SAE INTERNATIONAL

STATUS OF SAE G-27 LITHIUM BATTERY PACKAGING PERFORMANCE COMMITTEE

Presented to International Aircraft Systems Fire Protection Working Group
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Why is committee formed and why a packaging standard?

The Council of the International Civil Aviation Organization (ICAO) established a prohibition on the transport of lithium batteries as cargo on passenger aircraft as a temporary measure until controls were put into place which establish an acceptable level of safety. A performance-based packaging standard was identified as one of the controls.

ICAO's intent to have a performance based packaging standard declared in late 2015; SAE International chosen to lead this effort as SAE standard.

"Performance based package standard for lithium batteries as cargo on aircraft" (AS6413)

This SAE Aerospace Standard (AS) specifies a minimum performance package standard that supports the safe shipment of lithium batteries as cargo on aircraft.

SAE G27 Committee Charter

SAE G-27, Lithium Battery Packaging, is a technical committee in SAE's General Projects Systems Group with the responsibility for the development and maintenance of minimum performance package standards that support the safe shipment of lithium batteries as cargo on aircraft. The committee works in conjunction with related bodies such as the International Civil Aviation Organization (ICAO), International Air Transport Association (IATA), International Federation of Airline Pilots Association (IFALPA), International Coordination Council for Aerospace Industry Association (ICCAIA), European Association for Advanced Rechargeable Batteries (RECHARGE), Rechargeable Battery Association (PRBA), Battery Association of Japan (BAJ), defense agencies, and regulatory authorities.

The committee was established at the request of ICAO to develop a package performance standard for lithium batteries and packaging based on the high-level performance standards developed during the third Multidisciplinary Lithium Battery Transport Coordination Meeting.

SAE G27 Committee Charter

The objectives of the G-27 Committee are to:

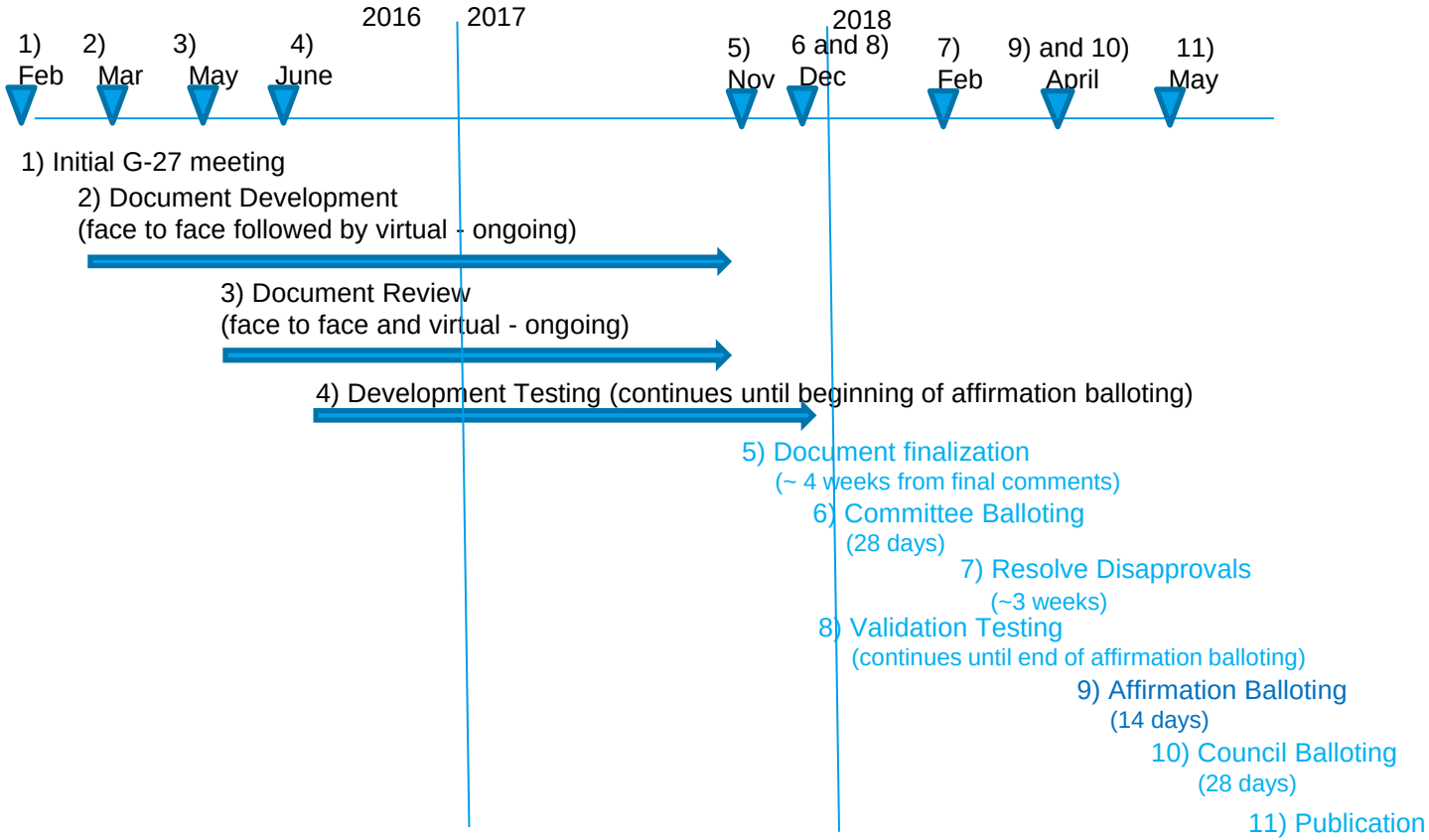
Develop Aerospace Standards (AS) for a minimum performance standard to safely ship lithium batteries as cargo on aircraft. The standard may include packaging design, qualification, test procedures and any other related tasks.

