

RTCA, Inc.
1150 18th Street, Suite 910
Washington, 20036 USA

Minimum Operational Performance Standards (MOPS) for Non-Rechargeable Lithium Batteries

RTCA DO-227A
September 21, 2017

Prepared by: SC-235
© 2017 RTCA, Inc.

Copies of this document may be obtained from

RTCA, Inc.

Telephone: 202-833-9339

Facsimile: 202-833-9434

Internet: www.rtca.org

Please visit the RTCA Online Store for document pricing and ordering information.

FOREWORD

This document was prepared by RTCA Special Committee 235 (SC-235), and was approved by the RTCA Program Management Committee on September 21, 2017.

RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal Advisory Committee and develops consensus-based recommendations on contemporary aviation issues. RTCA's objectives include but are not limited to:

- coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;
- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;
- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunications Union and other appropriate international organizations can be based.

The organization's recommendations are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration Technical Standard Orders.

Since RTCA is not an official agency of the United States Government, its recommendations may not be regarded as statements of official government policy unless so enunciated by the U.S. government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

"Disclaimer"

This publication is based on material submitted by various participants during the SC approval process. Neither the SC nor RTCA has made any determination whether these materials could be subject to valid claims of patent, copyright or other proprietary rights by third parties, and no representation or warranty, expressed or implied is made in this regard. Any use of or reliance on this document shall constitute an acceptance thereof "as is" and be subject to this disclaimer."

EXECUTIVE SUMMARY

This document was prepared by RTCA Special Committee 235.

The Committee membership includes representatives from cell and battery manufacturers, equipment manufacturers, aircraft manufacturers, regulatory and other government agencies, and related industry associations.

The SC-235 Committee reviewed and considered existing regulatory requirements and multiple standards and resources associated with non-rechargeable lithium batteries in developing this updated standard. These standards and resources include the AAIB Aircraft Accident Report 2/2015, Special Conditions related to non-rechargeable lithium batteries, DO-227, DO-347, DO-160 Rev G, UL 1642, UN Section 38.3, IEC 60952, and ISO-7137 [see References].

This standard provides design, testing, and installation guidance for non-rechargeable lithium batteries and battery systems which are permanently installed on aircraft or used in aviation.

The intent of this document is to assist equipment designers and manufacturers in the selection of non-rechargeable cells and battery systems whose safety and performance have been demonstrated as appropriate to the aviation environment.

Section 1 (Purpose and Scope) discusses the scope of this document, and provides guidance, best practices, and a list of some basic terms of reference.

Section 2 (Equipment Performance Requirements and Test Procedures) contains requirements and associated procedures for non-rechargeable lithium cells, batteries, and End Items powered by lithium batteries including general, performance, safety, and environmental requirements and tests.

Section 3 (Aircraft Installation Considerations) provides information that may impact the design or aircraft installation of the battery system or end item. It also provides cautions and advice for the installer. This section is intended to provide installation guidance and considerations that may help applicants to meet the airworthiness regulation requirements for the installation of non-rechargeable lithium batteries on aircraft.

This Page Intentionally Left Blank

TABLE OF CONTENTS

1	PURPOSE AND SCOPE.....	1
1.1	Purpose.....	1
1.2	Scope.....	1
1.3	Inclusions In This Document	1
1.4	Specific Exclusions From This Document.....	2
1.5	Regulatory Issues	2
1.6	Test Procedures	2
1.7	Safety Considerations	3
1.8	Definition of Terms.....	3
1.9	Storage	3
1.10	Shipping	3
1.11	Disposal.....	4
2	EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES	5
2.1	General Requirements and Design Guidance.....	5
2.1.1	Failure Modes and Effects Analysis (Hazard Assessment)	5
2.1.2	Airworthiness	5
2.1.3	Intended Function	6
2.1.4	Cell, Battery, and End Item Qualification Prerequisites	6
2.1.5	Flammability Properties.....	6
2.1.6	Safety Devices and Design guidance	6
2.1.7	Interference with Safety Features.....	7
2.1.8	Counterfeit Parts	8
2.1.9	Quality Management System	8
2.1.10	Marking.....	8
2.1.11	Authorized Replacement of Components	9
2.1.12	Isolation of Parallel Strings of Cells	9
2.1.13	Interconnections	10
2.1.14	Inadvertent Charging.....	10
2.1.15	Warning of Flight Critical System Battery Status.....	10
2.1.16	Criteria for Retesting.....	10
2.2	Functional and Safety Requirements	11
2.2.1	Cell Functional and Safety Requirements.....	11
2.2.1.1	Cell Functional Requirements.....	11
2.2.1.1.1	Pre-Test Cell Capacity	11
2.2.1.1.2	Cell Vibration.....	11
2.2.1.1.3	Cell Shock.....	11
2.2.1.1.4	Cell Temperature Cycling.....	12
2.2.1.1.5	Cell Altitude.....	12
2.2.1.1.6	Cell Humidity.....	12
2.2.1.1.7	Post-Test Cell Capacity.....	12
2.2.1.2	Cell Safety Requirements.....	13
2.2.1.2.1	Cell Discharge Current.....	13
2.2.1.2.2	Cell Polarity Reversal	13
2.2.1.2.3	Cell External Short Circuit with Protection Disabled	13
2.2.1.2.4	Cell Drop.....	14

