



Operating Experience Summary

OES 2025-02

February 2025

Consideration of Lithium-Ion Battery Hazards in DOE Nuclear Facilities

Purpose

This Operating Experience Summary (OES) addresses considerations of Lithium-Ion battery hazards that may impact nuclear facilities or materials. The focus of the OES is on Lithium-ion battery recommendations for Documented Safety Analyses (DSAs), interaction with safety systems, and Energy Storage Systems (ESSs). It also provides awareness of current Lithium-ion battery initiatives in the Department of Energy (DOE) Fire Protection Community.

Background

Lithium-Ion batteries are essential in our daily activities. We use them in many applications, personally and professionally. They can be constructed in different ways but typically consist of several identical cells (see **Figure 1**) that can be increased or decreased based on the power demand. They have unique advantages such as high energy density for their weight, longer life cycles compared to other types of batteries, are fast charging, come in a variety of sizes, and are low maintenance. Lithium-Ion batteries have unique disadvantages as well. They can be sensitive to extreme temperatures, have higher initial costs, and have specific safety concerns, which are the focus of this OES.

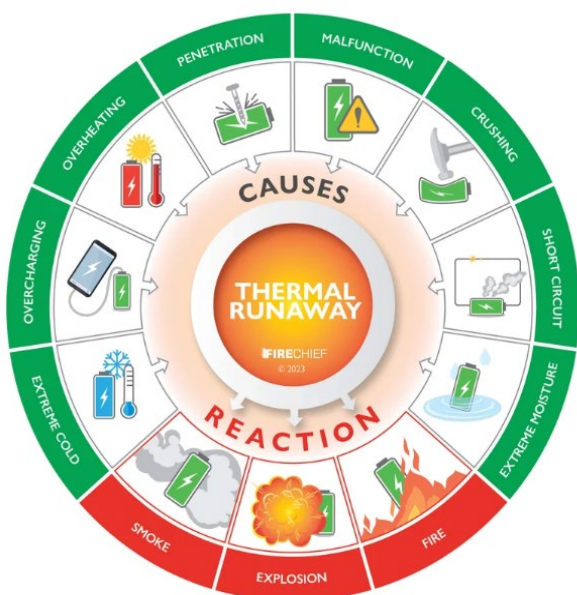
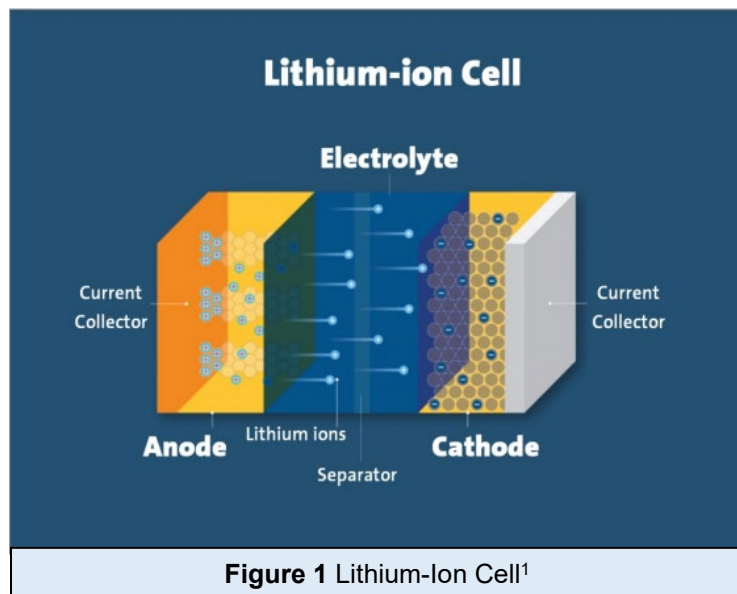


Figure 2: What is Thermal Runway?³

The main safety concern associated Lithium-ion batteries within DOE operations is the potential for fires and explosions. Specifically, under certain conditions, Lithium-ion batteries may enter a condition called thermal runaway, which is defined as “self-heating of an electrochemical system in an uncontrollable fashion”². During thermal runaway, battery cells rapidly release toxic, flammable gas. As the event progresses to other nearby cells, the failed battery cells tend to act as ignition sources resulting in an explosion hazard if the gas accumulates, and an intense fire as the battery cells are consumed. The causes of thermal runaway (see **Figure 2**) are numerous, therefore a multi-faceted approach to managing them is necessary to ensure safe operations.

Operational History

Lithium-Ion batteries are increasingly being used in DOE nuclear facilities and operations. Larger applications such as large-scale uninterruptible power supplies, ESSs, and Electric Vehicles (EVs) are of particular concern due to the potential to have significant energetic events that may affect nuclear materials and/or Structures Systems, and Components (SSCs).

Recent events in Arizona with an ESS and in Connecticut with an EV demonstrate the potential consequences of Lithium-Ion thermal runaway.

