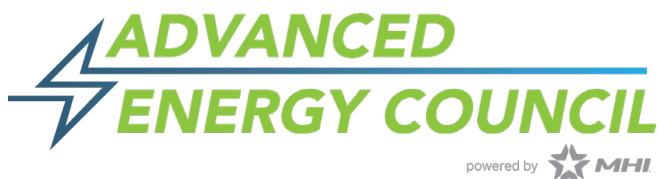


Li-ion Battery
Lithium

Customer Technical Reference

Lithium-Ion Battery Safety Guidelines & Best Practices for Operation in Electric Lift Trucks

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1 Introduction

Rechargeable Lithium-Ion batteries are an established and popular power source for consumer electronics, tools, appliances, and now passenger cars. One market which stands to benefit from the cost, efficiency and performance advantages of lithium-ion batteries is that of material handling equipment.

This document presents an overview of the Lithium-Ion platform, including advantages and challenges of Lithium-Ion systems.

2 Glossary of Abbreviations

This overview document includes a number of abbreviations common to the Lithium-Ion and rechargeable battery industries. These are defined throughout the document and provided in the table below for reference:

Term / Abbreviation	Definition
A	Amps
Ah	Amp-hours
BMS	Battery Management System
CAN	Controller Area Network – automotive communication protocol
EC (CE)	European Commission
ESS	Energy Storage System
EV	Electric Vehicle
FCC	Federal Communications Commission
FLA	Flooded Lead-Acid Battery
IC	Industry Canada
IFC	International Fire Code
LFP	Lithium Iron Phosphate (Lithium-Ion battery chemistry)
NCA	Nickel Cobalt Aluminum Oxide (Lithium-Ion battery chemistry)
NFPA	National Fire Protection Association
NMC	Lithium Nickel Manganese Cobalt Oxide (Lithium-Ion battery chemistry)
NRTL	Nationally Recognized Testing Laboratory
PPE	Personal Protective Equipment
SDS	Safety Data Sheet
SLA	Sealed Lead-Acid Battery
SOC	State of Charge
UL	Underwriters' Laboratories
V	Volts
VRLA	Valve Regulated Lead-Acid Battery
W	Watts
Wh, kWh	Watt-hours, kilowatt-hours

3 LITHIUM-ION PLATFORM OVERVIEW

3.1 Cell Array / Battery Pack Design

On the outside, a Lithium-Ion battery used in a piece of material handling equipment may look similar to other batteries that can be found in the same applications: They fit the same battery compartment, have similar connectors and, along with an appropriately sized counterweight enclosure, should have the same weight needed to keep the vehicle stable. Under the cover, however, Lithium-Ion batteries have some key differences.

A Lithium-Ion battery pack contains individual Lithium-Ion cells combined together to achieve the voltage and battery capacity required for the application.

This array of cells is then assembled into a battery pack that also incorporates a mechanical enclosure, wiring and connections, communications, as well as a dedicated electronic protection circuit used to monitor cell properties to ensure safe operating conditions and prevent failure and deterioration. This electronics package is the Battery Management System, or BMS.



To better understand how desired voltage and capacity is accomplished in a Lithium-Ion battery pack, it is important to understand the following electrical terms:

- **Voltage** – The difference in electrical charge between two points. This is analogous to the water pressure in a hose at the bottom of a tank. Voltage is expressed in units of **Volts (V)**.
- **Current** – The rate of flow of electric charge; current provides the ability to do work in an electric circuit and can be converted to heat, power and magnetism. In the water analogy, current is the flow of water through the hose. Current is expressed in units of **Amps (A)**.
- **Power** – The amount of energy passed through a circuit. Power is calculated as the voltage times the current and is expressed in units of **Watts (W)**.
- **Capacity** – The total electrical charge stored in a cell or battery. In the water analogy, Capacity would be the volume of water in the tank. Capacity is expressed in units of **Amp-hours (Ah)**. For example, a 100Ah battery can either produce 100A for 1 hour or 200A for 30 minutes.