2.2.1.2.5	Cell Venting Temperature Limit	14
2.2.1.2.6	Cell Pressure Control (Venting).....	14
2.2.2	Battery Functional and Safety Requirements.....	15
2.2.2.1	Battery Functional Requirements.....	15
2.2.2.1.1	Pre-Test Battery Capacity	15
2.2.2.1.2	Battery Vibration.....	15
2.2.2.1.3	Battery Shock.....	15
2.2.2.1.4	Battery Temperature Cycling.....	16
2.2.2.1.5	Battery Altitude Tolerance.....	16
2.2.2.1.6	Battery Decompression	16
2.2.2.1.7	Battery Humidity.....	16
2.2.2.1.8	Battery Discharge Current.....	17
2.2.2.1.9	Post-Test Battery Capacity.....	17
2.2.2.2	Battery Safety Requirements.....	17
2.2.2.2.1	(Battery) Series Cell Polarity Reversal	17
2.2.2.2.2	Battery Drop.....	18
2.2.2.2.3	Battery Impact.....	18
2.2.2.2.4	Battery External Short Circuit.....	18
2.2.2.2.5	Battery Single Cell Short Circuit with Protection Disabled.....	19
2.2.2.2.6	Battery External Short Circuit with Protection Disabled	19
2.2.2.2.7	Battery Handle Strength.....	19
2.2.3	End Item Functional and Safety Requirements.....	20
2.2.3.1	End Item Functional Requirements.....	20
2.2.3.1.1	End Item Vibration.....	20
2.2.3.1.2	End Item Shock	20
2.2.3.2	End Item Safety Requirements.....	20
2.2.3.2.1	End Item Thermal Management.....	20
2.2.3.2.2	End Item Thermal Runaway Containment.....	21
2.2.3.2.3	End Item Load Profile.....	21
2.3	Test Condition Requirements.....	22
2.3.1	Standard Test Conditions	22
2.3.2	Measuring Equipment	22
2.3.3	Specified Measurement Tolerances	22
2.3.4	Thermal Stabilization.....	23
2.3.5	Variance of Multiple Tests.....	23
2.3.6	Conformity of Test Articles	23
2.4	Test Procedures and Evaluation Criteria.....	23
2.4.1	Cell Test Procedures and Criteria	24
2.4.1.1	Cell Functional Tests.....	24
2.4.1.1.1	Pre-Test Cell Capacity Test	24
2.4.1.1.2	Cell Vibration Test.....	24
2.4.1.1.3	Cell Shock Test	25
2.4.1.1.4	Cell Temperature Cycling Test	28
2.4.1.1.5	Cell Altitude Test.....	28
2.4.1.1.6	Cell Humidity Test.....	29
2.4.1.1.7	Post-Test Cell Capacity Check Test.....	31
2.4.1.2	Cell Safety Tests	32
2.4.1.2.1	Cell Discharge Current Test.....	32
2.4.1.2.2	Cell Polarity Reversal Test.....	33
2.4.1.2.3	Cell External Short Circuit with Protection Disabled Test	34
2.4.1.2.4	Cell Drop Test.....	35
2.4.1.2.5	Cell Venting Temperature Limit Test	36
2.4.1.2.6	Cell Pressure Control (Venting) Test.....	36
2.4.2	Battery Test Procedures and Criteria	37

