



AEROSPACE INFORMATION REPORT	AIR6840™	
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Performance-Based Package Standard for Lithium Batteries as Cargo on Aircraft
Background Information and Rationales

RATIONALE

There are various areas of information that may or may not fit into a standard for performance of packaging for the transport of cells and batteries. This information is intended to support an understanding of the testing and to provide a full picture of all the activities surrounding the prevention and control of fire. This report provides the background rationales and calculations used to develop a performance-based package standard for lithium batteries as cargo on aircraft.

PREFACE

This document covers:

- Rationale for the choice of equipment, sizes, and volumes of certain equipment and information
- Rationale for the setup, conduct, and performance of the test
- Rationale for using different parts of the standard

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Documents

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides additional information and the rationale used for certain elements of AS6413. This AIR is provided to assist persons performing the tests described in AS6413 with an understanding of certain aspects of the test apparatus and the test criteria, such as the volume of the test chamber, cell heating rate, and the pass/fail criteria. It will be updated concurrently with AS6413 to explain changes, provide rationales, and cover future cell/battery technologies as they arise.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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.

AS6413 Performance Based Package Standard for Lithium Cells and Batteries as Cargo on Aircraft

2.1.2 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

2.1.2.1 FAA AC 120-121, "Safety Risk Management Involving Items in Aircraft Cargo Compartments," https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-121.pdf.

2.1.2.2 DOT/FAA/TC-16/37, "Summary of FAA Studies Related to the Hazards Produced by Lithium Cells in Thermal Runaway in Aircraft Cargo Compartments," June 2016, Webster, H. et al., <https://www.fire.tc.faa.gov/pdf/TC-16-37.pdf>.

2.1.2.3 DOT/FAA/TC-20/12, "Thermal Runaway Initiation Methods for Lithium Batteries", July 2019, Karp, M., <https://www.fire.tc.faa.gov/pdf/tc20-12.pdf>.

2.1.2.4 DOT/FAA/TC-15/59, "Lithium Battery Thermal Runaway Vent Gas Analysis," November 2016, Maloney, T., <https://www.fire.tc.faa.gov/pdf/TC-15-59.pdf>

2.1.2.5 DOT/FAA/TC-TT16/55, "Flammability Limits of Lithium-Ion Battery Thermal Runaway Vent Gas in Air and the Inerting Effects of Halon 1301," September 2017, Karp, M., <https://www.fire.tc.faa.gov/pdf/TC-TT16-55.pdf>.

2.1.2.6 DOT/FAA/TC-TN16/34, "Impact of Lithium Battery Vent Gas Ignition on Cargo Compartment Fire Protection," November 2016, Maloney, T., <https://www.fire.tc.faa.gov/pdf/TC-TN-16-34.pdf>.

2.1.2.7 "SAE G27 Packaging Tests," presented to the International Aircraft Systems Fire Protection Working Group by Maloney, T., May 2017, <https://www.fire.tc.faa.gov/ppt/systems/May17Meeting/Maloney-0517-SAEG27PackagingTests.pptx>.

2.1.3 Code of Federal Regulations (CFR) Publications

Available from United States Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

2.1.3.1 Code of Federal Regulations 14, Part 25, Appendix F, "FAA Fire Test Methods," <https://www.ecfr.gov/on/2017-01-03/title-14/part-25/appendix-Appendix%20F%20to%20Part%2025>.

2.1.4 Other Publications

2.1.4.1 AVICENNE Energy: "The Rechargeable Battery Market and Main Trends 2020-2030," September 2021, Lyon, France.

2.1.4.2 United Nations ST/SG/AC.10/11, "Recommendations on the Transport of Dangerous Goods - Manual of Tests and Criteria," Section 38.3.

2.1.4.3 ICAO DOC 10102 AN/50 (Paragraph 10), "Guidance for Safe Operations Involving Aeroplane Cargo Compartments."

2.1.4.4 "UN-IWG-LIBs Working Group Report, 3.1 Safety of Dangerous Goods Packagings and Batteries," Krug Von Nidda, J. and Schmidt, A., Bundesanstalt für Materialforschung und –prüfung (BAM), December 2022.

2.2 Definitions

AS6413, 2.3 shall be used unless otherwise stated.