See these report links for event details:

[Four Firefighters Injured In Lithium Ion Battery ESS Explosion \(Arizona\) April 19, 2019⁴](#)

[Fire on Battery Electric Transit Bus \(Connecticut\) July 23, 2022⁵](#)



Figure 3: Fire on Battery Electric Transit Bus⁵

Recommendations and Resources

1. DSAs

Per 10 CFR 830 (except for limited procurement and construction activities), a DOE-approved preliminary DSA is required prior to construction of a new Hazard Category 1, 2, or 3 DOE nuclear facility or a major modification to an existing Hazard Category 1, 2, or 3 DOE nuclear facility. Similarly, operations at a Hazard Category 1, 2, or 3 DOE nuclear facility require a DOE-approved safety basis with hazard controls that ensure adequate protection of workers, the public, and the environment.

These DSAs must evaluate normal, abnormal, and accident conditions, including consideration of natural and man-made external events and identification of energy sources or processes that might contribute to the generation or uncontrolled release of radioactive and other hazardous materials. Lithium-Ion batteries represent one such energy source that needs to be identified and evaluated, especially with regards to whether fire and explosion events have the potential to affect nuclear material at risk.

Some of the unique hazards of Lithium-Ion batteries that analysis teams should consider are as follows:

- thermal runaway as a potential event initiator or propagator
- delayed re-ignition (up to days later)
- production of explosive and/or poisonous gases

Once these events are identified and, if necessary, carried through to the Accident Analysis process, the DOE Hazard and Accident Analysis Handbook (DOE-HDBK-1224-2024) provides guidance for analyzing fires and explosions. NFPA 68, *Standard on Explosion Protection by Deflagration Venting*⁷ and NFPA 69, *Standard on Explosion Prevention Systems*⁸ are helpful resources for addressing explosion control and venting, which should be properly documented and evaluated with the support of a qualified fire protection engineer.

2. Negative interactions with safety systems

Failures and/or abnormal events involving Lithium-Ion batteries can negatively affect other facility SSCs, including safety SSCs. DOE O 420.1C states that interfaces—such as pressure retention boundaries, electrical supply, instrumentation, cooling water, and other support systems—may exist between safety SSCs and non-safety SSCs. These interfaces must be evaluated to identify SSC failures that would prevent safety SSCs from performing their intended safety function. One example is a fire or explosion event involving a Lithium-Ion battery ESS that is co-located near one or more safety SSCs. Other unique interactions or characteristics of Lithium-Ion batteries that should be considered for evaluation might include:

- the possibility that an installed water-based fire suppression safety SSC has insufficient capacity to fully control a fire involving Lithium-Ion batteries;
- on-going and uncontrolled thermal runaway (including the generation of explosive or poisonous gases) even after an installed gaseous fire suppression SSC has stopped (or suppressed) the combustion reactions; and
- production of poisonous gases that prevent an operator from performing a credited Specific Administrative Control.

Failure Modes and Effects Analysis, Fault Tree Analysis, and Hazard and Operability Studies are all recognized methods that can assist with identifying these potential interfaces.

3. Design requirements for new ESSs

Per DOE O 420.1 C, for design and construction activities, contractors must identify the applicable industry codes and standards.

The applicable standard for new Energy Storage Systems would be NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*². This consensus standard provides requirement for safe design, installation, and operation of ESSs. For applicable ESS installations, this standard represents the current best practices for battery safety. The use of other consensus standards may also be necessary based on the specific installation. As an example, the following website details additional consensus standards DOE may use when addressing ESSs: [Codes & Standards – Energy Storage Safety](#).

Figure 4 shows an example battery ESS with key codes and standards for various components.

