

Thermal runaway for propulsion battery

ANAC-EASA-FAA-TCCA Certification Management Team
Task Specific Team on Electric and Hybrid-Electric Propulsion Systems

A Certification Management Team Decision Document

Issue 1

30rd May 2024**Revision table**

<u>Issue Number</u>	<u>Reason for issuance</u>	<u>Date</u>
1	Initial issue	30rd May 2024

Table of content:

Contents

1. Introduction	4
2. Scope	4
3. Applicability	5
4. Caution regarding TSO C179b for Rechargeable Lithium batteries	5
5. Propulsion Batteries Thermal Runaway high level requirement	5
5.1. Prevention (Layer 1) - Safety Assessment	6
5.2. Cell to cell propagation evaluation (Layer 2)	7
5.3. Containment (layer 3)- Containment at module/battery pack level	7
5.4. Additional Considerations	8
6. Conclusion and way forward	10
7. Definitions	11
8. Participants List	12
9. Acronyms	13
10. References	14

1. Introduction

Recent advances in battery technologies have allowed the aviation industry to consider electric engines as a new propulsion option for the aviation sector. Electric engines have enabled new aircraft designs with vertical and forward flight capabilities. These propulsion concepts are currently being applied in the General Aviation (GA) domain and will gradually appear on different categories of products up to the large airplane applications.

EASA&FAA are currently working on several certification projects on/with electric engines. Both authorities have developed new airworthiness requirements for electric engines and propulsion systems that use electric engines, with the shared goal of making the safe implementation of these new propulsion concepts possible.

The use of large lithium battery storage systems to power electric engines challenges the existing regulatory framework and has prompted the agencies and industry to develop new regulations or to re-evaluate existing requirements and guidance to address this novel technology. Such propulsion energy storage devices used in electric and hybrid aircraft increase the importance of properly addressing hazards, due to their novel function, higher capacity, higher specific energy, higher voltage, and the lack of significant service experience in this context.

2. Scope

This white paper outlines a joint proposal from the Airworthiness Authorities Harmonisation Group (FAA & EASA) to provide a certification path for thermal runaway hazards in Propulsion Battery Systems (PBS)¹ that use Lithium batteries.

This proposal identifies high level considerations essential to mitigate the risk posed by thermal runaway hazards intrinsic to PBS design based on recent experience gathered with Industry, with the current knowledge and understanding of lithium battery technology in large, integrated battery systems.

FAA and EASA interacted with several companies at different technology readiness and development levels (research, development, certification) and with Standards Development Organizations of industry and government participants.

The Harmonisation Group defined a common strategy encompassing 3 steps to support and guide industry activities in this domain:

- **Short-term:** Mutual recognition of FAA-EASA MOCs for the on-going projects to avoid re-design burden.
- **Mid-term:** FAA and EASA will develop and agree the main high-level requirements that shall serve as a common position and guideline for industry standard development (long term)
- **Long-term:** Development of a specific standard for PBS that use Lithium batteries Systems to address thermal runaway risk mitigation (to be developed in collaboration with Industry, Authorities and SDOs such as EUROCAE, SAE, ASTM, RTCA...)

The current white paper addresses the mid-term step, providing the main high-level requirements.

¹ -See Definitions

3. Applicability

The mitigation means and protection high level requirements will be applicable to VTOL-capable aircraft (EASA), Powered-lift aircraft (FAA), PART/CS-23 (except for level I), PART/CS25, PART/CS-27 and PART/CS-29 aircraft, SC E-19 EHPS that use large Lithium batteries in the PBS.

EASA consider a certain degree of proportionality for CS23 level 1 aircraft. This category of aircraft is not applicable to the FAA at this point of time.

4. Caution regarding TSO C179b for Rechargeable Lithium batteries.

The harmonisation group found it useful to clarify an erroneous assumption made by Industry on the use FAA Technical Standard Orders (TSOs) C179b for Propulsion batteries. Such high energy storage batteries are primarily used for propulsion and shall not be compared to starter/system Lithium batteries.

FAA and EASA agree to publish a joint statement highlighting that FAA TSO C179b for Rechargeable Lithium batteries is not sufficient for propulsion batteries performance evaluation. At this stage of technology development and knowledge, no TSO/ETSO exists to address Propulsion Battery Systems (PBS). The Harmonisation Group considers it essential to first develop an Industry standard for PBS using Lithium batteries, and at a later stage to evaluate the suitability of a TSO/ETSO definition to determine if a relevant minimum performance standard for these systems can be derived from experience gathered from Industry as this technology matures.