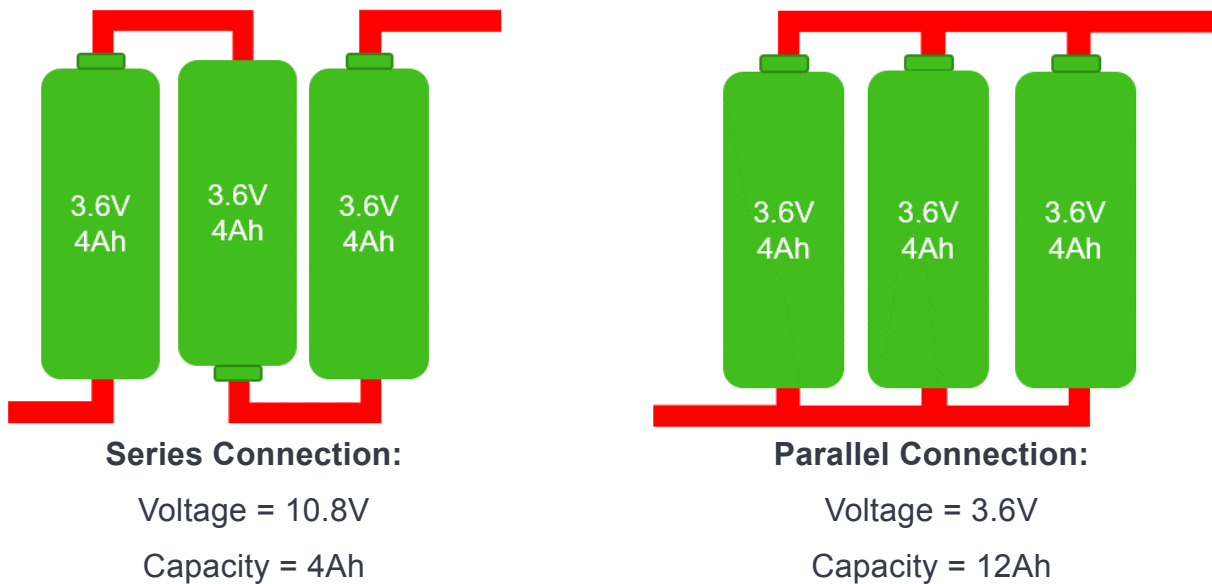
Battery capacity can also be defined as the total electrical energy stored in a cell or battery and is calculated as the capacity in Ah times the battery or cell voltage. For this definition, the units are **Watt-hours (Wh) or kilowatt-hours (kWh)**.

Building capacity and voltage in a battery pack uses a strategy of joining cells in combinations of **Series** and **Parallel** connections.

When cells are combined in **Series** (connected positive-to-negative), the individual cell voltages are added, while the capacity of the array remains the same as the individual cell.

When cells are combined in **Parallel** (all positive terminals connected together and all negative terminals connected together), the capacities of the individual cells are added, while the voltage of the array remains the same as the individual cell.

In the examples below, the three cells in the series connection provide a total voltage of 10.8V and the same capacity (4 Amp-hours) of a single cell. The three cells joined in parallel provide a total capacity of 12Ah and the same capacity (4 Amp-hours) of a single cell.



Note that for both arrays, the total electric energy capacity (in Wh) is the same:

