U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Guidance on Testing and Installation of Rechargeable Lithium Battery and Battery Systems on Aircraft

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Initiated By: AIR-133

This advisory circular (AC) provides manufacturers and installers with an acceptable means of compliance to meet the installation, operation, maintenance and airworthiness requirements for installation of lithium batteries on aircraft (14 CFR part 21, 23, 25, 27 and 29).

If you have any suggestions for improvements or changes, you may use the template provided at the end of this AC.

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE.

1.1.1 This AC provides an acceptable means to show compliance to the airworthiness requirements for installed rechargeable lithium battery and battery systems on aircraft using standards provided in RTCA, Inc., documents RTCA DO-347 and RTCA DO-311. This AC provides guidance on how to obtain installation approval for installed rechargeable lithium battery and battery systems on aircraft.

1.1.2 The guidance in this AC is intended for manufacturers, installers, maintenance personnel, and users of installed rechargeable lithium batteries and battery systems on aircraft. As with all advisory material, this AC is not mandatory and does not constitute a regulation. It is issued for guidance purposes and to outline a means of compliance with applicable airworthiness requirements.

1.1.3 For the purpose of this AC, installed rechargeable lithium batteries and battery systems will be referred to as lithium batteries.

1.2 SCOPE.

1.2.1 Chapter 2 of this AC applies to the certification of installed lithium batteries on aircraft approved under Title 14 of the Code of Federal Regulations (14 CFR) parts 23, 25, 27, and 29 per:

1.2.1.1 Type certificates (TC),

1.2.1.2 Amended type certificates (ATC),

1.2.1.3 Supplemental type certificates (STC)

1.2.1.4 Amended supplemental type certificates (ASTC), and

1.2.1.5 Parts manufacturer approvals (PMA).

Note: The guidance can be used for any FAA process to approve the installation of lithium batteries.

1.2.2 Chapter 3 of this AC provides guidance on maintenance and operational considerations for lithium batteries on aircraft. Appendix A defines battery sizes in terms of watt hours. Appendix B lists related regulations and documents. Appendix C provides definitions. Appendix D discusses special conditions. Appendices E and F discuss means of compliance (MOC) to the special conditions. Appendix G provides a flow chart for lithium battery means of compliance certification process. Appendix H contains the AC feedback form.

1.3 Rechargeable Lithium Batteries.

1.3.1 Lithium batteries are installed in various aircraft types and serve various purposes. Lithium batteries are of different sizes, chemistries, and produced under different manufacturing processes. They are also of different levels of complexity. Some of the benefits of lithium batteries include weight savings, high energy density per unit weight and per unit volume, relatively constant voltage during discharge, good low-temperature performance, and long shelf life. Because of their high energy content and potential thermal instability, lithium batteries can present hazards if improperly designed, tested, used, and/or stored. Failure of a lithium battery, often times results in thermal runaway, which is a self-sustaining uncontrolled increase in pressure and temperature. Thermal runaway often results in fire as the flammable gases vented from the battery are ignited due to the high temperatures. In addition, the unburned vented battery gases can be toxic. Some of the uses for lithium batteries on today's aircraft include, but are not limited to:

1.3.1.1 Emergency lighting;

1.3.1.2 Cockpit voice recorders, flight data recorders, and recorder independent power supplies;

1.3.1.3 Main batteries for standby or emergency power;

1.3.1.4 Auxiliary power units (APU) or main starting batteries; and

1.3.1.5 Special functions batteries (such as installed rechargeable flashlights, electronic equipment, safety equipment, avionics equipment, and communications equipment).

1.3.2 Lithium batteries have certain failure and operational characteristics, as well as maintenance requirements, which differ significantly from those of nickel-cadmium and lead-acid rechargeable batteries. The introduction of lithium batteries into aircraft applications raises the need for additional design, installation, maintenance and monitoring requirements.

1.4 Background.

1.4.1 The proposed use of lithium batteries for equipment and systems on aircraft prompted the FAA to review the adequacy of its guidance. Our review indicates the existing guidance does not adequately address failure, operational, and maintenance characteristics of lithium batteries that could affect the safety and reliability of aircraft lithium battery installations.