Provide a forum for the exchange of technical information related to lithium battery packaging for transportation by air.

Standards Development Process

- Writing Team developed draft for standard (~20 people)
- 4th Draft standard circulated to entire G-27 committee (over 160 people) for review and feedback (iterative process to incorporate comments)
- Balloting process involves all stakeholders with opportunity to comment on proposed standard:
  - Ballot disapprovals must be resolved between the commentor and document author.
  - Comments from non-voting members must be reviewed and considered.
- Voting members (~50) have been identified

Optimistic AS 6413 Projected Timeline (As of April , 2017)



Standards Development Process

- One telephone conference of full G27 committee per month since February, 2016
- Draft standard writing team of ~20 people have met multiple times starting with a 1 week face-to-face in March ‘16, June ‘16, Nov ‘16, March ‘17.
- Face to face meeting of G-27 committee May 19-20 in Toulouse, France and November 17-18 in Huntington Beach, CA, USA.
- 4th Preliminary draft of AS6413 on SAE G-27 website for feedback
- Next G-27 face to face meeting May 2-3 2017, in Cologne, Germany.

Writing Team

Approximately 20 individuals with standards and test experience balanced with geographic representation from the following stakeholders:

- **Aircraft cargo fire protection specialists**
- **Regulatory authorities**
- **Operators**
- **Pilots**
- **Packaging manufacturers**
- **Battery manufacturers**
- **Test houses**

AS 6413 Draft Content

- **This standard provides a test method to demonstrate and document the control of the potential hazards from Lithium metal batteries (UN 3090) and Lithium ion batteries (UN 3480) when transported as cargo on aircraft.**
- **It addresses the need to control the hazards which might arise from a failure of an individual cell by containing the hazards within the package.**
- **Controlling the consequences of a failure within the package is intended to prevent uncontrolled fire and pressure pulses that may compromise current fire suppression systems within the cargo compartment.**
- **The intent of this test is to severely abuse a single cell such that it is most likely to enter thermal runaway with the presumption that a single cell may enter thermal runaway during transport.**

