

7 THINGS OEMS MUST KNOW ABOUT BATTERIES AND ELECTRIFICATION

Whether stricter emissions regulations, high fuel costs or operator comfort is the tipping point for your customers, the demand for battery-powered equipment keeps growing. As an OEM, there is a lot to consider when selecting electrification power sources — especially when the design of batteries can vary greatly. As the battery power application expert, Vanguard® has the know-how to help give your machine the edge with electrification. We're here to help you make an educated choice with seven basics you need to know when choosing battery power.

1 THE FOUR MAIN TYPES OF RECHARGEABLE BATTERIES.

Lead-acid is one of the most common types of battery in industrial and commercial applications. There are two main types: flooded, which requires maintenance, and sealed, which does not. They're inexpensive and widely available, but they're also heavy. And they have a much shorter lifespan than other types of batteries.

Nickel-cadmium is another type of rechargeable battery, commonly found in electronics. It has a high temperature tolerance, fast charging, and is relatively inexpensive. However, these batteries are not as powerful as the new nickel-metal hydride batteries, and they suffer from self-discharge issues.

Nickel-metal hydride is a newer type of rechargeable battery typically used in electronics and some automotive packs. It does have a higher capacity than nickel-cadmium and lead-acid batteries and a lighter weight, but it is also expensive and has a high rate of self-discharge.

Lithium-ion is a popular choice for many different applications. It has a much higher energy density than other types of rechargeable batteries. It also has a lower self-discharge rate, a longer life and a lighter weight. However, it is a little more expensive than a lead-acid battery.

2 THE TOP ADVANTAGES OF LITHIUM-ION VERSUS LEAD-ACID.

Energy density. Lithium-ion has a much higher energy density than lead-acid, so you get more energy in the same amount of space, or for the same amount of weight — which is a big plus for a portable application.

Depth of discharge. Lithium-ion has a much greater depth of discharge than lead-acid without suffering a memory effect, which is a loss of capacity due to discharging the battery beyond its practical, usable capability.

Self-discharge rate. Lithium-ion has a much lower rate of self-discharge than lead-acid. As lithium-ion runs, you get

a longer period of consistent voltage versus lead-acid. This means that as you run your application, the motors run more consistently. With a lead-acid battery, as the application runs longer, the voltage drops more quickly, and the motors turn more slowly.

3 THE THREE MAIN TYPES OF CELLS FOR LITHIUM-ION BATTERIES.

Cylindrical cells are a very cost-effective, energy-dense way to add power to a pack, and allow the addition of safety features like thermal protection and current interruption devices. Vanguard chooses cylindrical cells for our packs, since they offer the best mix of safety, cost and performance.

Pouch cells are another type of common cell. With a flexible outer coating, pouch cells allow for a lightweight, easily adaptable cell that can fit into the available space — but they can have issues with expansion due to aging internal gas development.

Prismatic is a compromise to a pouch cell that adds a rigid metal shell for safety and improved energy density form factor, but this adds quite a bit of cost.

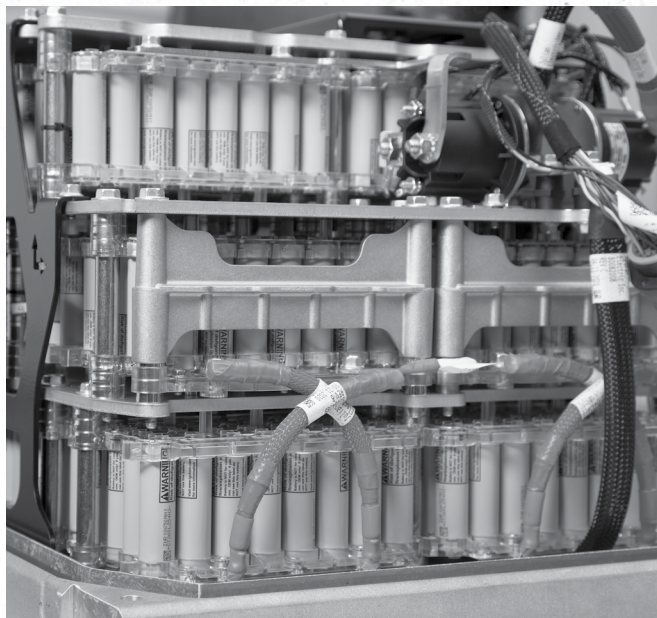


4 DIFFERENCES IN LITHIUM-ION CELL CHEMISTRY.

The chemistry of the cell affects the performance of the battery pack. A chemistry chosen for higher power might reduce cycle life, where a longer cycle life chemistry might result in lower power.

Nickel, manganese, cobalt is a good mix of power, weight and energy density — which makes it great for portable applications. That's why we use it in our battery packs.

Lithium-ion phosphate (LFP) is a topic of discussion, especially in the automotive space. There are trade-offs in power and energy density due to higher weight with LFP cells — making them better-suited for applications where weight is not critical, such as stationary applications.



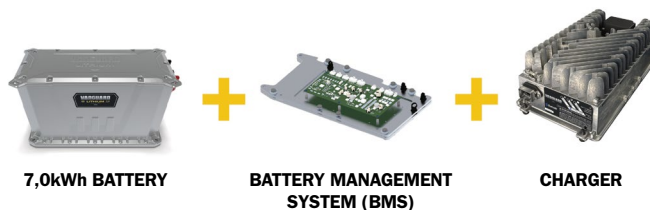
Cylindrical cells in a Vanguard Lithium-Ion commercial battery.