1.4.2 At present, there is limited in-service experience with the use of installed rechargeable lithium battery technology in applications on aircraft. However, users of this technology from aircraft operators to personal computer users, wireless telephone manufacturers, and the electric vehicle industry have noted safety problems with lithium batteries. These known potential safety problems may result from overcharging, over-discharging, internal cell defects and flammability of cell components. In general, lithium batteries are significantly more susceptible to internal cell failures that can result in self-sustaining increases in temperature and pressure (that is, thermal runaway) than existing nickel-cadmium or lead-acid batteries. The following are examples of the possible failures of lithium batteries. These possible failures are mitigated by following the tests and validation stipulated by MOC in Appendix E and F.

1.4.2.1 Overcharging.

Overcharging causes heating and destabilization of cell components, leading to a potentially unsafe condition. The electrolyte can ignite, resulting in a self-sustaining fire or explosion. The severity of thermal runaway due to overcharging increases with increased battery capacity because of the higher amount of electrolyte.

1.4.2.2 Over-discharging.

Discharge of some types of lithium batteries beyond the manufacturer's recommended specifications can cause corrosion of the cell electrodes, resulting in loss of battery capacity that cannot be reversed by recharging. This loss of capacity may not be detected by the simple voltage measurements commonly available to flight crews as a means of checking battery status, a problem shared with nickel-cadmium batteries. In addition, over-discharging has the potential to lead to an unsafe condition (creation of dendrites that could result in internal short circuit during the recharging cycle).

1.4.2.3 Flammability of Cell Components.

Unlike nickel-cadmium and lead-acid batteries, some types of lithium batteries use liquid electrolytes that are flammable. The electrolyte can serve as a source of fire. This material can serve as a source of fuel for an external fire if a cell failure occurs. Lithium battery cells have the potential to ignite spontaneously or experience an uncontrolled temperature and pressure increase, resulting in propagation to adjacent cells

1.4.2.4 Internal Defects.

Undetected internal defects within a cell have the potential to cause an internal short circuit, which may lead to an unsafe condition. These internal defects may not become apparent until long after the battery has been placed into service.

1.4.2.5 Extreme Temperature:

Exposure to an extreme temperature environment has the potential to create major hazards. Care must be taken to ensure that the battery remains within the manufacturer's recommended specification.

CHAPTER 2. INSTALLATION OF LITHIUM BATTERIES ON AIRCRAFT

2.1 Certification Process.

This chapter provides certification guidance for the installation of lithium batteries on aircraft. Coordinate the certification program with the responsible FAA Aircraft Certification Office and directorate as described in FAA Order 8110.4, *Type Certification* or in FAA Order 8110.42, *Parts Manufacturer Approval Procedures.*

2.2 Acceptable Means of Compliance (MOC) for Installation Approval.

2.2.1 Certification Plan.

Prepare a certification plan describing all aspects of showing compliance for the installation of the lithium batteries on the aircraft. The certification plan should be submitted early in the certification process to help the ACO understand the scope of the certification project. Include the following items at a minimum:

2.2.1.1 Project description and schedule;

2.2.1.2 System description, including a description of the aircraft system interfaces and any aircraft system modifications made to accommodate the aircraft battery system installation;

2.2.1.3 A plan for system safety assessment;

2.2.1.4 Certification basis and MOC, including itemized MOC to any applicable special conditions;

2.2.1.5 Communication and coordination of the test plan(s);

2.2.1.6 Conformity plan;

2.2.1.7 A plan for instructions for continued airworthiness; and

2.2.1.8 Compliance and substantiation documentation.

2.2.2 Compliance Checklist.

2.2.2.1 Lithium battery installations must meet all applicable airworthiness regulations of the product and any applicable special condition imposed by the directorate. These installations shall also meet the guidance in this chapter and the airworthiness regulations in Table 1 at a minimum.