3. RATIONALE FOR TESTING PACKAGE WITH FEWER CELLS THAN DESIGNED MAXIMUM CAPACITY

Refer to AS6413, 5.2.

The purpose of this section is to clarify the requirements that are used to qualify a package using a test article that contains fewer cells than the designed maximum capacity. It clarifies that a shipment of cells between a specific minimum and maximum quantity within the package is allowed. This qualification data demonstrates that the package is safe to ship when it contains a quantity of cells within these specified limits. The additional data collected using this method may enable the shipment of a variable number of cells within a package without needing to test every permutation when the multiple configurations will not affect the test result.

There is a benefit to ship variable quantities of cells/batteries in a given package (e.g., a package designed for a given number of cells may ship with reduced quantities depending on the customer order).

The costs of these tests can be very high. For example, a cell manufacturer may have a shipment of 100 cells. However, when they conduct the AS6413 test standard, only ten cells may be impacted by the thermal runaway and the remaining 90 cells need to be scrapped.

Propagation of thermal runaway within a package may be limited to a small number of cells. When it can be demonstrated that the propagation is consistently limited to a defined number of cells within a region surrounding the initiation cell, it is possible to conduct a limited number of tests to demonstrate the standard has been met without testing all configurations.

To address these scenarios, it was proposed to define a propagation zone, where cells are allowed to be affected by a cell in thermal runaway, and a periphery zone, where cells are not allowed to be affected by a cell in thermal runaway. The periphery zone encloses the propagation zone in all available x, y, and z directions to ensure the cell in thermal runaway does not affect cells beyond the propagation zone. The definition of these zones enables testing a package as prepared for transport with a reduced quantity of cells (see Figure 1).

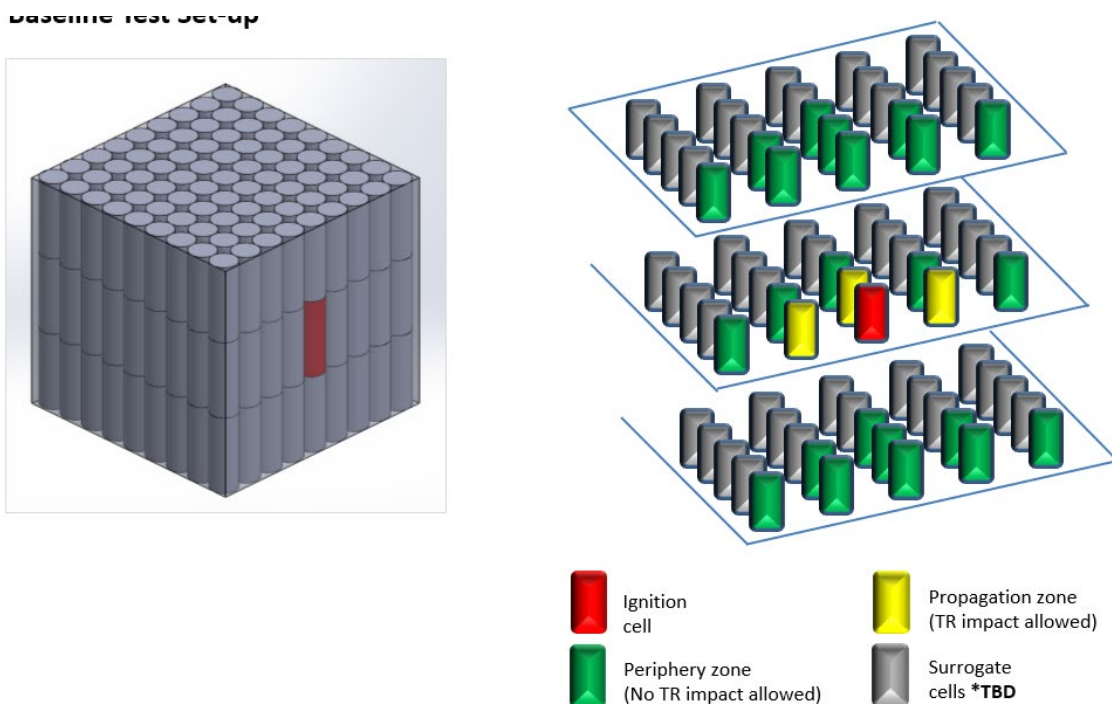


Figure 1 - Example configuration: ignition, propagation, periphery, and surrogate zones

Voids in the packaging from the missing cells increase the free volume of air for these tests. This possibly allows for a higher volume of gas to collect inside the package before reaching the lower flammability limit within the test chamber. To replicate a fully packaged box of cells, the remaining cell/battery spaces in the package are filled with surrogate cells. Surrogate cells can have an impact on the thermal dissipation of the thermal runaway energy in the package during the test. To address the impact of thermal dissipation, the thermal mass and conductivity properties of the surrogate cells should be the same or not exceed the properties of the missing cells.