AS 6413 Draft Content update

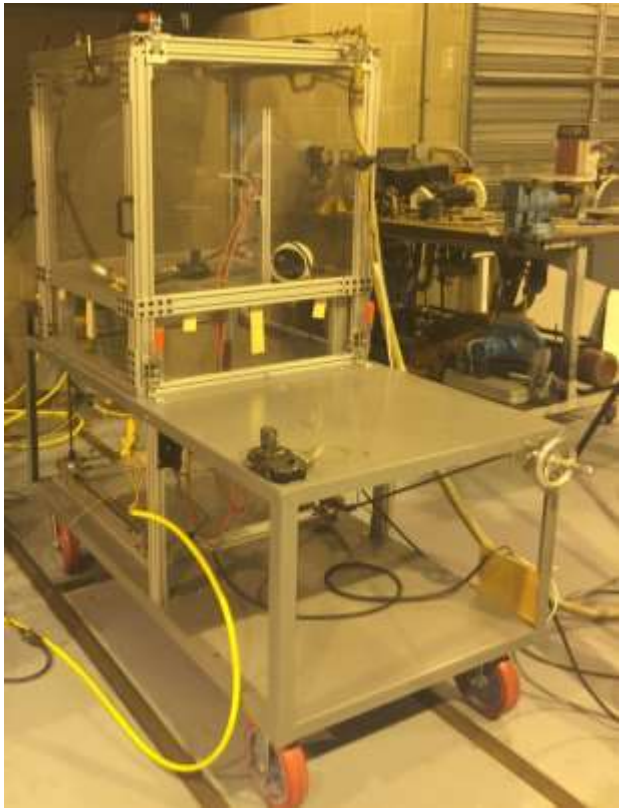
- **In addition to the “base line process” for testing, the group has recognized the need to clarify specific testing conditions for various categories of cells/batteries or packaging.**
  - **Large batteries**
  - **Cells and batteries that are “non hazardous” (do not result in a hazard when tested, regardless of packaging)**
- **A new structure of the standard has been proposed, including these specific conditions, in addition to the “base-line”.**
- **More content has been clarified with new paragraphs proposed:**
  - **witness panels for non-hazardous flames/fragments**
  - **Information requirements for traceability**

AS 6413 Draft Content

– Baseline Test Method

- The package will be placed in a transparent box with a [0.3] m^3 free volume that will contain gases generated from Thermal Runaway (TR). The box will have a rapid overpressure opening that will be sealed with a rupture foil. A spark ignition source will be energized continuously within the box volume, capable of igniting vapors reaching a flammable concentration within the box.