Table 1. Regulations Concerning Lithium Battery Installations

14 CFR Section	Subject Matter
§ 21.31	Type Design
§ 21.33	Inspection and tests
§ 21.50(b)	Instructions for Continued Airworthiness and Maintenance Manuals
§§ 23/25/27/29.301	Loads
§§ 23/25/27/29.303	Factor of Safety
§§ 23/25/27/29.305	Strength and Deformation
§§ 23/25/27/29.307	Proof of Structure
§ 25.581	Lightning Protection
§§ 27/29.610	Lightning and Static Electricity Protection.
§§ 23/25/27/29.785	Seats, Berths, Litters, Safety Belts, and Harnesses
§§ 23/25/27/29.787(b)	Baggage and Stowage Compartments
§§ 23/25/27/29.831	Ventilation (Smoke and Toxicity)
§§ 23/25/27/29.853	Compartment Interiors (Flammability)
§§ 23/25/27/29.863	Flammable Fluid Fire Protection
§ 23.867	Electrical Bonding and Lightning Protection
§ 25.869	Fire Protection: Systems
§§ 23/25/27/29.1301	Equipment Function and Installation
§§ 23/25/27/29.1309	Equipment, Systems, and Installations
§§ 25/27/29.1316	Electrical and Electronic System Lightning Protection
§§ 25/27/29.1317	High–intensity Radiated Fields (HIRF) Protection
§ 25.1322	Warning, Caution, and Advisory Lights
§§ 23/25/27/29.1351	Electrical Systems and Equipment, General
§§ 25/29.1353	Electrical Equipment and Installations
§§ 23/27.1353	Storage Battery Design and Installation

14 CFR Section	Subject Matter
§§ 25/29.1355	Distribution System
§§ 23/25/27/29.1357	Circuit Protection Devices
§23.1359	Electrical System Fire Protection
§29.1359	Electrical system fire and smoke protection.
§§ 25/29.1363	Electrical System Tests
§§ 23/27.1365	Electric Cables
§§ 23/27.1367	Switches
§§ 23/25/29.1431	Electronic Equipment
§§ 23/25/27/29.1529	Instructions for Continued Airworthiness
§§ 23/25/27/29.1541	Markings and Placards, General
§ 23.1559	Operating Limitations Placard
§§ 27/29.1559	Limitations Placard
§§ 23/25/27/29.1581	Aircraft Flight Manual, General
§§ 23/25/27/29.1583	Operating Limitations
§§ 23/25/27/29.1585	Operating Procedures

2.2.2.2 The following are additional compliance requirements pertaining to lithium batteries:

14 CFR 23/25/27 and 29.1353 do not adequately address lithium battery installation. Therefore special conditions will be mandated by the specific directorates to meet the equivalent airworthiness requirement of 14 CFR parts 23, 25, 27 and 29.

A typical special condition and intent is provided in Appendix D and a typical MOC for the special condition is provided in Appendices E and F. There may be cases where certain special conditions listed in Appendix D are not required. Each directorate should verify the applicability of these acceptable means of compliance for their respective products based on risk.

2.3 **Test Requirements.**

2.3.1 Environmental Test Requirements.

2.3.1.1 Lithium battery systems on aircraft must meet environmental qualification standards in:

2.3.1.1.1 RTCA/DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment*, dated December 8, 2010, or the most recent revision;

2.3.1.1.2 RTCA DO-347, *Certification Test Guidance for Small and Medium Rechargeable Lithium Batteries and Battery Systems*, dated December 18, 2013; and

2.3.1.1.3 RTCA DO-311, *Minimum Operational Performance Standards for Rechargeable Lithium Battery Systems*, dated March 13, 2008, or the most recent revision.

2.3.1.2 These environmental tests are representative of the conditions the battery system may encounter during its life cycle. Consider the following areas when determining the scope and type of environmental tests:

2.3.1.2.1 Equipment configuration,

2.3.1.2.2 Installation-specific environment encountered on in-service platforms,

2.3.1.2.3 Duration of exposure periods,

2.3.1.2.4 Geographical locations, and

2.3.1.2.5 Frequency of environmental occurrences alone or in combination.

2.3.2 Means of Compliance: Testing and Validation.

Follow the guidance in Appendix E to this AC for small and medium lithium batteries, and the guidance in Appendix F for large lithium batteries, to show compliance to the requirements of the airworthiness regulations and any special conditions imposed by the directorates. Ground tests should be performed to demonstrate that the lithium batteries installed on the aircraft will perform safely as intended. Flight tests may be required for conditions not demonstrated during ground tests.

