The Advanced Rechargeable & Lithium Batteries Association

7. SAE G-27 Lithium Battery Packaging Standard

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1. Why a standard for Lithium Batteries ?

1. The root cause of the issue:
   - Lithium batteries specific safety characteristic: potential for reaction and self ignition risk.
   - According the battery and packaging design, risk of reaction propagation.

2. Usual fire control means in airplane (i.e. halon gas extinguisher) have been shown inefficient in some cases.

3. Li Batteries are one among others Dangerous Goods transported by air, but quantities are much higher than others Dangerous Goods.

1. Why a standard for Lithium Batteries ?

- Some fire incidents identified where Li batteries are involved, and may be the root cause.
- Perception of an increasing risk linked to the increase in quantities transported by air.
- Identification of non compliant products (UN qualification tests of the batteries and packaging conditions) or undeclared products.

→ Required specific action for the Lithium batteries

2. What are the hazards to keep under control ?

Potential hazards of Lithium batteries

- ✓ **The potential hazards of batteries**
  - The Chemical hazard
  - The Electrical hazard (and the case of high voltage)
  - Cumulative Electrical and Chemical hazards : can lead to thermal run-away

- ✓ **The three major possible consequences in case of thermal runaway:**
  - Flammable/toxic gas emission
  - Flame ignition, and possible flame propagation in the cells or batteries casing and packaging.
  - Heat emission and Thermal Runaway Propagation (TRAP) from cell to cell or battery to battery, in absence of flames.

2. What are the hazards to keep under control ?

- Hazards to control and propagation risk can be a combination of complex and multiple phenomena and conditions.
  Not only flame, but heat can propagate and extend the hazard, specific risks may be linked to the gas flammability,…

- Main fire control systems in airplane are based on flame extinguishing: i.e halon is not a cooling system. In case of thermal run-away propagation, their efficiency may be insufficient.

3. Why a packaging standard ?

1. A multi-layered approach has to be considered when looking for mitigation means at cell, battery, packaging, palette, cargo compartment and aircraft level.

2. Multiple solutions could be applied at these various levels.

3. Considering the shipper responsibility, the package (including battery and packaging) represents a key unit for the containment of the risk.

➡ ICAO decision to require a containment at package level, based on a testing technical standard proving the efficiency. The decision was to mandate SAE.

5 . The standard practical implementation issues

5.1 : the simulation of the self ignition for cells:
it is aimed at triggering the potential thermal run-away of a single cell, with negligible influence on the rest of the cells, batteries and packaging.

- For cells the abuse method selected is the heating at 200°C .
  The heating system can be a cartridge, a tape or simila r devices, with suitable thermal insulation.

  One issue under discussion is the selection of the cell in the package: according its surrounding (number of cells and/or package material), heat dissipation can be different.
  ▲ Possible divergence observed in the test result.

5 . The standard practical implementation issues

5.2 : the simulation of the self ignition for batteries:
the goal is to use the same methodology applied to a single cell within the battery, but specific issues can be expected due to the battery various designs.

- For testing batteries: other abuse methods are allowed. Methods as described in IEC 62619 may be considered as alternative methods for initiating thermal runaway

- **One issue under discussion**: how to prove that an alternative triggering method is equivalent to the heating at 200°C ?
  Proposal: demonstrate that the alternate method will put an individual cell into thermal runaway giving the same results as if the cell had been thermally induced.

5 . The standard practical implementation issues

5.3 : the heating protocol details:

It is proposed to heat up at 5 to 10°C per minute, and maintain at 200°C

- **One issue under discussion**: how to control and measure the heating rate ?
  - The heater power and control system may be a limiting feasibility factor (very different behavior of button cells compared to large batteries
  - The place where the thermocouple measuring the temperature is placed can induce variability in the test results

5 . The standard practical implementation issues

5.4 : the testing of large batteries:

It is proposed to test modules or sub-parts in order to represent the large batteries (for feasibility and cost reasons)

- **One issue under discussion**: how to verify it is equivalent to the complete battery?

- **Proposal**: document the sub-system that in a complete battery assembly and packaging are thermally, mechanically and/or electrically connected such that the sub-system behavior accurately replicates the complete assembled battery behavior for the specific test.