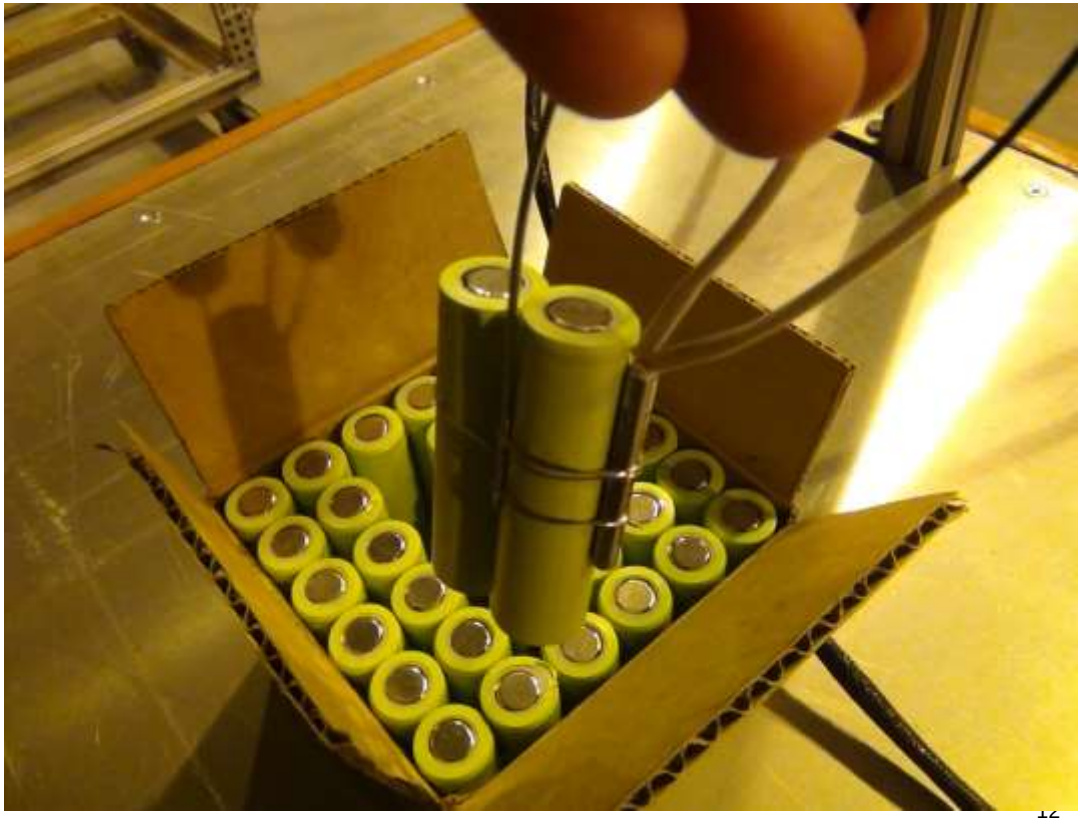
- Rationale for volume size is explained within draft standard



AS 6413 Draft Content

- For testing individual cells, Use a heat source (e.g. tape, cartridge) to create a temperature rise at 5 to 20 °C (9 to 18 °F) per minute as measured at an external point on the cell that is most representative of the cells internal temperature.

- If reducing SOC for shipment is part of package preparation to meet the performance requirements, a margin of safety is to be applied. Cells to be tested at the SOC of cells or batteries when tested in the package shall be at an SOC of 110% of maximum SOC allowed as presented for transport up to a max of 100%.



AS 6413 Draft Content

- If there is clear external evidence of cell thermal runaway, power to the heat source will be stopped.
- If clear evidence of cell thermal runaway has not occurred, monitor the cell temperature as measured at an external point on the cell that is most representative of the cells internal temperature and hold at 200°C (392°F) for 1 hour then remove power to the heat source.
- The unit under test will be monitored for 5 hours after removal of power to the heat source.
- ~~Test to be run until failure occurs or for 6 hours minimum in case no failure is observed~~.

For testing batteries, the goal is to use the same methodology applied to a single cell within the battery, but there may be more than one single method for triggering TR, depending on the battery type and construction.

AS 6413 Draft Content update

- After long discussions and lack of agreement about the pass/fail criteria defining what is a “non-hazardous flame” and a “non hazardous particle”, a new detection method, as an alternative to the visible observation of no hazard, has been introduced.
- The new detection method uses witness panels to determine the presence or absence of a hazardous flame or fragment.
- Witness panels shall be constructed of cardboard covered with a sheet of [cheesecloth]. The type of cheesecloth will be selected to represent the flammability of the plastic films often used to wrap pallets of packages.

- The pass/fail criteria have been modified accordingly
  - For test with video recording: no flame and no particles (but smoke is possible).
  - For test with witness panels, no detection of cheesecloth combustion or perforation.