2.4 System Safety Assessment.

2.4.1 Perform a system safety assessment to show compliance with §§ 23/25/27/29.1309 and any applicable special condition. This assessment should address concerns associated with the installation of the lithium batteries and battery systems, the possibility of direct (or indirect) injury to a person, any adverse effect on crew function, or any adverse effect on other equipment and systems. These effects could be a result of normal operation or a failure in the lithium batteries. Your system safety assessment should consider, but not be limited to, the following:

2.4.1.1 The levels of hazard associated with installation and use of the lithium battery:

2.4.1.2 Rationale addressing the lithium battery installation design assurance level as appropriate for performance and safety requirements based on location and intended function;

2.4.1.3 Ensure no interference due to any failures of the lithium battery;

2.4.1.4 System separation and zonal analysis;

2.4.1.5 Impact on flight crew and egress procedures;

2.4.1.6 Protection against fire, smoke, and electrical shock hazards;

2.4.1.7 Other safety analysis appropriate to the system being installed; and

2.4.1.8 Statement of compliance for each requirement identified by the SSA and each mitigating design feature in order to comply with XX.1309. You can find additional guidance in the following ACs:

2.4.1.8.1 AC 25.1309-1A, System Design and Analysis;

2.4.1.8.2 AC 29-2C, Certification of Transport Category Rotorcraft;

2.4.1.8.3 AC 27-1B, Certification of Normal Category Rotorcraft; and,

2.4.1.8.4 AC 23.1309-1E, System Safety Analysis and Assessment for Part 23 Airplanes.

2.4.2 Coordinate your assessment with the responsible FAA Aircraft Certification Office to determine the depth of analysis required. Include a system description, a description of how the system is installed on the aircraft, and a list of functions and criticality. You can find additional guidance in Appendix B to this AC.

2.4.3 The safety assessment of the lithium batteries installation should address the battery system, the aircraft interface, and the aircraft functional loads to which the battery system provides power.

2.5 **Software.**

AC 20-115C, Airborne Software Assurance, defines an acceptable means for showing compliance with the applicable airworthiness regulations for the software aspects of airborne systems and equipment certification.

2.6 **Complex Electronic Hardware.**

Any lithium batteries hardware containing complex electronic hardware should comply with the most recent revision of RTCA/DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*, and AC 20-152.

2.7 **Health Monitoring.**

Lithium batteries should be stored in accordance with the manufacturer's recommendations for state of charge and temperature; consideration should be provided for any monitoring circuitry that may drain the battery during the storage period. Additionally, overcharging of individual cells could lead to thermal runaway. Health monitoring of lithium batteries needs to be taken into account during testing and certification to ensure that proper state of charge can be maintained.

2.8 **Flammability.**

Aircraft batteries must meet the applicable flammability requirements of §§ 23/25/27/29.853, 23/25/27/29.863, and 25.869 that ensure the protection of structure and critical systems. Test the materials to ensure they meet applicable requirements of §§ 23/25/27/29.853, 23/25/27/29.863, and 25.869.

The FAA Aircraft Materials Fire Test Handbook, DOT/FAA/AR-00/12, describes an acceptable means of compliance with 14 CFR part 25, Appendix F. If thermal and acoustic insulation material is used as part of the battery equipment and exposed, the requirements of § 25.856(a), Appendix F, part VI, at amendment 25-111 (or later amendment) must be met. Refer to the test methods described by AC 25.856-1, *Thermal/Acoustic Insulation Flame Propagation Test Method Details*.

2.9 **Instructions for Continued Airworthiness (ICA).**

2.9.1 During the certification process of the lithium batteries, complete the ICA in accordance with the following as applicable to the certification basis of the product:

2.9.1.1 14 CFR part 21.50(b);

2.9.1.2 14 CFR part 23/25/27/29.1529;

2.9.1.3 14 CFR parts 25.1709 and 25.1729;

2.9.1.4 14 CFR part 23, Appendix G;

2.9.1.5 14 CFR part 25, Appendix H;

2.9.1.6 14 CFR parts 27/29, Appendix A; and

2.9.1.7 FAA Order 8110.54, *Instructions for Continued Airworthiness, Responsibilities, Requirements, and Contents*.

2.9.2 Develop the ICA so it is compatible with other maintenance instructions for the aircraft.

2.9.3 Refer to chapter 3 of this AC for additional details specific to the maintenance of lithium batteries on aircraft.

2.9.4 The ICA must contain an “Airworthiness Limitations” section if deemed necessary. The Airworthiness Limitations section is FAA-approved and specifies maintenance required under §§ 43.16 and 91.403, unless the FAA has approved an alternative program.

