



SURFACE VEHICLE RECOMMENDED PRACTICE

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Best Practices for Storage of Lithium-Ion Batteries

RATIONALE

With the increasing use of lithium-ion batteries in automotive-type applications, a need for recommendations on how to store lithium-ion batteries has been identified. The need results from multiple issues involving battery storage. Issues for such batteries include:

- Hazardous risks associated with electrical and chemical energy contained within the batteries,
- General lack of existing industry standards and codes for storage,
- Regulations that are in development, and
- Hazardous events that have occurred in storage facilities.

This document was developed to address those issues and provide corresponding storage recommendations for industry.

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Documents

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1. SCOPE

This document aids in mitigating risk for the storage of lithium-ion cells, traction batteries, and battery systems intended for use in automotive-type propulsion systems and similar large format (e.g., stationary, industrial) applications. Nothing precludes other industries and applications from using these recommendations.

1.1 Introduction

This document provides harmonized recommendations regarding facility storage and warehousing requirements to serve as common practice to enable operational safety across several industry functions. These practices can be referenced by supply chain partners throughout the lithium-ion battery life cycle. The work is based on the existing knowledge of the predominate lithium-ion chemistries. Future chemistries will require reassessment of these recommendations.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1715/2 Battery Terminology

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 International Code Council Publications

Available from ICC, 500 New Jersey Avenue, NW, 6th Floor, Washington, DC 20001, Tel: 202-370-1800, www.iccsafe.org.

International Fire Codes (IFC) (applicable publication years will vary by local jurisdictions)

2.2.2 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 5800 Battery Fire Containment Products

2.2.3 Energies Journal

A Review of Lithium-Ion Battery Fire Suppression. Volume 13, Issue 19, Published October 1, 2020. <https://doi.org/10.3390/en13195117>.

3. DEFINITIONS

This standard defers to SAE J1715/2 for all battery terminology. Definitions not found in SAE J1715/2 are listed below.

NOTE: The generic term “battery” shall be used interchangeably with the terms such as lithium-ion cells in a large container of equivalent quantities of cells that can be found in a traction battery, traction battery module, and traction battery pack.

3.1 ACTIVE THERMAL MANAGEMENT (ATM)

Intentional application of cooling and/or suppression technologies when thermal events are detected. Typically requires the input of energy to the system to cool and suppress a thermal event.

NOTE: The goal of the ATM is to control battery failure and attempt to prevent fire growth and spread. Battery storage containers and rooms can be outfitted with ATM technologies that might include smoke and gas detectors and sensors, fire suppression systems, pressure relief systems, and venting technologies.

3.2 EMISSIONS

Pressurized smoke, particulates, projectiles, and gasses generated from a thermal runaway event.

3.3 PASSIVE THERMAL MANAGEMENT (PTM)

Cooling and suppression technologies that rely solely on physical properties of the system where the cooling and/or suppression is applied without detection of a thermal event with the intent to contain a thermal event to its place of origin.

NOTE: Systems employing PTM are designed to slow fire spread and the heating of structural members. PTM materials can also be used to slow or stop the spread of failure byproducts such as smoke and toxic gases. PTM systems are usually made of materials and structures that are static and do not rely on motion to work. An example would be heat-resistant components that offer structural resistance. This might include heat shielding that reflects, absorbs, or reflects radiated heat. The materials are often built into structures such as battery storage containers and rooms.

3.4 STORAGE SYSTEM

Comprehends storage area (factory/warehouse, outdoor storage, etc.), detection, suppression systems, ventilation, partitions/walls, packaging/containers, spacing necessary, etc., to mitigate an uncontrolled fire resulting from the hazards of lithium-ion batteries.

3.5 THERMAL PROPAGATION

The continuation of a thermal event from one article to an adjacent article.

4. LITHIUM-ION HAZARDS

Lithium-ion batteries present hazards associated with chemical and stored electrical energy. In extremely rare incidents, these hazards can develop during a thermal runaway event. External hazards such as fire and physical damage to batteries may initiate the thermal runaway of a cell. Once a cell thermal runaway event has initiated, it may propagate to adjacent cells and batteries possibly creating an uncontrolled fire and ejection of fragments and other burning components. Another hazard associated with thermal runaway includes the potential for build-up of flammable and toxic gases in an enclosed space. To mitigate the potential hazards associated with a lithium-ion thermal runaway event, it is important to have in place strategic best practices for the storage of large quantities of lithium-ion cells and batteries.

4.1 Potential Hazards of Lithium-Ion Battery Storage

- a. Chemical Energy - Thermal runaway
- b. Electrical Energy - External/internal short circuit/high voltage
- c. Electrolyte Release
- d. Propagation - External
- e. Emissions - Flammable, toxic or explosive

4.2 Lithium-Ion Battery Failure Mitigation Strategy Matrix

Chemical energy of lithium-ion batteries is used to store and provide power to various battery applications. This chemical energy can be released in an uncontrolled manner, such as the decomposition of the cathode (typically oxidation) for lithium-ion batteries or, with lithium metal batteries, the reactivity of the lithium metal. This uncontrolled release of energy can lead to thermal runaway, high-heat generation, and open flames which may propagate to adjacent batteries or materials in storage. Understanding and assessing the lithium-ion battery failure risk is essential to developing sound failure mitigation strategies. Table 1 maps the hazards, risks, and mitigations for storage.