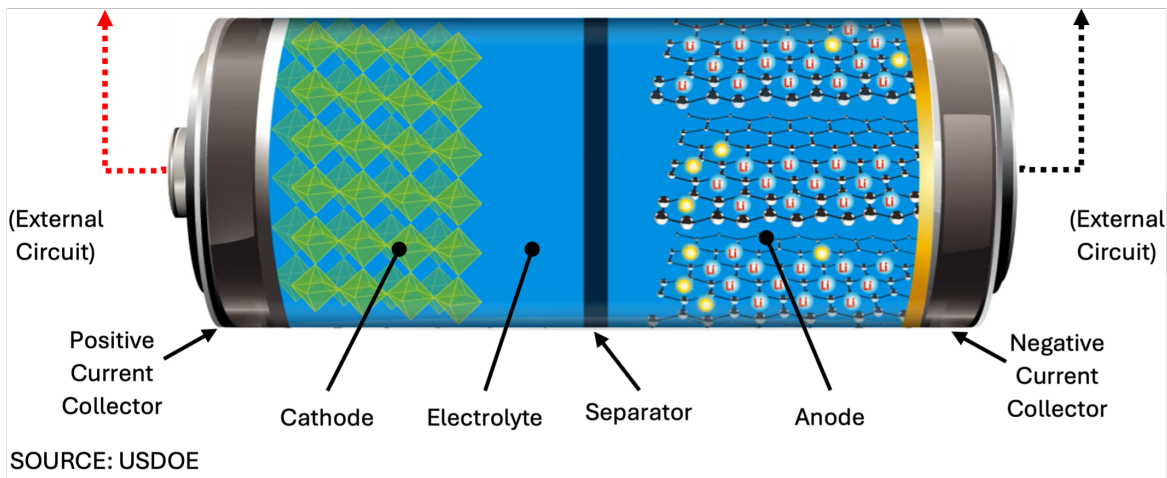
- **Series** – 10.8V X 4Ah = **43.2Wh**.
- **Parallel** – 3.6V X 12Ah = **43.2Wh**.

3.2 Lithium-Ion Cell Design

The design of a Lithium-Ion battery application must balance considerations such as performance, quality, and packaging requirements, in addition to safety – these considerations extend to the selection of the battery cell form factor itself.

Currently, Lithium-Ion cells are available in various sizes and form factors which share a common fundamental cell construction and basic elements – an **anode**, **cathode**, **separator**, **electrolyte**, and two **current collectors** (positive and negative). The electrolyte is a solvent liquid that transports positively charged lithium ions from the anode to the cathode when discharging and in the reverse direction when charging. The movement of the lithium ions creates free electrons in the anode which creates a charge at the positive current collector. The electrical current then flows from the current collector through an external circuit to the negative current collector. The external circuit contains the device being powered (cell phone, computer, vehicle, etc.)

The separator blocks the flow of electrons inside the battery, preventing an internal short-circuit.



An animated complete Lithium Ion circuit in operation can be seen [HERE](#).

These fundamental cell components are packaged into one of three form factors, each with relative advantages and tradeoffs:

Cylindrical – A cylindrical cell consists of an arrangement of sheet anodes, separators, and cathodes that have been rolled up and packaged in a rigid cylindrical container. This traditional form factor lends itself both to standard packaging sizes as well as mass manufacturing, so costs of this type of battery tends to be relatively low.



Another advantage of the cylindrical design is its mechanical stability. The round shape of the battery distributes the internal pressure from side reactions over the cell circumference almost evenly. This allows the cell to be more tolerant of internal pressure that causes swelling in prismatic and pouch battery designs. Lastly, cylindrical cells can incorporate features in the casing that can interrupt overcurrent and relieve pressure during a thermal event, providing additional protection.

The circular cross-section of cylindrical cells hinders the ability to minimize space of battery system designs; on the other hand, the cavities between cells allows for cooling circulation within the battery pack.

Prismatic – Prismatic cells contain anode/separator/cathode sheet arrangements that can be either rolled in a manner similar to cylindrical cells or stacked together. Unlike cylindrical cells, these sheets are contained in rigid metallic or plastic housings that are of a cubic or rectangular structure. This design allows for optimal use of space, yet it sacrifices the ease of thermal management found in the cylindrical cell design.



Prismatic cells can be more expensive than cylindrical cells to manufacture, and they run a higher risk of expansion with use.

Pouch – Pouch cells are largely similar to the prismatic design in that they enable more compact packaging at the expense of cooling. Where prismatic cells have a rigid container structure, pouch cells use soft foil packaging that has additional packaging as well as cost benefits. Drawbacks of the pouch design include requiring an external support structure and risk of swelling above that of prismatic cells.



