

ALL CHARGED UP

Are We Truly Ready for All Those Batteries?

By Greg Bordner, Scott Baranowski, Chris Butts, Mark D. Hansen and Lawrence Schulze

Current decarbonization and the shift toward clean energy in the U.S. will be one of the largest economic transformations in history (U.S. Department of Energy, 2024). Decarbonization is occurring in various sectors such as industrial and transportation, where clean energy options are being implemented to tackle climate change.

Batteries are vital for the storage of electrical energy and a key ingredient in decarbonization, with lithium-ion batteries set to play an integral role. Due to recent lithium deposit discoveries such as the McDermitt Caldera on the Oregon-Nevada border and the Smackover Formation in Arkansas, the availability and affordability of lithium will keep lithium-ion batteries a preferred energy storage format for the foreseeable future (Amazouz, 2025; The Daily Digest, n.d.; Smackover Lithium, 2025).

This article discusses lithium-ion batteries and best practices to reduce the hazards associated with their use. Lithium-ion batteries are inherently safe when properly designed and fabricated under a robust quality management system. However, if mishandled physically (e.g., dropped), electrically (e.g., overcharged) or environmentally (e.g., stored in extreme heat), they can become unstable and a thermal runaway can occur. A thermal runaway is caused by generation of more heat than the battery is able to dissipate, leading to

combustion and potentially an explosion. Proper handling, storage and disposal of lithium-ion batteries are essential to mitigate the risks associated with this battery technology. Safety professionals must understand the hazards of lithium-ion batteries and implement mitigation techniques for their organizations.

There are two types of lithium batteries:

Primary (non-rechargeable). These batteries utilize single-use cells of metallic lithium anodes and are commonly known as “lithium metal” batteries. Examples include coin cell batteries used in watches and small electronics and lithium manganese dioxide batteries used in medical devices, smoke detectors and emergency lighting.

Secondary (rechargeable). These batteries are rechargeable cells containing lithium compound for the cathode. These are the batteries commonly known as “lithium-ion” batteries. Examples where lithium-ion batteries are used include consumer electronics, electric vehicles and industrial equipment. The

six major types of lithium-ion batteries (cathode chemistries) are:

- lithium nickel manganese cobalt oxide
- lithium nickel cobalt aluminum oxide
- lithium iron phosphate
- lithium cobalt oxide
- lithium manganese oxide
- lithium titanium oxide

Concerns for the Safety Professional

Lithium battery use has proliferated, and this trend is not likely to change. These batteries may be small single-use chargeable or nonchargeable, typically found in small appliances and devices. They may be associated with small tools, larger machinery such as lift trucks, electric vehicles, or large-scale energy storage systems typically used for uninterruptable power supplies such as those associated with electric power grid storage and renewable power generation equipment.

As their use increases, concerns arise regarding storage, use and personal safety. The first step for safety professionals in mitigating these concerns is to determine and record what batteries are being stored and used along with the hazards presented by each. Once these hazards have been identified and analyzed, a risk analysis can be performed, including where and how they may be stored. Then, the appropriate risk treatment strategy and concerns can be managed. To make risk reduction a success, there must be a focus on change management, and the measures must be reevaluated on a continual basis.

The risk assessment can be short or more detailed and comprehensive, depending on the present hazards and locations. When developing the risk analysis, it is important to discern that small batteries with a low state of charge are on the low side of the hazard spectrum, larger batteries with a high state of charge are on the higher side of the hazard spectrum, various hazards exist in between. It is also important to discern that battery storage risk can be compounded by storage density, which

ENSURING LITHIUM-ION BATTERY SAFETY

•**Inventory and assess battery hazards.** Document all lithium-ion batteries used or stored in a facility, identify their types and states of charge, and conduct a risk assessment to determine potential fire, explosion or handling hazards.

•**Establish controlled charging practices.** Charge batteries only in dedicated, well-lit areas free of combustible materials, using manufacturer-approved chargers and cords, and ensure that charging is supervised.

•**Store batteries safely and reduce storage density.** Keep idle batteries at a low state of charge (preferably less than 50%), store them in designated battery containers or flammable storage cabinets, and limit the quantity stored in any single area.

•**Monitor battery condition and remove damaged units immediately.** Inspect batteries regularly for signs of swelling, cracks, leaks, overheating or loose wiring, and move suspected damaged or defective batteries to a designated quarantine or outdoor isolation area.