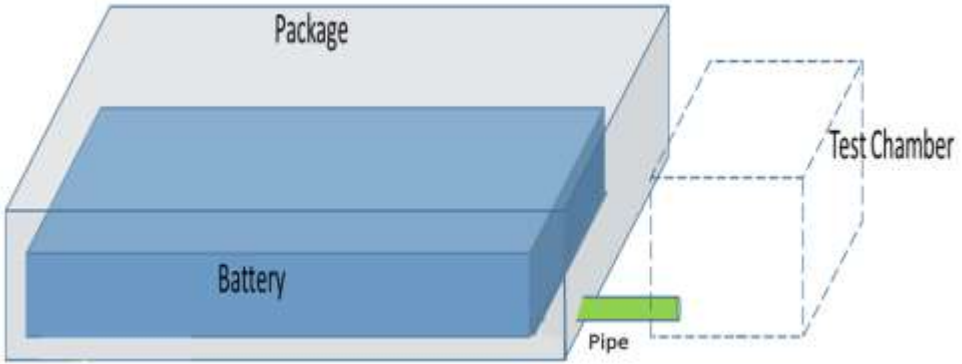
AS 6413 Draft Content update

- The pass test criteria shall include evidence of:
  - **No flame (as recorded by video) or Non-hazardous flame (as tested with the witness panels)**
  - **No fragments (as recorded by video) or Non-hazardous Fragment (as tested with the witness panels)**
  - **Non-hazardous Surface temperature**:
    - Temperature measured at center of each package surface will not exceed a peak maximum temperature of 200 C for [3] minutes with a tbd minute integrated average not to exceed 150 C.
    - This criteria is still under discussion, as depending on the position of the initiation cell in the package, also under discussion
  - **Non-Hazardous Quantity of Flammable Vapor**:
    - There shall be no evidence of flame other than allowed per non-hazardous flame.

AS 6413 Draft Content update

Specific conditions for large package of large batteries (too large to allow for the respect of the 0.3 m3 of gaz inside the chamber).

– Large package can be tested outside the test chamber, as long as the package or the battery has a vent which can be equipped with a pipe leading the gas inside the chamber.



– As an alternative to a complete package test, a sub-system may be tested instead. The sub-system shall consist of a set of components which are thermally, mechanically and/or electrically connected such that the subsystem behavior accurately replicates the complete package behavior for the specific test

Specific conditions for non hazardous cells and batteries

- The objective of this specific test is to describe the method based on the principle of carrying out the worst case test and demonstrating the benign behavior of the cell or battery design, showing that it does not depend on the packaging properties to maintain a non-hazardous condition in the event of cell thermal runaway failure.
- In order to demonstrate this performance, two tests (T1 and T2) are required:
  - Test T1: This is a test carried out in a specific package made of simple cardboard (non flame resistant) containing 3 cells/batteries in a row, packed in a manner to achieve the highest possible energy density, most likely to allow an exit of flame or a surface temperature increase, and tested according to the baseline procedure.
  - Test T2: A second test in a thermally insulative packaging with the intent of this test being to demonstrate the absence of propagation of thermal runaway in the worst case transfer of heat from one cell/battery to the next. The additive criteria for this test is the absence of thermal runaway propagation from cell to cell or battery to battery.

AS 6413 Draft Content update

Information requirements for traceability

- A similar approach has been proposed as in the UN model regulation: the description of a Summary Report Sheet, readily available for the transport stakeholders, and a detailed Test Report content (possibly containing restricted access information).

➢ Summary Report Sheet with a subset of the necessary data for documenting and validating the successful conduct and completion of the test:

List of identification and traceability information (Name of the test laboratory and contact information for the testing Laboratory, the package qualification owner, the part number and description of the cells/batteries and the the packaging, the tests results summary, the State of Charge tested, etc..)

➢ Test Report with the detailed laboratory information for traceability (data recording, video recording, test set up and result detailed description, etc…)

AS 6413 Draft Content to be completed

Some parts of the standard are intended to be completed:

- **A section of the document is intended to address an appropriate analytical method to use test data involving specific cells and specific minimal packaging as the basis for not repeating the testing for similar configurations (e.g. same cell part number and characteristics, but fewer cells, etc).**
  - **specification of "equivalent" package: definition of cells/batteries, packaging and package configuration that would be considered equivalent to a tested package, and would not require another test.**
  - **Discussion about the definition of products "type": is it similar to the "tested type" used in UN Manual of test and criteria, or should it be different, and differently identified.**
  - **Discussion about the required identification and traceability of equivalent packages.**
- **The definition of a "pre-qualified packaging", allowing to transport any type of cell/battery of a specified maximum size.**
  - **Discussion about an additional test condition to validate this packaging.**

G27 Open Issues: “external fire”

A subcommittee has met to address the potential hazards of lithium batteries packaged as required by the Dangerous Goods Technical Instructions in the event of a cargo fire due to some external event: “external fire”.