3.3 Evaluating the Lithium-Ion Platform

Currently, selecting a rechargeable battery platform for a material handling application entails weighing the tradeoffs between Lithium-Ion and Lead-Acid battery technologies. The following battery characteristics may be considered when evaluating these two platforms:

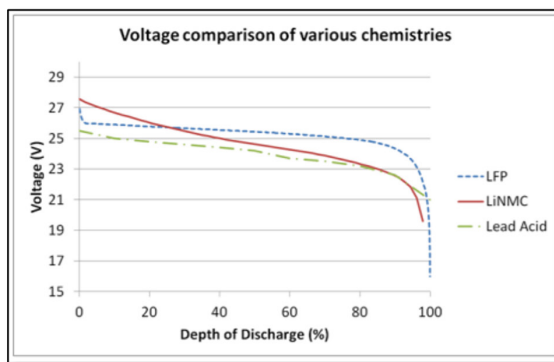
- **Energy Density:** Energy density refers to how much energy a battery contains in proportion to its weight (measured in Wh per kilogram) or volume (Wh per liter) and is a function of the active materials used in the battery construction. Lithium-Ion has the potential for higher energy density compared with other material handling battery platforms. This can enable a longer period of operation (for a given size) before recharging.
- **Operating Temperature:** All batteries prefer to operate at room temperature. Lithium-Ion batteries are able to operate well at higher temperatures (up to 45°C/113°F charging and 60°C/140°F discharging – reference cell manufacturer SDS for specific temperature limits), although this can run the risk of shortening battery life. Lithium-Ion cells cannot be charged at temperatures below freezing – below this temperature, plating of metallic lithium occurs on the anode during charging, which can lead to a permanent degradation in performance and safety. To mitigate the risk of shortening battery life, a Lithium-Ion battery's BMS controls operation to maintain optimal system temperature. Additionally, a combination of cooling and heating elements can be used to keep the battery in its optimal temperature range during charge/discharge.
- **Charging:** Historically, material handling applications were discharged and recharged in an eight-hour pattern, discharging for 8 hours, charging for 8 hours, then cooling for eight hours. More recently, material handling applications are moving to an Opportunity Charging methodology that is characterized by charging the battery during breaks and between shifts, the goal of which is to maintain an adequate state of charge, so the battery does not need to be removed from the equipment. Lithium batteries can function in the historic type of application, although the often-reduced energy content of lithium batteries needs to be verified capable of covering the eight-hour discharge but perform very well in Opportunity Charging applications. Some lithium chemistries offering charge rates up to and even in excess of 1C, which enhances Opportunity Charging capability.

- **Charging Safety:** Lithium-Ion batteries utilize a prescribed charging cycle that is quite safe if followed. Overcharging poses a risk to Lithium-Ion batteries – in this case, the elevated temperatures caused by overcharging could cause Lithium-Ion cells to become unstable, a condition that can lead to a thermal runaway in which flaming gases are vented.

Lithium-Ion chargers as well as the BMS present in Lithium-Ion battery packs closely monitor battery properties and control charging to prevent overheating and thermal runaway. Additionally, certain Lithium-Ion chemistries have a lower susceptibility to thermal runaway.

- **Maintenance:** Lithium-Ion batteries are largely maintenance-free. Routine maintenance tasks that should be performed include physical inspections of power connectors for wear or damage.
- **Cycle Life/Energy Throughput:** The cycle life of traditional material handling equipment was measured using a single discharge per day to a specific depth of discharge (DoD), typically 80%. The cycle life can vary, depending on the DoD and manufacturers typically stated an estimated number of cycles to expect at the particular DoD for the application. With the onset of opportunity charging, non-traditional shift usage, and advancements in battery technology, companies are moving to a daily or lifetime energy throughput measurement in lieu of cycle life. This value is expressed in amp-hours, watt-hours or kilowatt hours. This value represents the total energy throughput the battery is expected to deliver before its end of life. This value is typically expressed as total discharged amp-hours or watt-hours. Many batteries have a maximum daily energy throughput value stated as well.