5. Propulsion Batteries Thermal Runaway high level requirement

Based on recent experience gathered with industry, and requirements derived from other industry applications using such technology, the Harmonisation Group considers it essential to define requirements that ensure an adequate level of safety of the product for the intended operational conditions and applicable regulations.

EASA and FAA consider that the most common causes of a thermal runaway initiation can be minimised through adoption of standardized practices and processes throughout the design, manufacturing, installation, operation, and maintenance. Others cannot be completely avoided (i.e., cell internal short-circuit) and their effect should be mitigated in service by safely managing the risk when such an event occurs. Therefore, in the event of a thermal runaway, continued safe flight and landing /safe landing and occupants' egress will have to be ensured.

FAA and EASA commonly consider that safety of PBSs using Lithium batteries is ensured by a combination of:

- Independent and redundant protection.
- Mitigation layers starting at the cell level and building up to module, pack, and battery system level.
- Evaluation of installation level effects/conditions.

This White Paper identifies EASA and FAA common grounds and differences when looking at the different protection layers identified.

When differences are identified, the White Paper will provide high level objective considerations commonly agreed by EASA and FAA to support industry activities and guide future industry standards development.

Battery cell quality assurance and configuration control must be established by the responsible Applicant.

5.1. Prevention (Layer 1) - Safety Assessment

The aircraft level safety assessment shall be conducted and cascaded to the system level to define the appropriate targeted safety level associated with each function.

EASA and FAA agree that the PART/CS23 subpart F §23.2510 and subpart E §23.2410 requirements are applicable to small airplanes and eVTOL aircraft (US). §23.2410 addresses areas where failure conditions are likely and permits minimization. Minimization from a propulsion system perspective acknowledges that it may not be possible to eliminate all possible CAT occurrences from a specific risk event but requires adequate mitigation at the aircraft level considering the existing technical and economic feasibility of those mitigation strategies. The [SC E-19](#) EHPS.80 – Safety Assessment” emphasis (especially the paragraph (a)(3)) the need to derive the safety requirements for the propulsion system from the aircraft ones. As such 23.2410 and 23.2510 should be considered in the Safety Assessment of the EHPS.

For [SC-VTOL](#), known differences on the overall regulatory framework and associated Safety Objectives and are under discussion in the context of the eVTOL COB and will not be addressed in this harmonisation working group effort.

Both authorities consider thermal runaway as a likely event that needs to be considered as part of the safety assessment process of the energy storage system which should be considered as a failure condition in and of itself due to its impact on the aircraft. It is considered that the thermal runaway of a propulsion battery is Catastrophic for all categories of products unless continued safe flight and landing can be ensured. The energy storage system shall be evaluated considering all the elements and interfaces.

The comprehensive evaluation of the energy storage system and the assignment of the Development assurance level are contributing to the minimisation of the risk. Development assurance activities do not replace or supersede the containment evaluation.

The aircraft-level safety assessment, system-safety assessment and the propulsion level safety assessment shall be consistent. In particular, assumptions made as part of the safety assessment shall be coherent and traceable between the different levels.

EASA [SC-VTOL MOC3](#) defines safety requirements (“Battery thermal runaway” is defined as Thermal runaway of 2 or more cells, and it is considered Catastrophic) to increase the safety level, that should be used by applicants to specify the maximum probability requirement for the cell failure, as well as the safety objectives of the control and protective functions (i.e., DAL of the BMS). This consideration will be further discussed between EASA and FAA based on examples for common understanding and alignment.

For what concerns PART /CS 25, PART /CS 27 and PART/CS 29, safety objectives are derived from 2X.1309 and the relevant AMCs.

5.2. Cell to cell propagation evaluation (Layer 2)

FAA & EASA identified some differences in the approach adopted for single cell evaluation.

EASA is promoting non-propagation from cell to cell. If this criterion is not met, applicants are requested to provide further mitigation means, which will be design dependant (isolation, venting...).

FAA considers the single cell test essential to foster a better understanding of the cell behaviour. Based on the test result evaluation, FAA might consider necessary to implement further isolation material or venting capacity. FAA consider it is difficult to require and test non-propagation at cell level as this is very dependent on the design and the test implementation.

In conclusion, both EASA and FAA recognize benefits of the single cell test and the need of a cell characterization to understand the thermal runaway behaviour. Process and standards are to be developed in collaboration by Industry, Authorities and SDOs, and enough flexibility shall be provided on the non-propagation criteria.