2.4.2.1	Battery Functional Tests	38
2.4.2.1.1	Pre-Test Battery Capacity Test	38
2.4.2.1.2	Battery Vibration Test.....	38
2.4.2.1.3	Battery Shock Test.....	39
2.4.2.1.4	Battery Temperature Cycling Test.....	41
2.4.2.1.5	Battery Altitude Tolerance Test.....	42
2.4.2.1.6	Battery Decompression Test	42
2.4.2.1.7	Battery Humidity Test.....	44
2.4.2.1.8	Battery Discharge Current Test.....	45
2.4.2.1.9	Post-Test Battery Capacity Test.....	46
2.4.2.2	Battery Safety Tests	46
2.4.2.2.1	Battery Cell Series Polarity Reversal Test	46
2.4.2.2.2	Battery Drop Test.....	48
2.4.2.2.3	Battery Impact Test.....	49
2.4.2.2.4	External Short Circuit Test.....	50
2.4.2.2.5	Battery Single Cell Short Circuit Test with Protection Disabled.....	52
2.4.2.2.6	Battery External Short Circuit with Protections Disabled	53
2.4.2.2.7	Handle Strength Test.....	54
2.4.3	End Item Test Procedures and criteria	54
2.4.3.1	End Item Functional Tests	55
2.4.3.1.1	End Item Vibration Test.....	55
2.4.3.1.2	End Item Shock Test.....	56
2.4.3.2	End Item Safety Tests	57
2.4.3.2.1	End Item Thermal Management Test.....	57
2.4.3.2.2	End Item Thermal Runaway Containment Test.....	58
2.4.3.2.3	End Item Load Profile Test.....	61
2.4.4	Test Samples and Test Sequences.....	62
3	AIRCRAFT INSTALLATION CONSIDERATIONS.....	65
3.1	Use of Lithium cells in Explosive Atmospheres (Hazard).....	65
3.2	Interference Effects (Precaution)	65
3.3	Aircraft Warning System (Precaution).....	65
3.4	Safety Assessment (Recommendation).....	65
3.5	Installation Aspects of Reportable Test Results (Recommendation).....	65
3.6	Design Assurance Levels (Recommendation)	66
3.7	Additional Considerations for Installed Equipment (Recommendation)	66
3.8	Equipment Scheduled Maintenance (Recommendation)	66
4	MEMBERSHIP.....	67
	APPENDIX A: SAFETY GUIDANCE FOR USERS OF LITHIUM BATTERIES.....	A-1
A.1	Mixing of Cells or Batteries (Hazard).....	A-1
A.2	Electric Burn Hazards	A-1
A.3	Electric Shock Hazard.....	A-1
A.4	Thermal Runaway Hazard.....	A-1
A.5	Battery Emission Hazard.....	A-2
A.6	General precautions when handling or working with Lithium batteries:	A-3
A.7	General Recommendations:	A-3
A.8	Safety Design Review and Verification (Recommendation):	A-4

APPENDIX B: ALTERNATE METHODS OF INITIATING THERMAL RUNAWAY B-1
B.1 Overcharge Method:..... B-1
B.2 Polarity Reversal Method:..... B-3
APPENDIX C: COMPLIANCE MATRIX..... C-1
APPENDIX D: GLOSSARY OF TERMS D-1
APPENDIX E: LIST OF ACRONYMS AND ABBREVIATIONS..... E-1
APPENDIX F: REFERENCES F-18

1 PURPOSE AND SCOPE

1.1 Purpose

The purpose of this document is to establish a Minimum Operational Performance Standard (MOPS) for non-rechargeable lithium cells and batteries installed as or in End Items on aircraft. This MOPS contains a set of requirements, tests, and evaluation criteria to establish and assure the safe operation of End Items which are powered by non-rechargeable lithium batteries containing lithium metal or lithium alloys. This MOPS applies to batteries used as the main power source or that are used for back-up or stand-by power. Guidance is also provided on design, safety, handling, and storage of these items.

Lithium batteries with a number of chemistries, sizes, and construction details are widely used today, and due to a variety of factors can present hazards if improperly designed, manufactured, tested, handled, used, or stored.

Compliance with the requirements contained within this document is recommended as a means of assuring that the cell or battery will perform its intended function(s) safely under conditions encountered in routine aviation operations. To ensure safe operation on the aircraft, it is imperative that users of this standard thoroughly understand the aircraft performance requirements (which establish the operating environments for End Items) and the capabilities and limitations of the batteries and battery systems which power those End Items. It is the equipment installers' responsibility to ensure that the batteries and battery systems meet the certification and installation requirements of the aircraft. Any regulatory application of this document is the sole responsibility of the certifying civil aviation authority.

1.2 Scope

This standard applies to non-rechargeable lithium cells, batteries, and battery systems that are permanently installed on aircraft.

For the purposes of this standard, a non-rechargeable lithium battery and battery system is considered permanently installed equipment when it is included as part of the type design of the aircraft (or a supplemental/amended type design). This standard also applies to non-rechargeable lithium batteries and battery systems contained within Portable Electronic Devices (PEDs) that are part of the type design.

Non-rechargeable lithium batteries within PEDs that are not part of the type design are outside the scope of this document; these PEDs fall under the purview of Federal Aviation Administration (FAA) Flight Standards division and are regulated by operational rules under Title 14 of the Code of Federal Regulations (CFR). PEDs that are not part of the type design, especially those located on the flight deck, can pose similar hazards as permanently installed equipment.

This standard does not apply to secondary (rechargeable) lithium batteries or to passenger-carried items regardless of their battery type.

1.3 Inclusions In This Document

The performance and safety of non-rechargeable lithium cells, batteries, and battery systems are covered by this MOPS as stand-alone items or when installed in an End Item.