- **Battery Discharge Characteristics:** Lithium-Ion batteries maintain most of the rated voltage over the discharge period, while Lead-Acid gradually loses available voltage while discharging, resulting in a more stable voltage for the truck components and a greater depth of discharge for the battery (more useability)



SOURCE: <https://www.osti.gov/servlets/purl/1596204>

- **Cost:** The initial purchase price of Lithium-Ion batteries is typically higher than that of Lead-Acid batteries, which by itself can be a key factor in selecting a rechargeable battery platform. Long-term, evaluating factors such as cost-per-cycle as well as the number of batteries and support systems needed for a given fleet size may make the two energy platforms more closely matched in terms of cost.

While a number of the tradeoffs above may seem clear-cut, the decision on a preferred battery platform may ultimately rest on evaluating additional factors such as the number of shifts in the operation, existing facility infrastructure, and initial capital available for investment.

3.4 Protecting Against Overheating / Over-current

3.4.1 What is Thermal Runaway?

Temperature can have a significant impact on the performance, life, safety and (ultimately) cost of Lithium-ion batteries. Temperatures above the rated temperature range can degrade battery materials more quickly and increase temperature variance across cells. High temperatures also increase the risk of thermal runaway, where the self-heating rate of the cell is greater than the rate at which heat can be dissipated to the surroundings. Resulting cell temperature rises exponentially resulting in all remaining thermal and electrochemical energy being released to the surroundings, along with irreparable hardware damage and safety risks.

Overcurrent is a leading cause of temperature increase leading to thermal runaway. Overcurrent refers to a situation where the current passing through a circuit exceeds the rated or safe limit. Common causes of overcurrent include:

- **Short Circuits:** Short circuits occur when there is an unintended electrical connection between the positive and negative terminals of the battery. This results in a sudden surge of current, which can be extremely damaging.
- **Overcharging:** Charging a lithium battery beyond its recommended voltage or current limits can lead to overcurrent. This can happen due to faulty chargers, incorrect charging algorithms, or even damaged battery cells.
- **Over-Discharging:** Similarly, discharging a lithium battery beyond its safe voltage limits can result in overcurrent. This can occur when a device continues to draw power from the battery even when its voltage has dropped below the recommended minimum threshold.
- **Sudden Load Spikes:** Some applications, such as electric vehicles and power tools, can experience rapid changes in load demand. These load spikes can cause overcurrent if not managed properly.

3.4.2 Battery Management System BMS

Each Lithium-Ion battery pack should contain a Battery Management System (BMS). The BMS firmware constantly monitors the safe operations of the battery, including cell voltage, current, temperature and state of charge (SOC), and detects any abnormalities or issues. Accurate temperature measurement is critical to ensure cells do not overheat. Lithium batteries can become dangerous if they overheat, so the BMS will trigger a shutdown algorithm if integrated battery temperature sensors detect temperatures outside of the safety zone. Battery shutdown prevents overheating, and the cells should never exceed their thermal runaway threshold.

The BMS has the ability to control charging rates, cooling fans (where applicable) and everything else needed to maintain optimal operating conditions.

A very important characteristic of the BMS on Lithium-Ion battery systems is that, in addition to the software protection features already described, there are also circuits in place that shut off electronic switches integrated into the BMS. Current is measured with current sensors located in

the current path of the cell arrays. The current signal is then processed by the BMS over-current detection circuit, and a resultant over-current signal is sent to the electronic switch control circuit. If the current rises too fast for the software to detect, the voltage changes too fast for the software to detect, or the software just generally ceases to correctly monitor voltage, current or temperature, the hardware protection circuits will still ensure that the electronic switches close, preventing further battery operation and overheating.

3.5 Lithium-Ion Cell Chemistry Comparison

The broader Lithium-Ion platform includes cells based on several related Lithium-Ion chemistries. Lithium-Ion cells are typically differentiated by the minerals that – along with Lithium – make up the **cathode** (positive electrode). Graphite construction of the cell’s **anode** (negative electrode) is common across the platform.

Lithium-Ion battery chemistries favored for Material Handling applications include **Lithium Nickel Manganese Cobalt Oxide** (LiNiMnCoO₂, or **NMC**), **Lithium Nickel Cobalt Aluminum Oxide** (LiNiCoAlO₂ or **NCA**), and **Lithium Iron Phosphate** (LiFePO₄ or **LFP**).