2.9.5 The ICA should also include, but are not limited to, the following information:

2.9.5.1 Specifics of the lithium batteries installation, including individual component part numbers and any other unique installation requirements;

2.9.5.2 Electrical wiring diagrams/schematics, electrical equipment drawing;

2.9.5.3 Maintenance instructions, basic control and operation, testing, servicing, maintenance schedule, inspection, troubleshooting, removing and replacing parts, repairs, special tools, fixtures and equipment, component manual; and

2.9.5.4 Configuration control, storage instructions.

2.9.6 The ICA must contain the recommended manufacturer's maintenance and inspection requirements to ensure the batteries whose function is required for safe operation of the aircraft will perform their intended function as long they are installed in the aircraft. The ICA must contain:

2.9.6.1 Operating instructions and equipment limitations in an installation maintenance manual.

2.9.6.2 Installation procedures and limitations sufficient to ensure cells or batteries, when installed according to the installation procedures, still meet the airworthiness requirements of the aircraft. The limitations must identify any unique aspects of the installation.

2.9.6.3 Maintenance requirements for measurements of battery capacity at appropriate intervals will be performed to ensure the batteries, whose function is required for safe operation of the aircraft, will continue to meet their intended function as long as they are installed in the aircraft.

2.9.6.4 Scheduled servicing information to replace batteries per the manufacturer's recommendations.

2.9.6.5 Maintenance and inspection requirements to visually check for a battery and/or charger degradation.

2.9.7 The ICA should also contain maintenance procedures for lithium batteries in spares storage to prevent the replacement of batteries with batteries that have experienced degraded charge retention ability or other damage due to prolonged storage.

2.9.8 The ICA must contain instructions to replace batteries based on the lithium batteries original equipment manufacturer (OEM) maintenance manual.

2.9.9 Replacement of individual cells within lithium batteries must be approved by the lithium battery's OEM and the FAA. Mixing of cells from different manufacturers within a lithium battery is not permitted unless an alternate means proposed by the lithium batteries OEM and approved by the FAA exist.

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CHAPTER 3. MAINTENANCE AND OPERATIONAL CONSIDERATIONS FOR LITHIUM BATTERY SYSTEMS

3.1 **Aircraft Battery Maintenance**.

At a minimum, follow the battery Original Equipment Manufacturer's (OEM) instructions because maintenance and inspection requirements for aircraft lithium batteries vary with the type of chemical technology and physical construction. Performance of lithium batteries at any time in a given installation will depend on several factors that include, but are not limited to the following:

3.1.1 Lithium Battery Chemistry.

The electrolyte and cathode materials used in lithium batteries can be a highly reactive substance; therefore, care must be exercised to maintain them in accordance with their OEM maintenance manual.

3.1.2 Age.

To determine the life and age of the lithium battery, record the manufacturing and/or installation date of the battery. During normal battery maintenance, document battery age in either the aircraft maintenance log or the shop maintenance log. Do not keep batteries in service longer than recommended by the lithium battery manufacturer.

3.1.3 State of Charge.

State of charge of the lithium battery will be determined by the cumulative effect of charging and discharging the battery. Safeguards must be implemented to ensure the aircraft does not begin flight with a battery not sufficiently charged to accomplish the intended function of the lithium battery.

3.1.4 State of Health.

Follow OEM instructions. The following list may be useful considerations:

3.1.4.1 Length of time the battery has been in service,

3.1.4.2 Environmental factors (such as excessive heat or cold), and

3.1.4.3 Observed failures (such as low voltage under load).

3.1.4.4 Appropriate battery performance measurements as specified by the battery manufacturer such as capacity, voltage, internal resistance, etc.

3.1.5 Mechanical Integrity.

To ensure proper mechanical integrity, the battery must be installed and connected correctly and be free of any physical damage. The buildup of explosive gases can be avoided by incorporating battery and battery compartment venting systems. Check periodically to ensure the venting system is securely connected and oriented in accordance with the maintenance manual's installation procedures. Follow the procedures approved for the specific aircraft and battery system to ensure the battery system is capable of delivering specified performance. The venting system should take into account specific installation requirements of the aircraft and battery manufacturer.