The scope of the working group is the following:

- **Description of the external fire risk: occurrence, ambient conditions to consider, consequences on the hazardous and non-hazardous cargo, …**
- **Identification of the available mitigation means: technical solutions, level of application (cargo, container, package, …).**
- **Analysis of the expected efficiency of the mitigation means and the possible ways to test it.**

As various stakeholders were present in this working group, different approaches to addressing this scenario have been expressed. The group has not finished its task. The output of the group to date will be discussed in the G-27 face tot face meeting in Cologne on May 2-3 2017.

G27 Open Issues: “external fire”

Description of the external fire risk: occurrence, ambient conditions to consider, consequences on the hazardous and non-hazardous cargo, …

- **Probability calculations for occurrence of shipments of lithium batteries being involved in a cargo compartment fire have been provided and discussed but not agreed upon by the working group.**

- **There are fire scenarios already defined by the fire suppression capability requirements for certification: (Halon replacement Minimum Performance Standards have embodied the existing certification requirements for Halon and the requirements for any halon replacement)**
  - **Already a “standard” for oxygen generator packaging – disagreement on applicability for this purpose.**
    - 5 minute, 1700 F oil burner – CFR 25 Appendix F, Part III
    - 3 hours 400 F oven test

G27 Open Issues: “external fire”

Description of the external fire risk: occurrence, ambient conditions to consider, consequences on the hazardous and non-hazardous cargo, …

- **Hazard severity and likelihood of lithium cells/batteries involved in an aircraft cargo fire have been identified as requiring action to be taken**
  - The introduction of the new package requirement is expected to reduce the risk of flame propagation in various cases, but maybe not all. As a result, the batteries may become only a flammable material, like many other transported goods.
  - More discussion and testing may be needed on the impact of lithium cells/batteries packaged per the proposed performance standard to define consequences of external fire on the package of concern and other cargo.

G27 Open Issues: “external fire”

Identification of the available mitigation means: technical solutions, level of application (cargo, container, package, …).

Although there was general consensus that an external fire needed to be addressed in some way, not everyone agreed it needed to be addressed at the package level. Some believed addressing at the package level was the only option, others believed it could be done with additional operational measures, and others a combination of both. The ultimate goal was to reduce the risk of the carriage of lithium batteries exposed to an external fire to an acceptable level in all cases. Some of the mitigation measures raised, at both the package level and beyond, included:

a. Packaging requirements for lithium metal and for lithium ion cells/batteries to be in the package requirement or implemented by use of an overpack

b. Reduced state of charge for lithium batteries

c. Cargo containers with or without suppression

d. Fire containment covers

e. Separation requirements (Halon would be more effective if batteries were spread around)

G27 Open Issues: “external fire”

Analysis of the expected efficiency of the mitigation means and the possible ways to test it.

- Most mitigation methods identified have not been designed for external, but internal fire (containers, covers,..): efficiency to be checked or tested?
- Some aircraft (narrow body aircrafts) may not have access to external protections (covers , container).
- Some proposed packages have been tested to the 5 minute flame and 3 hour oven test with varying results.

G27 Open Issues: “external fire”

External fire group preliminary conclusions:

- **Proposal for the standard: no agreement on the need to generate a standard for external fire.**
- **Tests are needed to understand the benefit of the new packaging and the remaining hazards: what is a benign battery or package for the external fire test?**

Discussions will continue on these topics regarding appropriate location – in the packaging standard, in guidance to be used with the packaging standard, or in a different document.

It is anticipated that these open issues will need to be addressed prior to final approval of the packaging standard

QUESTIONS?

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