Selecting one of these battery chemistries involves comparing characteristics of each and weighing them against the requirements of the application: A brief comparison of the tradeoffs of the three principal Lithium-Ion chemistries is shown below:

Li-Ion Chemistry	Advantages	Drawbacks
NCA	<ul style="list-style-type: none"> Superior energy density 	<ul style="list-style-type: none"> Low thermal runaway temperature Relatively low cycle life
NMC	<ul style="list-style-type: none"> High cycle life High energy density 	<ul style="list-style-type: none"> Lower thermal runaway temperature Environmental concerns due to cell chemistry contents
LFP	<ul style="list-style-type: none"> Superior cycle life Close match to lead-acid voltage profile Inherent stability/safety 	<ul style="list-style-type: none"> Relatively lower energy density

A note on cost: As of 2023, NCA battery cells are approximately 20% higher cost on a per kWh basis than LFP, with NMC cost falling in between the other two. This comparison is subject to change based on demand, supply chain considerations, and projected raw material costs.

It should be noted that the simplified table above only compares the relative properties of the chemistries in a general sense. Similar to the Lithium-Ion – Lead-Acid comparison, selecting a preferred battery chemistry may likely differ based on the needs of the application. For example, an on-highway EV manufacturer may prefer superior energy density to minimize charging requirements during a cross-country road trip, while a material handling application may prioritize superior cycle life, in order to maximize the overall longevity of the batteries.

3.6 Power Cable Connectors

Battery connectors link the battery and the application’s electrical system or charging device, enabling the flow of electrical current necessary to either charge the battery or power the vehicle. They come in various sizes, materials, and designs to cater to different battery capacities and vehicle models. Leading connector types for material handling applications include Flat and Euro-DIN connectors shown below.



Besides simply making electrical connections, heavy-duty connectors contribute to the overall safety of a battery system by using features such as identifiable colors and molded key geometries to ensure the battery is matched to the correct lift truck or charger. Additional connector features available with some batteries include auxiliary pins that allow Controller Area Network (CAN) communication between the BMS and the charger to limit current or cancel charging altogether to prevent overcharging and overheating.

3.7 Cell Balancing

Battery cells age and discharge at different rates depending on conditions such as life, drive cycles, and thermal effects. Without balancing, charging presents the risk of thermal events (with overcharging) and cell damage (with undercharging). Rebalancing ensures safe charging and discharging and ensures that all available capacity is always usable. How well this is done differentiates performance, safety and accuracy of SoC.

The most common form of cell balancing is known as **Passive Balancing** and involves draining a small amount of energy from high SoC cells during charging so that all cells charge to their maximum SoC. The high SoC cell is bled off through a discharge resistive circuit so that charging can continue until all cells are fully charged.

Other **Active Balancing** techniques available use a process that redistributes charge between battery cells during the charge and discharge cycles, thereby increasing system run time by increasing the total useable charge in the cell array, decreasing charge time compared with passive balancing, and decreasing heat generated while balancing.

4 REGULATORY CODES AND AGENCIES

A number of regulatory codes and agencies provide requirements and guidelines, compliance to which helps ensure acceptable levels of safety of rechargeable battery products used in the materials handling industry. Several of these are briefly described below:



4.1 National Fire Protection Association

- The National Fire Protection Association (NFPA) is a U.S.-based international nonprofit organization devoted to eliminating death, injury, property, and economic loss due to fire, electrical, and related hazards.
- NFPA 70 – National Electrical Code (NEC) – is adopted in all 50 states as the benchmark for safe electrical design, installation, and inspection to protect people and property from electrical hazards.
- NFPA 505 (Fire Safety Standard for Powered Industrial Trucks) provides comprehensive fire safety guidance for Powered Industrial Trucks (PITs) and applies to fork trucks, platform lift trucks, motorized hand trucks, and other specialized industrial trucks powered by electric motors or internal combustion engines.
- More information can be found at <https://www.nfpa.org/>