3.1.6 Reliability of Charging/Monitoring Systems.

Follow the manufacturer's recommendation for maintenance inspections concerning the battery charging and monitoring systems.

3.1.7 Shop-Level Maintenance Procedures.

Shop procedures must follow the lithium battery manufacturer's recommendations.

3.1.8 Aircraft Battery Inspection.

Evidence of battery failure can sometimes be detected by a visual inspection. Manufacturer-recommended inspections should include, but not be limited to, the following actions:

3.1.8.1 Inspect battery terminals and all other connections for evidence of corrosion, pitting, arcing, and burns. Clean as required.

3.1.8.2 Inspect the battery for improper installation (loose terminal screws, battery terminal links, or connector).

3.1.8.3 Inspect the battery mounting.

3.1.8.4 Inspect for evidence of physical damage including heat damage/discoloration.

3.1.9 Batteries in a rotating stock must be functionally checked at the manufacturer's recommended inspection intervals. Some failure modes may include degraded charge retention capability, settling of particulates, or other damage due to prolonged storage. Batteries in rotating stock may also require periodic servicing per the manufacturer's instructions.

3.2 **Aircraft Battery Replacement.**

3.2.1 Make sure replacement batteries are in airworthy condition. Refer to the battery manufacturer maintenance manuals for proper maintenance of lithium batteries. Refer to the aircraft maintenance procedures for replacement of lithium batteries.

3.2.2 The ICA should include the manufacturer's recommendations for the battery mandatory replacement schedule and periodic maintenance.

3.2.3 Installation of lithium batteries differs from aircraft system to aircraft system. Refer to the applicable aircraft manuals to remove and install batteries.

3.2.4 When replacing batteries, check for corrosion and moisture on the battery interfaces.

3.2.5 When replacing batteries, check for short circuit to battery case such as insulation resistance test.

3.2.6 The maintenance record should reflect all battery replacements. Record the expiration date of the battery.

3.2.7 The lithium batteries should be replaced with an approved battery for the specific aircraft application.

3.2.8 Deep discharge may result in a potentially unsafe condition. Replace the battery based on the manufacturer's recommendation.

3.3 **Aircraft Battery Storage and Handling.**

3.3.1 Storage requirements can vary with the battery type, so follow the manufacturer's recommended storage procedures to achieve the best results.

3.3.2 Record the date of charging. If the battery is not used within the manufacturer's recommended interval, service the battery per the manufacturer's recommendation.

3.3.3 To maintain battery integrity, follow the manufacturer's recommendation for charged batteries being held in "ready for service" areas.

3.3.4 Handling procedures and precautions vary with battery size and configuration. Follow the manufacturer's recommendation to prevent mishandling of the battery.

3.3.5 Follow the manufacturer's recommendation procedure to prevent electrostatic discharge during storage and handling.

3.3.6 For packaging and shipping, follow the manufacturer's recommended procedures.

3.3.7 Check batteries before use for any leakage or deformity. Do not use the batteries if there is any evidence of leakage or deformity.

3.3.8 Aircraft vibration and/or contact oxidation can result in poor electrical connections. Ensure proper connector maintenance procedures are followed.

3.3.9 Observe the following precautions when handling lithium batteries:

3.3.9.1 Do not store lithium batteries with other hazardous or combustible materials.

3.3.9.2 Do not heat or incinerate lithium batteries.

3.3.9.3 Do not dispose of lithium batteries with other waste unless allowed by applicable regulations.

3.3.9.4 Use special care in handling lithium batteries. Do not open, puncture, crush, disassemble, or subject batteries to physical abuse.

3.3.10 Lithium batteries can be a personal safety hazard due to the possibility of lethal shock and must be labeled to clearly indicate the hazard.

3.3.11 Follow all manufacturer's recommended safety precautions and procedures.

3.3.12 Material Safety Data Sheets must be enclosed with lithium batteries for shipping. Follow all original equipment manufacturer's recommended specifications.