•**Develop emergency response and training programs.** Create an emergency action plan based on your battery risk assessment and train staff regularly on procedures such as disconnecting power, using fire blankets and safely removing devices.

•**Ensure compliance with codes and transport regulations.** Review applicable standards and HazMat transport rules, obtain required permits for large storage quantities, and follow special packaging requirements for damaged or defective batteries.

is the quantity of battery types stored in proximity within a given space.

A tailored emergency action plan should be developed directly from the risk assessment and staff training should be performed on a frequent, recurring basis. Decisions must be made to determine how staff are expected to manage the event, such as removing the battery or device from power and covering with a fire blanket or removing the device or battery from the area.

Lithium-ion batteries temporarily stored in manufacturing production areas or as part of manufactured equipment in assembly is tolerable as long as adequate sprinkler protection is provided and battery units have adequate separation and a low state of charge.

Lithium-ion batteries located and stored idle or as part of commodity packaging or finished manufactured products in warehouse operations typically are not subject to internal ignition unless damage has occurred during handling. However, idle batteries should be stored separately from other storage areas, and packaged batteries that are part of a commodity or manufactured product can be stored together in the same area, provided sprinkler protection is in accordance with appropriate level of protection strategies in terms of storage arrangements and heights, and additional safeguards such as thermal detection, improved ventilation and fire barriers are present.

Best Practices for Safe Battery Use

Batteries exist in various types and sizes, with varying states of charge, and are located in different areas. As such, batteries present a wide spectrum of hazards and require different safety practices to address them. The following list offers basic strategies and best practices for mitigating the risk of commercial and residential battery use, including lithium-ion batteries.

- Use only batteries supplied by the product manufacturer or a reputable supplier. Follow all manufacturer requirements, recommendations and guidelines. Avoid the use of refurbished batteries.

- Charge devices in a dedicated and well-lit charging area with no combustibles present.

- Use only power charging cords and equipment supplied by the product manufacturer or those recommended by the manufacturer.

- Do not use power cords that show



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signs of wear or damage (e.g., smashed, nicked, frayed) to reduce shock hazards.

- Charging batteries should always be supervised; never use an extension cord or multiplug adapter for charging batteries.

- Maintain unused batteries in a low state of charge until needed, preferably no greater than 50%. The lower the charge, the lower the energy.

- Do not overcharge batteries; remove the cord in a timely manner when fully charged. Store the equipment out of reach when not in use.

- Maintain the battery or device within temperature tolerances in accordance with the manufacturer's instructions, typically between 40 and 80 °F, to help minimize the risk of thermal runaway from manufacturing defects or internal failures. Extreme cold or hot temperatures can affect a battery.

- Do not use or charge swollen or bloated batteries. Discard batteries that show evidence of physical or mechanical damage in a safe manner as required by the battery manufacturer such as via a recycling center.

- Store batteries in a storage container specifically designed for batteries. Locate the container in an easily accessible area away from a means of egress so it can be removed from the area in the event of an emergency.

- Use flammable storage cabinets with wheels for small- to medium-size batteries when not in use to provide a safer degree of separation.

- Limit the storage quantity of medium to large batteries per area to reduce density.

- Provide and maintain a safe distance between battery areas to provide a safer degree of separation.

- Avoid charging and storing micromobility devices inside buildings.

- Charge electric vehicles outside of garage structures.

- Consider providing combination smoke and carbon monoxide detectors and fire sprinklers in the compartment where charging occurs.

Regulatory Requirements for Lithium-Ion Batteries

Regulatory requirements and guidance have been developed for the safe use, storage and handling of lithium-ion batteries. For example, Section 320 of the 2024 International Fire Code calls out requirements for the indoor and outdoor storage of lithium-ion batteries (International Code Council, 2024). Some of the major requirements are:

- permits from the local Authority Having Jurisdiction (AHJ) for accumulation of more than 15 cubic ft of lithium-ion batteries

- fire safety plan

- technical opinion and report (required prior to permit being issued) that evaluates the fire and explosion risks associated with the indoor storage of lithium batteries and identifies whether changes to the existing fire suppression systems are required

- outdoor storage areas shall not exceed 900 square ft

As AHJs begin to adopt the 2024 International Fire Code, companies must evaluate their operations to ensure that they are in compliance.