4.2 International Fire Code

- The International Fire Code (IFC) is a set of provisions written by the International Code Council and designed to address life and property hazards associated with buildings and related premises.
- The IFC has been adopted as a legal regulatory standard in 42 U.S. States. Each U.S. State and County has adopted some revision of the IFC.
- The 2024 International Fire Code (IFC) contains regulations to safeguard life and property from fires and explosion hazards. Applicable topics included in the 2024 IFC include:
 - Lithium-ion batteries. Research, storage, and manufacturing of such technologies are being regulated through active systems. The IFC contains a specific section to provide tools to manage the collection of lithium-ion batteries.
 - Electrical Energy Storage Systems are referred to as ESS.
 - IFC Section 1207 (with references to NFPA 855) regulates ESS. The provisions continue to evolve with technologies.
 - The ESS threshold quantity is stated as 20 kWh for Lithium-Ion batteries.
 - For storage quantities above 20 kWh, a permit shall be obtained.

4.3 Nationally Recognized Testing Laboratories

- Nationally Recognized Testing Laboratories (NRTL's) perform safety testing and certification of the specific products covered within its scope of recognition. This includes Lithium-Ion battery systems.
- Obtaining certification is important for demonstrating manufacturer competency and product safety. Any deviations or failures must be addressed before certification can be granted.
- According to State and Federal OSHA laws (e.g., 29 CFR 1910.178), electric powered industrial trucks must be certified to UL 583 for hazardous designated environments, and their battery packs must be certified under UL2580.
- UL standards targeting EV batteries include the following:
 - **ANSI/CAN/UL 583 (Electric-Battery-Powered Industrial Trucks)** – covers electric-battery-powered industrial trucks, with respect to a risk of fire, electric shock, and explosion. UL 583 addresses wiring, enclosures, motors, and other electrical components of the truck, including batteries.
 - **UL/ULC 2580 (Batteries for Use In Electric Vehicles)** – sets forth comprehensive guidelines for testing, evaluating, and certifying batteries used in electric vehicles. This standard covers battery performance, thermal management, design, and construction, addressing potential hazards like overheating, short-circuiting, and mechanical failure to ensure that the battery can withstand the demanding conditions of everyday use.
 - **UL 991 (Safety Compliance Testing of Solid-State Devices)** – defines environmental tests required for solid-state devices that may be used in some rechargeable batteries. Environmental testing referenced in this standard includes thermal cycling, humidity, dust, and vibration testing.
 - **UL/ULC 2271 (Batteries for Use In Light Electric Vehicle (LEV) Applications)** – UL 2271 is a safety standard for the battery system used in Light Electric Vehicles (LEVs), such e-scooters and hoverboards. This standard sets requirements for the design, construction, and testing of the battery packs used in these devices. The certification tests the batteries for safety against overcharging, short-circuiting, and temperature abnormalities. This standard ensures that battery packs have adequate measures in place to prevent fire and explosions.

5 CERTIFICATION AND TESTING

As with any emerging technology, it is important to address safety concerns and provide guidance for those new to the Lithium-Ion platform. Understanding the rigorous safety measures undertaken by battery manufacturers and Material Handling Equipment OEMs can help alleviate any fears and offer a helpful buying guide for individuals looking to explore the world of lithium-ion batteries.

Ensuring compatibility in the integration of batteries and material handling equipment can be achieved through a dual commitment to safety from both Battery OEMs and material handling equipment OEMs.

5.1 Battery OEMs' Commitment to Safety Standards

Battery manufacturers prioritize safety by subjecting their products to rigorous testing and certification processes conducted by independent organizations. This commitment to safety is reflected in various certifications, including UL 1642 for lithium cells, UL 991/UL 1998 for the BMS, UL 2580 or 2271 for the overall battery, and UN 38.3 for battery cells.

To meet strict safety standards, battery manufacturers are adopting a technology-agnostic approach, meaning they are not limited to specific lithium chemistries. These companies conduct a range of tests to ensure their products meet high performance, reliability, and safety requirements. These certifications serve as assurance of compliance with stringent safety standards. Testing conducted under UL 2580 or 2271 certification includes fire propagation, drop testing, crush testing, vibration, and shock testing.