APPENDIX A. DEFINITION OF SIZE IN TERMS OF WATT HOURS (WH) ON LITHIUM BATTERY AND BATTERY SYSTEMS

Table A-1

Installed Very Small, Small, Medium, and Large Size Rechargeable Lithium-Battery and Battery System Categories Means of Compliance

Battery Size	Single-Cell Battery Electrical Energy (Wh)*	Multi -Cell Battery Electrical Energy (Wh)*	Acceptable Means of Compliance
Very Small	**Wh < 2**	**Wh < 2**	Very small batteries include most button cells. No further testing is required if they have already met the requirements of **UL 1642, UL 2054, or IEC 62133**. Otherwise, they shall be tested to the requirements of small batteries in the next row (refer to Appendix E of this AC).
Small/Medium	**2 ≤ Wh < 60**	**2 ≤ Wh < 300**	***RTCA DO-347, Certification Test Guidance for Small and Medium Sized Rechargeable Lithium Batteries and Battery Systems***, provides guidance for an acceptable means of compliance to each of the special condition requirements (refer to Appendix E of this AC). In addition to the testing of Appendix E, compliance with all other applicable airworthiness requirements is required. Compliance test plans and results are required. A Functional Hazard Assessment, System Safety Assessment, Fault Tree Analysis and /or Failure Modes and Effects Analysis, as applicable, must be accomplished per 14 CFR 23/25/27/29.1309 and 25.1709. Coordinate this evaluation with the Aircraft Certification Office as early as possible for the project.
Large	**Wh ≥ 60**	**Wh ≥ 300**	***RTCA DO-311, Minimum Operational Performance Standards for Rechargeable Lithium Battery Systems and selected sections of RTCA DO-347, Certification Test Guidance for Small and Medium Sized Rechargeable Lithium Batteries and Battery Systems***, provides guidance for an acceptable means of compliance to each of the special condition requirement (refer to Appendix F of this AC) regardless of the installation location and intended function of the battery and battery system. In addition to the testing of Appendix F, compliance with all other applicable airworthiness requirements is required. A system safety assessment must be accomplished per 14 CFR 23/25/27/29.1309 and 25.1709. Coordinate this evaluation with the Aircraft Certification Office as early as possible for the project.

***A Watt hour (Wh) is defined as the rated capacity (in ampere-hours, Ah) times the nominal battery voltage.**

Note: When approved and published by RTCA, DO-311A, *Minimum Operational Performance Standards for Rechargeable Lithium Battery Systems***,** can also be used to provide compliance to the special conditions in lieu of Appendix E and F in this AC. Coordinate with the cognizant ACO and directorate if you would like to use this alternate means of compliance to the special conditions.

APPENDIX B. RELATED REGULATIONS AND DOCUMENTS

B.1 Regulations

14 CFR Part 21	Certification Procedures for Products and Parts
14 CFR Part 23	Airworthiness Standards: Normal Utility, Acrobatic, and Commuter Category Airplanes
14 CFR Part 25	Airworthiness Standards: Transport Category Airplanes
14 CFR Part 27	Airworthiness Standards: Normal Category Rotorcraft
14 CFR Part 29	Airworthiness Standards: Transport Category Rotorcraft
14 CFR Part 43	Maintenance, Preventive Maintenance, Rebuilding, and Alteration
14 CFR Part 145	Repair Stations

B.2 Advisory Circulars

AC 20-136B	Protection of Aircraft Electrical/Electronic Systems Against Indirect Effects of Lightning
AC 20-152	RTCA/DO-254 Design Assurance Guidance for Airborne Electronic Hardware
AC 20-158A	The Certification of Aircraft Electrical and Electronic Systems for Operation in the High Intensity Radiated Fields (HIRF) Environment
AC 21-16G	RTCA Document DO-160 versions D, E, F, and G, "Environmental Conditions and Test Procedures for Airborne Equipment"
AC 23.1309-1E	System Safety Analysis and Assessment for Part 23 Airplanes