AS6413, 6.4, Note 1, encompasses the ability to meet the performance requirements when a package contains a lesser, or a minimum, quantity of cells. In a reduced quantity test configuration, the cells tested is the sum of the initiation cell and cells within the propagation zone and periphery zone, which then becomes a minimum quantity allowed for a qualified package. The surrogate cells are not counted for the purpose of the allowable minimum quantity.

As an example, if a test article included 100 cells and surrogates, and the minimum allowable quantity is ten cells, the packaging instructions would describe how to prepare a package for any quantity between ten and 100, with all materials used in the packaging the same as tested. The packaging materials would be the same for ten cells as for 100 cells except that 90 cell locations would not need to have cells or surrogate cells but would need to have appropriate filler material.

It may be beneficial to conduct some testing of cells and package to have measured data supporting the defined propagation zone and periphery zone prior to conducting the AS6413 testing. Criteria for successfully completing AS6413 is defined in AS6413, 5.4.h.

4. RATIONALE FOR 10% SOC INCREASE FOR TESTING

Refer to AS6413, 5.2.1.

The state of charge (SOC) of the cells being tested has a significant impact on the outcome of the test. It was determined that applying a 10% margin to the SOC at which the cells are to be shipped takes into account the following:

- Accuracy of the calculation of the actual SOC. There is a margin in the range of $\pm 1\%$ to $\pm 2\%$ in determining the SOC using the standard industry methods.
- Impact of a percentage increase of SOC on the result: Nonlinear effect as a transition from a highly energetic to a less energetic reaction is in the range of 25 to 35%. So, if a margin based on a percentage of the nominal energy of the cell were used (such as 10% of the Wh rating), this would completely change the result.

5. RATIONALE FOR CONDITIONING PARAMETERS

Refer to AS6413, 5.2.1.7.v and AS6413, 5.2.1.7.vi.

The environmental conditions of testing are critical for cells and the packaging. The measured performance of many packages is affected by the conditioning and testing atmospheres.

Fiberboard packaging materials are hygroscopic in nature and, as such, will absorb moisture over time. To address this, AS6413 requires that the test article must be conditioned at a standard temperature and humidity for a set period of time prior to commencing the test. This ensures that there is repeatability and reproducibility of the tests.

The tests described in the UN Model Regulations (see 2.1.4) for conditioning of fibreboard packagings and the FAA test protocol for fire testing of materials (see 2.1.3.1) do not specify exactly the same temperature and humidity ranges. However, as these exact conditions are not considered critical for the conduct of the test, both are acceptable. The conditioning described in AS6413, 5.3 has been created as a specific condition that includes both sets of specifications.

In preparing this standard, there have been discussions that the hazards of thermal runaway may be addressed by some means of preparing the package such that it will not be possible for any of the cells to go into thermal runaway during the course of transport. A package that has been temperature-controlled and will be maintained at a temperature below freezing may be a means to prepare a package to prevent a thermal runaway. The standard could still be applied to such a package, but the conditioning of the test article would then need to account for the special conditions of the package preparation and carriage.

6. CLARIFICATION OF “ANY INDICATION OF A FOLLOW-ON EVENT” WHILE EVALUATING OUTSIDE THE TEST CHAMBER

Refer to AS6413, 5.3.1.

If there is any cell reaction after the test article is removed from the chamber, there is a possibility that additional gas is released. If the article is not in the chamber that collects the gas, it is not possible to confirm that the additional gas would not have caused the total volume of gas to be flammable. If there is an indication of some follow-on event, the test is inconclusive.

Often, a specific sound or emitted smoke is characteristic of a cell opening. Therefore, smoke and sound are suggested as indications of a follow-on event.

The thermocouples that are part of the test article will continue to be monitored, and an increase in temperature would also suggest an indication of a follow-on event.