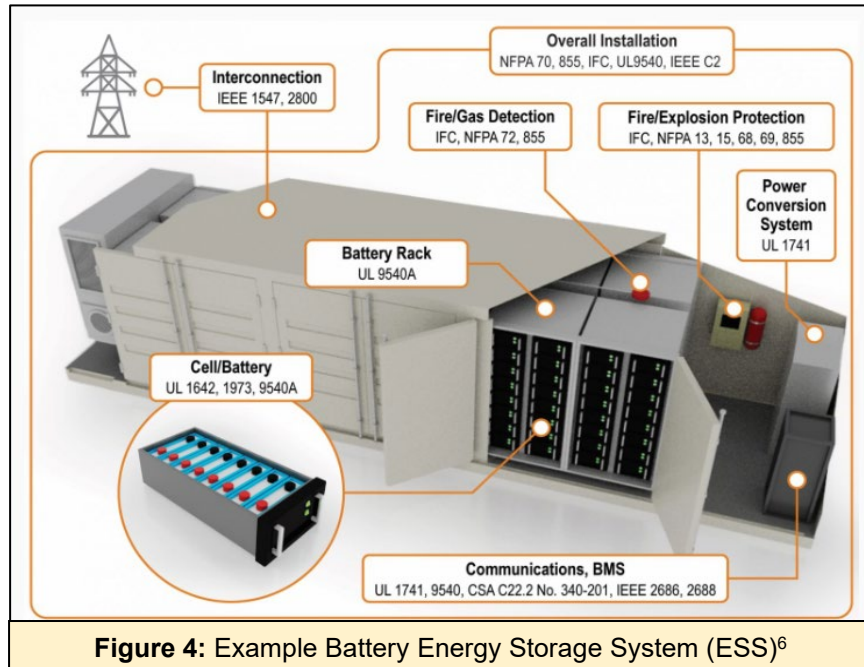


Figure 4: Example Battery Energy Storage System (ESS)⁶

Also, an ESS Safety Working Group has been established where experts in the community can be contacted. Email the ESS Safety Working Group at energystorage@sandia.gov for more information on how to engage with the working group's activities.

4. Initiatives from the DOE Fire Protection Community and additional information

The Environmental Protection Agency, [Lithium-Ion Battery Task Force](#)⁹, identifies four major categories for Lithium-ion battery systems: ESSs, EVs, Micro Mobility Devices (e.g. bikes, scooters, scooter-chairs for limited mobility persons), and batteries used in personal electronics (cell phones, tool batteries, computers, flashlights, etc.). This OES focuses on ESSs but recognizes that the other categories are widely used throughout the DOE complex.

There is not industry-wide code consensus on the management of battery hazards involving EVs, Micro Mobility Devices, and personal electronics. In the interim, the DOE Fire Protection community is actively evaluating how Lithium-ion batteries should be managed at DOE facilities. The Energy Facility Contractor Group has an established fire protection working group that is focusing on Lithium-ion battery issues.

Below are several resources that are helpful in understanding Lithium-ion battery hazards, operations considerations, and information for responders.

NNSA published guidance on EVs and the associated charging stations. It is available on the Organizational Excellence (Org Ex) website through the Nuclear Safety Basis forum topic at this link: [Consideration of Lithium-Battery Hazards in DOE Nuclear Facilities](#) (*OrgEx account required for access*).

The DOE Office Energy Efficiency & Renewable Energy published:

[Electric Vehicle Fire Primer for Fleet Managers \(February 2024\)](#) and

[Electric Vehicle Safety Training Resources for First and Second Responders](#),

The National Transportation Safety Board (NTSB) published [Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles](#) (November 13, 2020).

The [DOE Fire Protection PowerPedia website](#) is a good general Fire Protection resource which also houses documentation of previous workshops on Lithium-ion battery hazards.

Other items to consider for EV's operating at DOE facilities include:

- they have high mass but can also accelerate more rapidly than a traditional vehicle, this may change assumptions for maximum speed and resulting damage significance / ratios
- they may have uncontrolled remote operation, diagnostics, and/or surveillance (e.g., Tesla vehicles)

Summary

This OES provides considerations for Lithium-Ion battery hazards in nuclear facilities and shares DOE Fire Protection Community initiatives and resources. Introduction of Lithium-Ion batteries into DOE facilities should be carefully planned, implemented, and all necessary hazard analysis and control processes, along with their associated industry codes and standards, should be followed. The unique characteristics of these batteries must be considered to ensure safety and continued reliable operations.

The Office of Environment, Health, Safety, and Security (EHSS) appreciates feedback on this topic, such as projects that plan to incorporate Lithium-Ion battery ESS's, new information not discussed in this OES, or lessons learned that would be helpful to the DOE community.

EHSS-31 has established an Org Ex Forum on this topic for information sharing and collaboration. See, [Consideration of Lithium-Battery Hazards in DOE Nuclear Facilities](#). To gain access to the Org Ex website, visit OrgEx.energy.gov to easily establish an account.

Endnotes: Cited References

1. UL Research Institutes, [What Are Lithium-Ion Batteries?](#), September 14, 2021.
2. NFPA 855, 2023 Edition, *Standard for the Installation of Stationary Energy Storage Systems*
3. FIRE CHIEF, [What causes Lithium-Ion battery fires?](#)
4. Underwriters Laboratories, [Four Firefighters Injured In Lithium-Ion Battery Energy Storage System Explosion \(Arizona\)](#), July 28, 2020.
5. NTSB report, [Fire on Battery Electric Transit Bus \(Hamden, Connecticut\)](#), March 4, 2024
6. ESS codes and standards, <https://www.sandia.gov/energystoragesafety/codes-and-standards/>
7. NFPA 68, 2023 Edition, *Standard on Explosion Protection by Deflagration Venting*
8. NFPA 69, 2024 Edition, *Standard on Explosion Prevention Systems*
9. EPA Lithium-Ion battery task force, https://response.epa.gov/site/site_profile.aspx?site_id=16734

For further information or questions about this OES, please contact the EHSS Office of Nuclear Safety (EHSS-30) by email at NuclearSafety@hq.doe.gov.



Operating Experience Summary

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