Transportation Requirements for Lithium-Ion Batteries

Lithium-ion batteries are regulated as Class 9 Miscellaneous dangerous goods (HazMat) pursuant to United Nations Recommendations on the Transport of Dangerous Goods Model Regulations (United Nations Economic Commission for Europe, 2023b). The UN Model Regulation requirements are incorporated into local and modal dangerous goods regulations, including:

- 49 CFR HazMat Regulations (U.S. Department of Transportation, n.d.)

- International Air Transport Authority (IATA) and Dangerous Goods Regulations

- International Maritime Dangerous Goods (IMDG) Code

Prior to shipping lithium-ion batteries, the shipper must have a copy of the United Nations Manual of Tests

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and Criteria, Part III, subsection 38.3 Test Summary Report (United Nations Economic Commission for Europe, 2023a). The test summary report verifies that the battery can successfully withstand typical conditions encountered during transportation.

Damaged, defective, or recalled (DDR) is a term used to identify lithium-ion batteries with compromised condition that pose severe risks. In transportation, DDR is used to indicate the increased risk associated with the transportation of compromised lithium-ion batteries compared with that of non-DDR lithium-ion batteries. The following hazards can lead to a lithium-ion battery being damaged and at risk of experiencing a thermal runaway event leading to the release

of flammable, toxic and corrosive gases and an intense fire:

- mechanical:** physical damage due to mishandling (e.g., dropped, crushed, struck); manufacturing defects leading to internal short circuit

- electrical:** overcharging, over-discharging

- environment:** exposure to high temperatures, water

If a lithium-ion battery is suspected of being mishandled, it should be moved to a quarantine area designated for short-term storage (1 to 2 hours) until it can be inspected and the condition of the battery determined. If fire, flames, smoke or high temperature are observed, it is a DDR battery and should be moved immediately to an

outdoor isolation area. Observed visible damage such as cracks or dents, loose wires, a swollen appearance, leakage or warm temperature also indicate that the battery is damaged and as a DDR battery must be moved immediately to an outdoor isolation area identified by the facility. The isolation area should be away from buildings or other structures (confirm with local AHJ or insurance carrier for specifics). Figure 1 illustrates the steps to take with a mishandled lithium-ion battery.

It is the shipper's responsibility to determine if a battery is DDR prior to shipping the battery. The shipper can either develop an inspection checklist to visually determine if the battery shows signs of physical damage (refer to