5.3. Containment (layer 3)- Containment at module/battery pack level

Containment test consideration was identified as the main point of discussion between Airworthiness Authorities. While EASA is relying on guidance for certification, FAA has built from the experience from known standards. Along the exchanges and discussion, airworthiness authorities' difficulty to converge on this topic was specifically linked to either:

- Established dedicated guidelines, already implemented in type certification based on Industry consultation, for EASA.
- Development of guidance along industry experience building up from experience derived from the use of known standards, for the FAA.

Both authorities agreed that such divergence strikes the need for a dedicated common standard development driven by Industry standardisation groups (owner of the design) with the possibility for industry to detach from the existing guidance and standards. Establishment of such standard is considered as a long-term goal.

Along the discussion, the Harmonisation Group found common grounds on main high-level requirements to be addressed when considering containment.

When considering containment, each applicant shall challenge the propulsion battery design to identify the scenario stressing the following parameters:

○ Highest temperature
○ Highest pressure
○ Longest time duration of heat transfer to surrounding structure and systems to secure continued safe flight and landing (as a function of the state of charge)

Based on recent experience gathered from industry, each applicant shall proceed with the containment evaluation based on a series of tests considering the most adverse operational temperature and the effect of different battery states of charge.

The containment test characterisation will require 3 levels of testing activities.

Test	Details/comments
Single cell propagation test	Require initiating thermal runaway on a single cell for evaluation of its potential for propagation (to be evaluated at different location of the battery module/pack). Possibly non-propagation could be a result of this test. This testing should also consider the types of failures that could cause a single cell TR to manifest into propagation based on the type of cell (i.e., cylindrical cell, pouch cell or prismatic cell).
Propagation test (called "N+1 test")	Require initiating thermal runaway on the minimum number of cells to overcome thermal resistance and generate slow propagation.
Multiple cells initiation method	Require initiating thermal runaway on multiple cells to produce worst temperature and pressure for the evaluation of each specific design. The test will challenge the module/pack containment design and demonstrate sufficient margin to failure. The goal is to initiate TR with a minimum of 20% of the cells depending on the design within approximately 1 minute. The test implementation is design dependant and shall be determined by each Applicant based on cell characterisation, and thermal resistance. Thermal modelling can be used for this determination however the demonstration must be completed in a full- scale test.

5.4. Additional Considerations

- Each applicant will detail the type of cell TR initiation considered when implementing the above required tests.
- In case thermal runaway propagation cannot be obtained while implementing the tests due to no-propagation, further evaluation, and discussion with the Authority will be required before determining the suitability of the test to substantiate compliance with the TR containment requirement.
- TR effects on any surrounding systems and structures shall not preclude continued safe flight and landing, control emergency landing and egress with margin.
Consequently, at least the following criteria must be respected for the expected test completion:
 - No module-to-module propagation shall be ensured (no fluids, flames, gasses, smoke, or fragments enter other modules). Each module should be tested considering the aircraft installation.
 - For designs where a single vent/exhaust is provided for multiple modules, exhaust/debris of multiple modules needs to exit without damaging other modules.

- Exhaust/debris of venting effect on any surrounding systems and structures shall not preclude continued safe flight and landing, control emergency landing and egress with margin.
 - In case of use of modularisation, applicants are expected to explain the influence of selected modularisation.
 - Each applicant shall define the longest time duration to demonstrate containment based on the continued safe flight and landing, egress + margin (including state of charge)
 - Ageing and environmental effect linked to operational condition shall be considered in the evaluation of thermal runaway.
-
- Used of well correlated simulation/ digital support is only considered appropriate to support the critical cases identification. Containment must be demonstrated by full scale test.

All evaluation will be subject to EASA and FAA acceptance.

6. Conclusion and way forward

The harmonisation effort allows both authorities to step out the standard/means of compliance considerations to foster a common understanding of each other's approaches, facilitate a mutual recognition of means of compliance in the short term and focus on essential high-level considerations to address thermal runaway on propulsion batteries. The defined high-level considerations shall be used as guidelines for the development of a standard dedicated to thermal runaway safety for PBSs that use lithium batteries involving Industry, authorities, standardisation groups (EUROCAE, SAE, ASTM, RTCA...).

The Harmonisation Group has progressed significantly on the high-level requirements considered essential to address TR. The group has not identified any obstacle that would prevent harmonisation and will continue working jointly to address any identified open action.

This document will be submitted to the Certification Management Task Secretary (CMTS) for endorsement and publication.

Note This document is likely to be subject to update based on further input of the CMT and the propulsion Battery harmonisation group discussion.

7. Definitions

For the purpose of this white paper the following definitions can be considered applicable.

