



SURFACE VEHICLE RECOMMENDED PRACTICE

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Lithium and Lithium-Ion Cell and Battery Containment Performance Recommended Practice

RATIONALE

IFC 2024 Fire Codes allow for storage in certified containers, but industry has not developed a standard for demonstrating container performance for thermal runaway. SAE believes this performance recommended practice can benefit Authorities Having Jurisdiction (AHJs) and insurance companies implementing fire codes for safe storage of lithium batteries.

1. SCOPE

Prescribe test conditions to quantify the effectiveness of containment devices for containing thermal runaway hazards of lithium/lithium-ion cells, batteries, and equipment during storage resulting from the failure of a cell within the container. Due to the many storage locations (indoors, outdoors, etc.), the hazards shall be classified individually to allow for varying performance based on a given storage location.

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 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9500, www.astm.org.

ASTM E3057 Standard Test Method for Measuring Heat Flux Using Directional Flame Thermometers with Advanced Data Analysis Techniques

2.2 Related Publications

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

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2.2.1 SAE Publications

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

AIR6840 Performance-Based Package Standard for Lithium Batteries as Cargo on Aircraft, Background Information and Rationales

AS6413 Performance-Based Package Standard for Lithium-Ion Cylindrical Cells as Cargo on Aircraft

2.2.2 ICC Publications

Available from International Code Council, 200 Massachusetts Ave., NW, Suite 250, Washington, DC 20001, Tel: 202-370-1800, <https://www.iccsafe.org>.

2024 International Fire Code (IFC), Version October 2023

2.2.3 IEC Publications

Available from IEC Secretariat, 3 rue de Varembe, PO Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 0211, www.iec.ch.

IEC 62133-2 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications - Part 2: lithium systems

2.2.4 NFPA Publications

Available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471, Tel: +1 800-344-3555 (U.S. and Canada) or 1 617-770-3000 (International), www.nfpa.org.

NFPA 855 Standard for the Installation of Energy Storage Systems (2023 edition)

2.2.5 United Nations Publications

Copies of these documents are available online at <https://digitallibrary.un.org>.

Recommendations on the Transport of Dangerous Goods - Manual of Tests and Criteria

Recommendations on the Transport of Dangerous Goods - Model Regulations

2.2.6 Other Publications

LaRue, D.L. (2002). *Fire Indicators* (Engineering Project Report). U.S. Consumer Product Safety Commission, Directorate for Engineering Sciences. <https://www.cpsc.gov/s3fs-public/fip2003.pdf>.

3. DEFINITIONS

3.1 CHEESECLOTH

A tightly woven, untreated, 100% cotton cloth running 14 to 15 yd²/lb (26 to 28 m²/kg) and a thread count of 32 by 28 per inch (12.6 by 11.0 threads per centimeter).

3.2 CRITICAL HEAT FLUX

The minimum heat flux required to ignite a combustible material.

3.3 HIGH OCCUPANCY

Indicative of a storage location where the number of people occupying the site is larger than the number of storage containers. Examples may include office buildings, retail stores, and educational sites.

3.4 LOW OCCUPANCY

Indicative of a storage location where the number of storage containers is larger than the number of people occupying the site, such as a storage warehouse.

3.5 PERIPHERY ZONE

A row of live cells, batteries, or equipment within a test article surrounding the propagation zone in all applicable X, Y, and Z directions. The periphery zone is used to demonstrate that the thermal runaway propagation between cells stops in the propagation zone.

3.6 PROPAGATION ZONE

Area defined within a test article where propagation of thermal runaway between cells, batteries, and equipment is allowed during testing.

3.7 STORAGE COMPONENT

The intended storage device containing lithium or lithium-ion cells. This could be cells, batteries, or equipment.

3.8 SURROGATE CELL

An object that supports the same transport of heat as a cell but does not add energy to the test. For example, an electrically and chemically inert object having similar form, volume, and heat capacity as the cells that may be used for testing in place of a cell is a surrogate cell.

4. CONTAINER PERFORMANCE REQUIREMENTS

NOTE: These are the high-level performance requirements that are the basis of this test standard. Specific test pass/fail criteria to prove these performance requirements are provided in Sections 5 and 7.

4.1 Thermal Runaway Fire Hazards

4.1.1 The container shall contain the initial thermal runaway and the consequences of the thermal runaway during storage.

4.1.2 No flames or fragments exiting the container that could ignite surrounding material.

4.1.3 No surface temperatures on the container that could ignite surrounding material or impede occupant egress.

4.2 External Fire Hazards

4.2.1 The container shall resist heat from an external flame source and mitigate the risk to the storage components.

4.2.2 No damage may occur that would cause potential harm to personnel or equipment under normal storage conditions.

4.2.3 No damage may occur that would cause damage to storage components causing potential thermal runaway.

5. INTERNAL CELL THERMAL RUNAWAY TEST

Successful completion of three consecutive tests using the same test procedure and acceptance criteria is required.

5.1 Purpose

This test describes the method to evaluate the performance of a storage container to limit the consequences of a single cell in thermal runaway from becoming hazardous. The test is conducted in a container with the stored cells, batteries, and/or equipment at a specified state of charge as prepared for storage.

5.2 Test Article

The test article is comprised of the container and storage components it is intended to store. A container with multiple storage locations may be tested with all available storage locations in a container filled with the intended quantity of storage components or by using a lesser number of storage components than the container is designed and intended to store. At a minimum, storage components are required to be present in a propagation zone and a periphery zone. The tested article is permitted to be modified as required to accomplish the test and gather the required data.

If the storage container is equipped with a safety system, such as a fire suppression system, it shall be included in the testing with all controls and monitoring as designed.

5.3 Preparation of Test Article

5.3.1 State of Charge (SOC) Preparation

The stored components in the test article shall be prepared such that each cell SOC shall be at 110% of the maximum SOC intended for storage. Cells and batteries greater than 90% SOC shall be tested fully charged. Non-rechargeable cells shall be tested undischarged.

EXAMPLE: At 50% SOC; 110% means 55% SOC for testing; $50\% (\text{storage SOC}) + (10\% \text{ of } 50\%) = 55\% (\text{SOC as tested in the test article})$.

5.3.2 Location of Initiating Cell

The initiation cell is the cell that is driven into thermal runaway to demonstrate the container thermal runaway performance. The initiation cell shall be located based on determination of a position that is considered to balance competing requirements for achieving maximum container surface temperature, longest path of vented cell gas to container vent, and transfer of heat from cell to cell to maintain thermal propagation.

Items to consider in determining the location should include:

- Heat transfer from the initiation cell to an adjacent cell(s) in each X, Y, and Z direction as appropriate.
- Available cells to propagate from initial thermal runaway reactions.
- Location of vents and closure seals with respect to escape paths for thermal runaway off-gassing.
- Thermal management devices.
- Discharge or flow pattern of any active suppression systems (e.g., fire suppression agents).

EXAMPLE 1: Container that is filled with cells and has a cover that seals the top of the container when stored (see Figure 1A). In this case, the initiating cell should be located at the center of the second row from bottom to maximize layer. This location is the furthest from the cover seals while providing maximum paths for propagation to occur. This also allows the measurement of the thermal runaway effect on the container surface during the test. If the bottom row end cell was selected, two cells would be in contact with the cell; however, the available propagation paths would be reduced as compared to the middle of the bottom row.