5 HOW TO DETERMINE BATTERY CELL DIMENSIONS.

One of the common terms you'll hear when discussing cells is an 18650 or 21700 cell. What does that number really mean? It describes the diameter and height of the cell in millimeters. So, a 21700 cell is 21 mm wide by 70 mm tall.

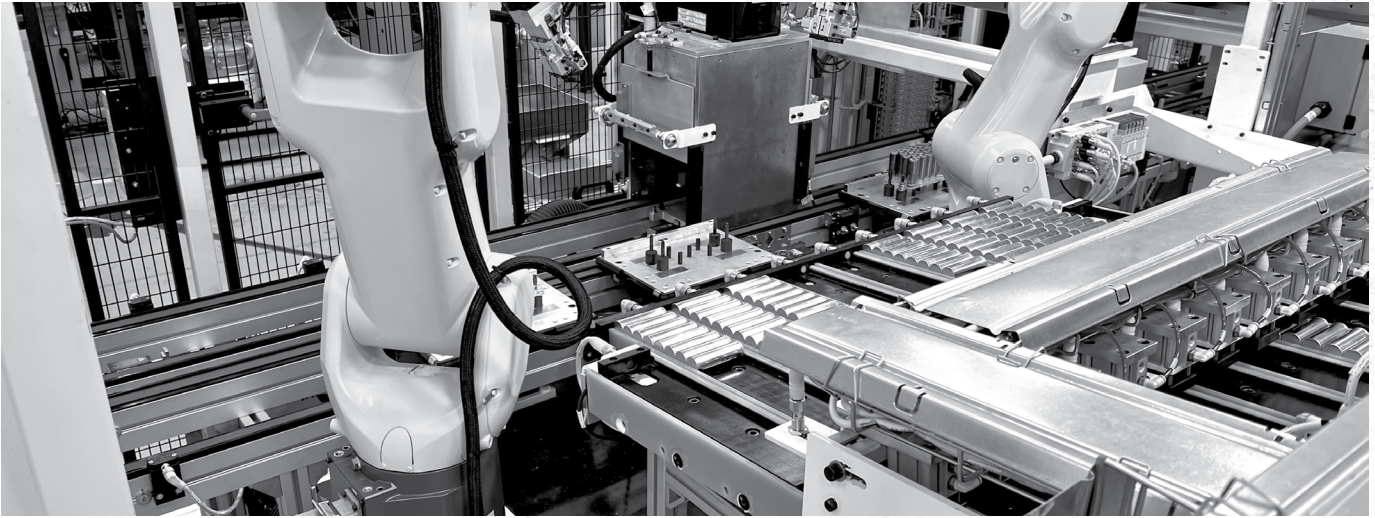
6 WHAT VANGUARD DOES DIFFERENTLY TO MAKE A SAFE AND EFFECTIVE BATTERY.

Here's why you can feel confident using Vanguard battery packs and know that you'll have a safe battery for your application.



More than a battery pack. This flexible, integrated system includes the battery, an integrated Battery Management System (BMS) and a charger. With all three components, Vanguard offers you a very flexible, easy-to-integrate solution for your application.

Built-in features to provide the highest levels of safety. We use cylindrical cells that limit thermal expansion and have predictable failure behavior. Then we wire bond those cells so each cell is connected with an individual fuse that will remove it from the pack if there's a failure. Cell Module Assembly (CMA), made up of smaller units,



makes it easier to understand temperature changes in the pack, resistances and voltage changes. The choice of CMA creates a serviceable pack, as well. There are quarter-inch aluminum tear plates throughout the pack that prevent propagation and ensure any issues are contained inside the pack. Our design includes redundant contactors, so the terminals on the pack are not live until the BMS confirms and closes the second contactor as a backup for any potential failure in the closed position. Finally, our onboard BMS monitors for thermal runaway and makes sure each pack is performing the way that it should.

Unique, swappable design. Vanguard Lithium-Ion 48V 1.5kWh* Commercial Batteries are quick and easy to change out on the jobsite — providing unmatched power, emissions-free operation, virtually no maintenance and lower total cost of ownership. Designed, engineered and manufactured in the USA, our batteries are rigorously tested and validated to operate in any environment. And because they are set up for optimized network communication with the product and the internet via an IoT device, our commercial batteries can be monitored and controlled remotely.

**WE'RE HERE TO
HELP YOU MAKE AN
EDUCATED CHOICE
WHEN CHOOSING
BATTERY POWER.**

7 HOW VANGUARD APPLIES BATTERY POWER TO YOUR EQUIPMENT.

Vanguard takes the guesswork out of electrification with adapted battery power that's proven to perform. Our Power Application Center will work with you to understand the unique needs of your machines, and then deliver a Vanguard Commercial Lithium-Ion Battery Pack from our 1.5kWh* – 10kWh* capacity lineup that seamlessly maximizes your equipment's performance, efficiency and reliability — and ultimately elevates your customers' experience and your brand.

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



Explore Vanguard batteries, view our educational Battery 101 videos or start the conversation with our electrification experts at: vanguardpower.com.