FIGURE 1
STEPS FOR MISHANDLED LITHIUM-ION BATTERIES

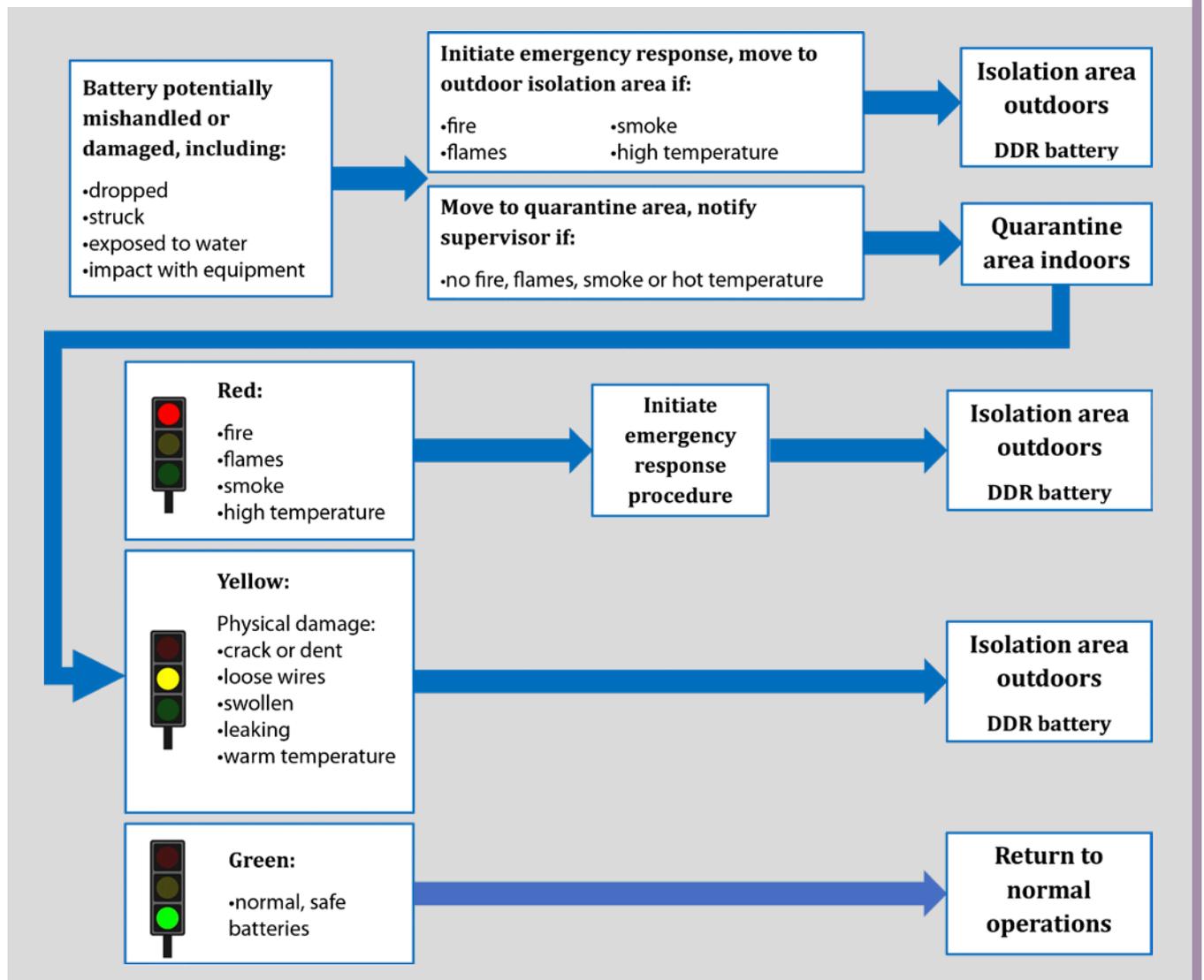


Figure 1) or contact the manufacturer to evaluate the condition of the battery. This may require additional time and resources versus inspecting the battery and shipping the battery as DDR as appropriate. This option does not remove liability from the shipper if the battery is misclassified and improperly packaged. If the battery has been recalled, the shipper must contact the manufacturer to verify if the battery is being recalled for safety reasons such that the battery is at risk of entering a thermal runaway event.

Shipping DDR lithium-ion batteries requires special packaging. It is important to note that the U.S. Department of Transportation allows only one DDR battery per package when being shipped unless shipped in packaging that has a special permit from the Department of Transportation allowing for more than one DDR battery in a package.

Conclusion

Lithium-ion batteries are not new and have been available for many years, but as they have proliferated, their risk has not gone unnoticed. The rise in use of lithium-ion batteries has created concerns largely due to their potential to cause fire and even be explosive. Battery size (Watt-hour rating) and state of charge, along with how they are used and stored, vary greatly. Recent loss events involving lithium-ion batteries highlight that each of these factors must be carefully assessed and considered. Codes, standards, and regulatory requirements provide direction on how to safely transport, handle, store and use these batteries, but they are lagging behind. Lithium-ion batteries are present almost everywhere, and they are likely here to stay for the foreseeable future. Practicing good housekeeping measures and implementing specifically tailored management policies, emergency response procedures, common sense safety strategies and best practices are important considerations both in the workplace and home. As reflected in the hierarchy of controls, the favored response and the most effective solution for identified issues is elimination—to physically remove the hazard. For further reading on fire hazards of lithium-ion and other battery types, see Wang et al. (2019) and Parker et al. (2020).

When the hazards associated with electrical power supply for mobile devices cannot be eliminated, there are

options regarding substitution and engineering controls. Substitution includes selecting an alternate power source that does not present the hazards that lithium-ion batteries do to the user. For engineering controls, isolating power to mobile devices using engineering design and fail-safe measures can be implemented to prevent these hazards from affecting the user population. These are key safety measures in preventing lithium-ion battery hazards from occurring asynchronously. Lithium-ion batteries likely will play a large role in providing power to mobile devices in the near future, and it is imperative that safety professionals have the tools to ensure a safe workplace. **PSJ**

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