Each battery platform goes through comprehensive quality control procedures and tests to meet industry standards.

5.2 Certification for Manufacturer's Battery Compatibility

The Material Handling industry relies on UL and ANSI/ITSDF for product safety standards. The OEMs utilize UL 583 and 558 as standards primarily aimed at preventing fire and electrical shock while the governing standard for forklift safety in North America falls under ANSI/ITDF B56.1.

The compatibility of the battery and application is essential to avoid potential risks, such as operator injury caused by an abrupt stop in the event of a sudden power loss. Specific criteria and protocols, unique to each manufacturer, are implemented to establish effective communication between the application and battery, including interrupt and emergency warning signals.

Another important aspect is ensuring that the battery does not damage the application itself. Most material handling applications are designed for compatibility with lead-acid batteries, with some exceptions in newer models. As a result, certain adjustments and calibrations need to be made when integrating different battery types. Failure to perform these adjustments can pose risks.

For instance, inaccurate SOC readings may lead to the vehicle mistakenly assuming that it has insufficient energy remaining, causing it to stop operating prematurely. An analogy would be having a faulty calibrated gas gauge in a car.

In conclusion, certifications are quality guarantees or assurances that the claims made by battery manufacturers are true and verified. It is therefore essential to inquire about these elements when purchasing powered industrial truck batteries. This is important not only for safety but also financially, as a material handling equipment OEM may not honor its warranty if the equipment is used with a battery that they have not approved.

There are also other types of certifications, such as FCC/IC and CE in Europe, which indicate compliance with electromagnetic compatibility and safety standards. By promoting awareness on the safety measures taken by battery manufacturers and material handling equipment OEMs and providing buying guides, the industry can help ensure the safe use of Lithium-Ion batteries in material handling equipment.

5.3 Certification for Charger Manufacturer's Battery Compatibility

Similar to Lithium-ion batteries themselves, manufacturers of battery chargers are subject to testing and certification to established standards to ensure quality and safety of their products.

- UL1564 (Standard for Industrial Battery Chargers)
 - The requirements in this testing standard covers battery chargers rated 600 volts or less.
 - They are intended to be used in accordance with the National Electrical Code, NFPA 70, to charge industrial storage batteries which are used to provide power for material handling trucks, tractors, personnel carriers, and similar motive equipment.
 - These chargers may be either cord and plug connected or permanently connected.
- CSA C22.2, No. 346:22 (DC Charging Equipment for Electric Vehicles)
 - A trinational product safety certification standard for the electric vehicle supply equipment providing AC power to an on-board EV charger
 - Provides safety requirements for the construction, performance, testing and marking of DC fast charging equipment in North America.
 - Also addresses protection of users against injury.

6 LITHIUM-ION BATTERIES BEST PRACTICES

6.1 Overview

- Always follow applicable manufacturers and employers' recommended safety practices as well as any applicable State, Federal and Provincial regulatory requirements.
- Lithium-ion battery manufacturers provide important information on how to safely use their products in SDS (Safety Data Sheets) and on GHS (Globally Harmonized System) labels.
- Lithium-ion battery use and response to lithium-ion battery accidents are in some situations significantly different than for lead acid batteries. Therefore, users and technicians who work with lithium-ion batteries should be trained on all aspects of lithium-ion batteries for industrial trucks, including but not limited to:
 - SDS and GHS labels
 - Operating and maintenance instructions
 - Installation and removal instructions (if applicable)
 - Hazardous voltage (if applicable)
 - Accident response

6.2 Installation Considerations / Precautions

- Follow material handling equipment OEM's recommended installation procedures and ensure battery meets the minimum weight and dimensional requirements for the lift truck.

6.3 Disposal / Recycling

The following disposal requirements help ensure safety and minimize environmental damage:

- Follow all manufacturer Disposal / Recycling guidelines.
- Dispose of the battery system in accordance with all local regulations relating to disposal of lithium batteries. Failure to do so may result in serious damage being assessed.
- Do not dismantle, incinerate, or crush battery systems.
- Ensure recycled lithium batteries go through an approved lithium recycling center and do not enter the lead-acid recycling network.