5 . The standard practical implementation issues

5.5 : the testing of equivalent products:

Due to the high number of cells and batteries “versions” which are of a similar type, it is a major cost question to define appropriate cells and batteries type, for which cells and batteries could be transported based on the same test result.

- It is proposed to define cells, battery and packaging types, and define “equivalent test” qualification.

- **One issue under discussion**: how to verify it is equivalent to the original battery? How to manage the complexity of the identification.
  - **Proposal under discussion**

5 . The standard practical implementation issues

5.6: the testing of cells or batteries which do not produce the identified hazards, independently of the packaging (called C0 cells and B0 batteries).

It is important that such type of cells can be qualified for transport in any type of usual UN packaging.

- It is proposed to define some specific additional conditions to the standard test, in order to prove the safety performance of the cells or batteries: for example, test in a high density package configuration, with a minimum packaging (single layer cardboard box).

- **Text under discussion.**

6 . The performance criteria & assessment issues

The definition of what should be the “controlled hazard” at the package level is raising a lot of concerns.

6.1 Discussions about “hazardous flame”, “hazardous fragments”

The principles retained for the criteria definition are:

- The control should be possible (visibility of the flame and fragments).
- The resulting hazard should not represent any risk to the surrounding packaging.

6 . The performance criteria & assessment issues

6.2 Discussions about the maximum temperature:

Practical questions have been raised:
What is the maximum acceptable, possibility of a peak transition, of which duration?
-> it is expected that real tests results may help defining relevant criteria for this parameter.

Where should the temperature be controlled (risks of packages heterogeneity thermal heterogeneity, dependence on the situation of the triggering event,…?)
-> test results also may clarify the potential importance of this question.

6 . The performance criteria & assessment issues

6.3 Discussions about the gas explosion risk

Due to the variety of flammable properties of the gas obtained in thermal runaway of the lithium batteries, it has been decided to concentrate:

- T, gas: aggregation of volume and explosivity in one test (explosive has become flammable due to progressive).
- Limit volume calculation link to aircrafts cargo size and liner properties.

6 . The performance criteria & assessment issues

6.3 Discussions about the gas explosion risk

Due to the variety of quantities and flammable properties of the gas obtained in thermal runaway of the lithium batteries, it has been decided to concentrate on the global result of an explosion in a chamber:

- a spark ignitor is used to check if the gas emitted during the test has reach the limit of flammability in a fixed volume chamber.
- The volume of the chamber has been determined based on the explosion test of a similar volume of gas in an aircraft cargo compartment.

6 . The performance criteria & assessment issues

6.3 Discussions about the gas explosion risk

Questions can be raised about the representativity of this test, and the probability of real events simulated by this method (calculation of volume, probabilities..)

Issues identified with the testing apparatus:

- The fixed volume rule generate some complexity when testing packaging of various sizes.

- The test chamber may fill with smoke, thus limiting the capacity to check the flame and particle risk.

Issue under discussion

6 . The performance criteria & assessment issues

6.4 Discussions about the reproducibility and the minimum number of tests

Because this standard is checking properties of batteries in case of abuse, and depending on a complex chain of events, it is expected that some lack of reproducibility is observed.

The requirement proposed is the successful completion of three consecutive tests verifying each non-hazardous result.

7 . Application of the Standard

- **The standard addresses the risk of self-ignition**

- **Question is raised about the way to address the external fire risk.**

Preliminary technical approach indicates that a different test method should be required, but:

- The reference conditions have not been clearly described and agreed.
- The need to request additive protection properties at the package level, in addition to the benefit of the “non-propagation”, has also to be clarified (other mitigations mean could be much efficient)

7. Application of the Standard: move to regulation?

The objectives as provided by the G-27 Committee are:

- Develop Aerospace Standards (AS) for minimum performance packaging requirements to safely ship lithium batteries as cargo on aircraft. The standard may include packaging design, qualification, test procedures and any other related tasks. **Upon completion of the standard, ICAO will reference the standard in ICAO's Technical Instructions for the Safe Transport of Dangerous Goods by Air (TIs) Packing Instructions for Lithium Batteries.**

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

Thank you for your kind attention !

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