Battery Cell - Individual electrochemical unit consisting of anode, cathode, separator, and electrolyte contained within a sealed casing.

Battery Module - Sub-assembly of cells that are electrically connected in series or parallel, or a combination thereof. It may include a battery management system (BMS) or BMS components. Battery packs may or may not include modules.

Battery Pack - Assembly of cells or modules that are electrically connected in series, in parallel, or a combination thereof, along with the BMS. It represents the fully packaged article that is installed in the aerospace vehicle.

Battery system or ESS (Energy storage system): Top-level configuration for installations that include multiple battery packs or a dedicated battery charger.

Cell characterization - Characterize cell operational properties, for thermal runaway energy and mass release, failure modes, and effects “Propulsion Battery system” or ESS (Energy storage system): Top-level configuration for installations that include multiple battery packs or a dedicated battery charger.

Propulsion Battery (System) - Means a battery or battery system used primarily for electric and hybrid propulsion applications. The battery system may supply power to other systems as well.

Propulsion ESS – Energy storage systems used to supply power to the aircraft engines.

Thermal resistance - Resistance to heat transfer between cells.

Note: Propulsion Batteries (Systems) shall not be compared to starter/system lithium batteries as they are primarily used for propulsion.

8. Participants List

Seattle Face to Face meeting (21 st to 23 rd May 2024			Participation
EASA	Carlos MUNOZ	EASA Propulsion-Focal point New Propulsion Technology Expert CT4.3)	F2F
	Herdrice HERESON	EASA Propulsion-Focal point Section Manager Propulsion and Powerplant GA&VTOL -CT4.3	F2F
	Lionel TAUSZIG	PCM VTOL -CT2.5	23 rd May Online
FAA	Paul SIEGMUND	FAA Electrical systems- Focal point Manager-Avionics & Electrical Systems (AIR-626)	F2F
	Daniel POBLETE	FAA Electrical systems- Focal point Electrical Systems expert (AIR-626)	
	Michael WALZ	FAA propulsion Propulsion &Electrical Expert (AIR 625)	
	Jeff PRETZ	FAA propulsion Propulsion &Electrical Expert (AIR 625)	Online 24th May
	Diane COOK	FAA propulsion Propulsion Group Manager ((AIR 625)	Online 21 st ,22nd May
	Caspar WANG	FAA Policy Management Policy Manager for Emerging Aircraft and Small Aircraft (AIR-62B)	F2F 21 st &23 rd May
	Nazih KHAOULY	Electrical Systems expert (AIR-626)	F2F+ Online (23rd May)
	Norman PEREIRA	Electrical Systems expert (AIR-626)	Online
	Roxanna MOORES	Electrical Systems expert (AIR-626)	Online
	Eddie NG	Electrical Systems expert (AIR-626)	F2F
	Jignesh PATEL	Product Policy Advisor: GA, Rotorcraft & Emerging Aircraft Aerospace Engineer, (AIR-62B)	Webex
	Thomas MALONEY	FAA Technical center Electrical engineer (ANG-E283)	FTF
	Doyle, JONATHAN	FAA Technical center Supervisory Engineer (ANG-E283)	Online
Sheila Mariano	Manager, Safety Risk Management, AIR-633	F2F	

Additional participants to previous Webex meetings		
EASA	Oswaldo LOPEZ	E-VTOL Section manager (CT2.5)
	Volker ARNSMEIER	VTOL Senior Expert Initial Airworthiness (CT2.0)

	James BLYN	Product Policy Advisor: GA, Rotorcraft & Emerging Aircraft Aerospace Engineer, (AIR-62B)
---	-------------------	---

9. Acronyms

AIR	
AMC	Acceptable Means of Compliance
ASTM	American Society for Testing and Materials
BMS	Battery management System
CA	General Aviation
CAT	Catastrophic
CMTS	Certification Management Task Secretary
COB	Certification Oversight Board
CS	certification specification
EASA	European Union Aviation Safety Agency
EHPS	Electric and/or Hybrid Propulsion System
ESS	Energy Storage System
ETSO	European Technical Standard Order
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAR	Federal Aviation regulations
MOC	Means of Compliance
RTCA	Radio Technical Commission for Aeronautics
SAE	Society of Automotive Engineering
SDO	standards development organization
PCM	Project Certification Manager
TR	Thermal Runaway
TSO	Technical Standard Order
VTOL	Vertical Take off and Landing

10. References

- [1] [Special Condition for VTOL and Means of Compliance \(18 Dec 2023\)](#)
- [2] [SC E-19 EHPS \(europa.eu\)](#)