damage the battery by diluting the electrolyte solution or causing the battery to overflow, while not watering at all can lead to performance issues and shortened replacement intervals. This level of maintenance can be burdensome and time-consuming for end users who may not be familiar with watering best practices — especially if the equipment they are using is rented.

An OEM can't just replace a lead-acid battery with any Lithium-Ion battery and expect all of these problems to be solved. Lithium-Ion batteries are famous for their no-maintenance ease, but not all Lithium-Ion batteries are created equal. An important but often overlooked distinction is the crucial role a battery management system (BMS) plays in a battery's optimized performance, safety and overall battery life. A well-designed BMS will monitor the voltage and temperature of each cell module assembly (CMA) to make sure it's operating within the nominal range for safety. BMS technology also shares the battery's power and energy utilization as well as the battery's state of health.

LEAD-ACID VS. LITHIUM-ION DISCHARGE[2]

This graphic illustrates the voltage difference between lead-acid and Lithium-Ion over the time of a discharge cycle. A constant voltage brings a constant current to provide continuous power. If voltage is dropping steadily, current has to increase to make up for it in order to provide the same amount of power. Notice how much voltage drops off with lead-acid as a battery gets closer to charging. Lithium-Ion, on the other hand, has a very consistent voltage right up until it needs to be charged.



WHAT MAKES A BATTERY SAFE?

Addressing concerns regarding the safety of Lithium-Ion batteries is paramount when comparing lead-acid to Lithium-Ion. If one of the reasons you're on the fence about making the switch to Lithium-Ion is safety concerns, know that a lot of strides have been made in enhancing safety features in batteries to minimize some of the more common issues.

Let's take a look at the different levels of safety that can be built into a Lithium-Ion battery to ensure maximum protection against potential hazards.

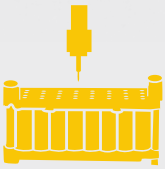
LEVELS OF SAFETY

Cylindrical cells

Benefit: No thermal expansion, largely predictable reaction to abuse, smallest potential energy unit.

An alternative: Pouches

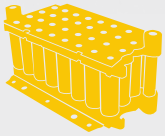
Wire bonding



Benefit: Each cell connected with individual fuse, removing a failed cell electrically from the pack.

An alternative: Resistance welding

CMA modules



Benefit: Smaller unit to have finer resolution on temperature, currents, resistance, voltage within the pack. Serviceable.

An alternative: Single module

1/4 in. aluminum tier plates

Benefit: Helps to limit propagation if an issue occurs.

An alternative: No plate, sheet metal at best.

Redundant contactors

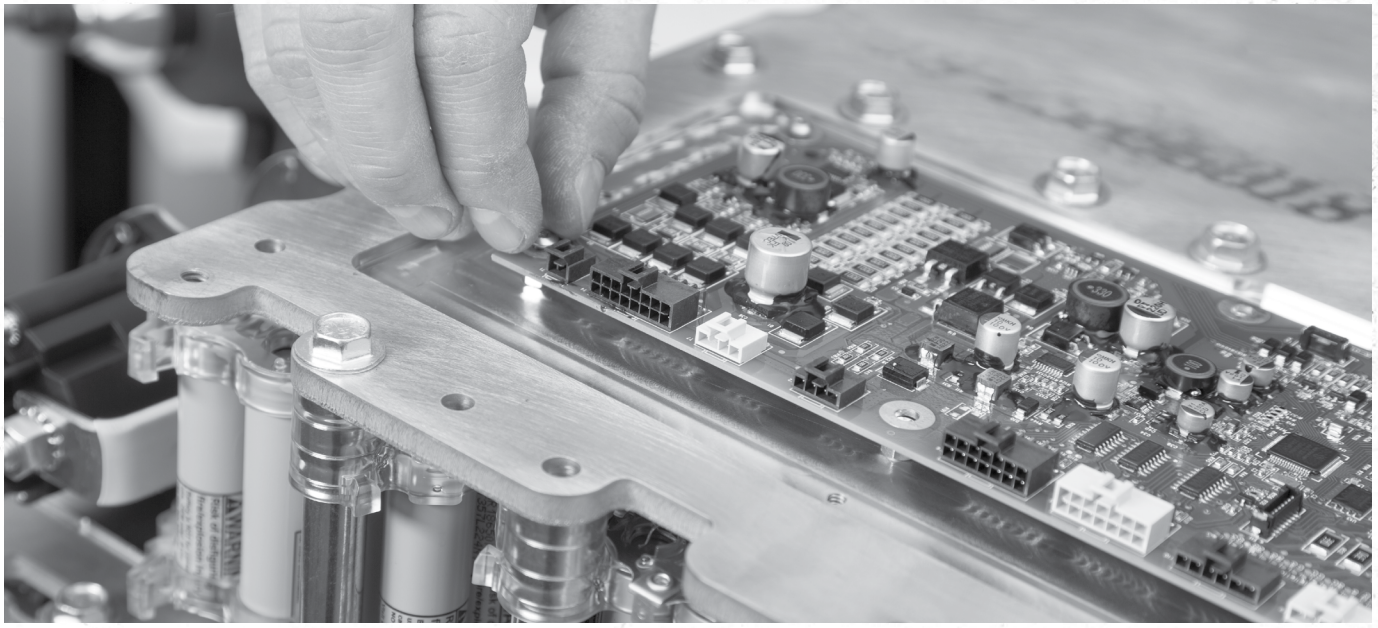
Benefit: Terminals not live until BMS confirms and closes. Second contactor as backup for potential of failure in closed position.

An alternative: No contactors

Onboard BMS

Benefit: Protection from over voltage, over temperature, or over current events which could lead to pack failure. Communicates with application to avoid inadvertent shutdowns.