Table 1 - Lithium-ion battery hazards

Section	Hazards	Concerns and Safety Risks	Storage Failure Mitigation
5.1	Chemical Energy	- Thermal runaway - High-heat generation - Open flame	- Physical containment - Control SOC (State of Charge) as storage - Detection (e.g., state-of-health monitoring, heat rate-of-rise, infrared, smoke, early off-gassing, etc.) - Ambient storage temperature (cold storage, etc.)
5.2	Electrical Energy	- Short circuits (internal/external) - Shock hazard - Ignition source, including reignition - Arc flash	- Physical containment - Battery size by voltage and energy - Battery terminal protection - Control SOC (State of Charge) as storage - High voltage identification (labelling)
5.3	Electrolyte Release	- Ignition/flammable sources - Potentially caustic material - Skin absorption/irritant - Environmental (SDS) - Electrically conductive - HF gas (and acid) produced when contacts moisture	- Physical containment. - Absorbent materials - Non-aqueous fire - Detection - early off-gassing - Runoff controls
5.4	Propagation	- Uncontrolled fire/smoke - Conductive heat spread to nearby flammables	- Physical containment - Spacing - Control SOC (State of Charge) - Fire propagation control (materials and battery/package design) - Barriers/walls - Packaging - Battery design - Fire suppression systems/automatic sprinkler system - Fire alarm system
5.5	Emissions	- Toxic (e.g., HF gas) - Flammable - Explosive - Pressure buildup - Projectiles - Particulates	- Detection - Emissions management - Pressure relief systems (open venting, pressure valves, HVAC, etc.) - Toxic gas scrubbing/filtering - Particulate filtering - Misting/fog (suppression) - Physical containment - Breathing apparatus/SCBA - Explosion control

5. LITHIUM-ION HAZARDS, CONCERNS AND SAFETY RISKS, AND FAILURE MITIGATION STRATEGIES

5.1 Chemical Energy

5.1.1 Concerns and Safety Risks

The concerns relative to lithium-ion battery chemical energy include the initiation of thermal runaway, generation of high-heat, and the production of open flame. These can potentially contribute to an initial fire occurrence and/or the propagation of intense heat or fire to surrounding materials.

5.1.2 Mitigation Strategies

The unintended release of chemical energy may be mitigated by:

5.1.2.1 Containment

Physical containment can limit the propagation that results from an uncontrolled release of energy. The containment can be obtained via packaging, facility structures, and/or limiting the amount of energy for a given space.

5.1.2.2 State of Charge (SOC)

The severity and effects of an uncontrolled chemical energy release can be significantly mitigated by storing the lithium-ion battery at a reduced SOC. It is generally recognized that limiting a lithium-ion battery limiting a lithium battery SOC will significantly reduce the possibility of a thermal runaway event and reduce the risk of propagation between battery cells. Due to air transportation regulations, many lithium-ion batteries are shipped and stored at an SOC not exceeding 30%. Primary batteries typically do not control SOC during storage as it is not recoverable.

5.1.2.3 Storage Temperature

Maintaining cool storage temperatures also helps to mitigate the uncontrolled release of chemical energy. The lower the temperature, the less reactive the cell chemistry will be and will require a higher temperature rise internally for the chemistry to reach the onset temperature for cathode decomposition.

5.1.2.4 Detection

The ability to detect the release of chemical energy enables early notification and faster deployment of fire suppression and control technologies to limit the propagation of such an event. Sensors for detecting CO, H₂, and heat, etc., have all been investigated and utilized for early detection of an uncontrolled release of chemical energy. Other sensors may detect smoke or Volatile Organic Compounds (VOC).

5.2 Electrical Energy

5.2.1 Concerns and Safety Risks

Lithium-ion battery cells are commonly interconnected in series and/or parallel to create larger battery modules and battery packs or systems. Automotive and other large-format batteries often contain high voltages above 60 VDC that can pose an electric shock hazard, as defined in SAE J2344. Responders should be aware of the risks present when responding to emergencies involving batteries.

Another electrical energy concern with lithium-ion batteries is the potential for both internal and external short circuits. Short circuits can lead to thermal runaway events. External short circuits can occur by mishandling, improper design, or improper packaging, and lead to other concerns such as arc flash, heat generation, or thermal runaway. An external short circuit can also be an ignition source if flammable materials, gasses, or liquids, such as electrolyte, are present.

5.2.2 Mitigation Strategies

There are several mitigation strategies that can be deployed for electrical energy:

5.2.2.1 Physical Containment

Containment provides protection for both high voltage exposure and short circuit protection. The containment for the electrical hazards is typically via packaging or a battery enclosure/casing itself. Most automotive traction battery packs are designed to isolate the battery voltage from external exposure typically exceeding 100 ohms per volt while in storage. High voltage exposure is only allowed when contactors internal to the battery are closed. Further protection is typically provided by finger proof connection systems. For serviceable components from a battery pack, such as modules, exposure to high voltage may be more likely and is more reliant on packaging to provide protection in these cases. For electric short circuits, design features such as recessed terminals and spacing of circuits can provide protection from unintended exposure to conductive materials, but packaging is a primary means to protect cells and batteries when not contained in an isolated battery pack enclosure. Another mitigation means is the ingress or egress protection rating for an enclosure or packaging type to prohibit contaminants such as water, dust, or other external environmental influences.