An alternative: Master BMS



SAFETY

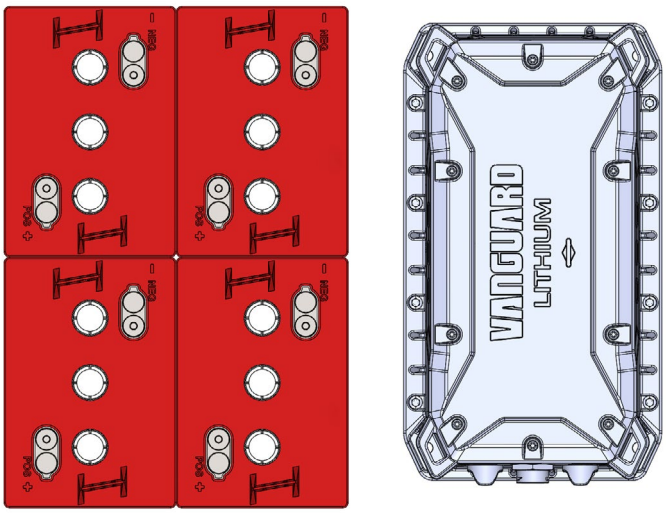
Another area to consider when comparing lead acid to Lithium-Ion is the potential for misuse. 30% to 40% of Lithium-Ion battery fires are caused by external factors, such as short-circuit, overcharge and over-discharge.[3] The risk of thermal runaway in a Lithium-Ion battery is greatly reduced when a smart BMS and current interruption devices such as fuses, contactors or field effect transistors are built into the battery pack. Similar to how a physician uses a patient's symptoms to diagnose and treat their illness, a BMS can diagnose conditions within the battery pack and make decisions to optimize a pack's performance and maintain safe operation of the pack. A well-engineered BMS measures the temperatures of cells throughout the pack to ensure that no cells are getting too hot. To make sure a battery stays within its operating range, a good BMS is constantly monitoring and measuring not only the temperature but also the charge and discharge currents and the voltages of each individual cell bank. These data points can help a BMS provide high-temperature shutdown capabilities and assist with smarter charging practices.

If you're an OEM seeking a Lithium-Ion battery supplier, it's important to partner with a manufacturer that adheres to stringent safety standards and has comprehensive protection systems in place to reduce safety and performance risks.

LEVELING UP LITHIUM WITH SMART CAPABILITIES

We've established that Lithium-Ion is both more capable and more efficient than lead-acid. Lithium-Ion batteries feature a high energy density and low self-discharge, meaning they offer a much larger usable range in terms of capacity compared to lead-acid batteries. What truly sets Lithium-Ion batteries apart are the smart capabilities enabled through a well-designed BMS.

Smart Lithium-Ion batteries bring a wealth of capabilities to an application, including temperature monitoring, data on power utilization and voltage, the ability to integrate with Internet of Things (IoT) devices and more. OEMs can leverage these insights from the BMS to get the full value out of their battery and find ways to optimize their machine's performance for the best possible return on their investment.



PACKED WITH POWER
Li-Ion batteries are often more energy dense than lead-acid batteries You can get more power in a smaller, simpler package.

THE RESULTS: MAKING THE SWAP FROM LEAD-ACID TO SMART LITHIUM-ION

The proof is in the numbers. See the results of a recent repower Vanguard did where a lead-acid battery system in a lightweight electric vehicle was replaced with a Vanguard™ Commercial Lithium-Ion Battery.[4]

OLD BATTERY SYSTEM

- (6) 8V lead-acid batteries in series for 48V
- Rated energy:
  - 1.51 kWh per battery
  - 9.06 kWh total
- Weight
  - 63 lbs per battery
  - 378 lbs total

NEW BATTERY SYSTEM

- (1) 48V 5 kWh Vanguard™ Lithium-Ion battery*
- Rated energy:
  - 5.09 kWh
- Weight
  - 110 lbs
  - **Note:** The new 5 kWh diecast Vanguard batteries are even lighter.

**Total energy measured using a 0.2C discharge per IEC 61960-3:2017*

RESULTS

- 70% reduction in battery weight
- 18.6% reduction in total vehicle weight
- The weight reduction combined with the higher depth of discharge and energy at higher discharge rates resulted in runtimes being about the same.

VANGUARD ADVANTAGES

With the variety of Lithium-Ion battery solutions on the market today, it's hard to know which solution is leading the pack in performance, power and integration capabilities. At Vanguard, we pride ourselves on not only knowing batteries but also understanding the applications our batteries are going into. Vanguard™ batteries are constructed with multiple protective features and tested to withstand harsh conditions, including extreme temperatures, impact, vibration, moisture and dirt. Another distinguishing feature of our Lithium-Ion solutions is the integrated BMS that monitors, controls and protects the battery to help prevent misuse and abuse, safeguarding your investment.

Our Power Application Center engineers are always thinking of ways to better power applications as the industry continues to embrace electrification. When you work with Vanguard, you get the support of expert engineers who leverage their integration expertise to help you bring a reliable electrified product to market. The powerful performance of our batteries in the field has given us both the data and confidence to extend our commercial limited warranty to **eight years** on our entire lineup of batteries. This serves as a further testament to how confidently we stand behind our batteries and the value and support we aim to provide for our customers.

Ready to leave lead-acid behind?

Fill out the contact form on our website to connect with our team of experts and see why OEMs across industries trust Vanguard® smart Lithium-Ion power to get the job done.

Sources

[1] Vanguard® Charged: Lead-acid v. Lithium-ion Batteries
[2] Data provided by the Vanguard Power Application Center
[3] Lithium-Ion Battery Fire Statistics: Market Report & Data
[4] Data provided by the Vanguard Power Application Center