AC 23-17C	Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships
AC 25.1309-1A	System Design and Analysis
AC 25-16	Electrical Fault, Fire Prevention and Protection
AC 25-1581-1	Airplane Flight Manual
AC 27-1B, Change 1	Certification of Normal Category Rotorcraft
AC 29-2C, Change 1	Certification of Transport Category Rotorcraft
AC 120-16	Air Carrier Maintenance Programs
AC 120-42A	Extended Range Operation with Two Engine Airplanes (ETOPS)
AC 43.13-1B	Acceptable Methods, Techniques and Practices, Aircraft Inspection, and Repairs
AC 43.13-2A	Acceptable Methods, Techniques, and Practices – Aircraft Alterations
AC 20-115C	Airborne Software Assurance

B.3 **Orders and Handbooks**

FAA Order 8110.4	Type Certification
FAA Order 8110.42	Parts Manufacturer Approval Procedures
FAA Order 8110.54	Instructions for Continued Airworthiness, Responsibilities, Requirements, and Content
FAA Aircraft Materials Fire Test Handbook	http://www.fire.tc.faa.gov/handbook.stm

B.4 **Other**

DOT/FAA/AR-04/26	Flammability Assessment of Bulk-Packed, Non-rechargeable Lithium Primary Batteries in Transport Category Aircraft, June 2004
TSO-C179a	Permanently Installed Rechargeable Lithium Cells, Batteries and battery Systems.

B.5 **Industry Documents**

Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 4754	Certification Considerations for Highly-Integrated or Complex Aircraft Systems
SAE ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
RTCA DO-178C	Software Considerations in Airborne Systems and Equipment Certification
RTCA DO-254	Design Assurance Guidance for Airborne Electronic Hardware
RTCA DO-311	Minimum Operational Performance Standards for Rechargeable Lithium Battery (Systems)
RTCA DO-347	Certification Test Guidance for Small and Medium Rechargeable Lithium Batteries and Battery Systems
RTCA DO-160G	Environmental Conditions and Test Procedures for Airborne Equipment

APPENDIX C. TERMS AND DEFINITIONS

C.1.1 For purposes of this AC, the following definitions apply:

C.1.2 Airworthiness. The compliance of a battery or part thereof with all conditions and regulations required by the regulatory authorities for their safe operation and performance in an airborne environment.

C.1.3 Battery Cell. In a battery, a cell is a single energy or charge-storing unit within a pack of one or more cells that form the battery. Each cell has a voltage rating that is combined with the other cells' voltages to form the overall battery voltage rating.

C.1.4 Battery. One or more electrically connected cells, assembled in a single container having positive and negative terminals. A battery may include inter-cell connectors and protective and other devices.

C.1.5 Battery System. One or more electrically connected batteries that provide power to equipment. A battery system may include a charger, controlling circuitry and means for monitoring of battery temperature, battery state, and current as well as system testing and related functions.

C.1.6 Charged Battery. A battery that has been fully charged in accordance with the battery manufacturer's instructions or as defined in the design documentation.

C.1.7 Continued Safe Flight and Landing. The aircraft is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. Upon landing, some aircraft damage may occur as a result of a failure condition.

C.1.8 Failure. An occurrence that affects the operation of a component, part, or element such that it can no longer function as intended (this includes both loss of function and malfunction). Note: Errors may cause Failures, but are not considered to be Failures.

C.1.9 Primary (Non-Rechargeable) Versus Secondary (Rechargeable) Battery. One of the basic differences among battery types is whether the battery is to be used once or is to be recharged. Batteries that are used and discarded are known as primary or non-rechargeable. Batteries that can be used repeatedly are known as secondary or rechargeable.

C.1.10 Redundancy. The presence of more than one independent means for accomplishing a given function or flight operation.

C.1.11 Serviced Battery. A battery that has been fully prepared and maintained in accordance with the manufacturer's instructions or as defined in the design documentation.

C.1.12 Service Life. The maximum combined shelf life and installed life of an undischarged cell or battery. Service life will be stated by the equipment manufacturer. The end of service life is indicated by a “replace-by” or expiration date. Service life is equivalent to useful life.

C.1.13 Shelf Life. The maximum period at which an undischarged cell or battery stored under standard conditions retains 80 percent of rated ampere-hour capacity. The cell/battery manufacturer specifies shelf life.

C.1.14 System. A combination of components, parts, and elements, which are interconnected to perform one or more functions.

APPENDIX D. TYPICAL SPECIAL CONDITION (SC) AND INTENT FOR EACH SC FOR PARTS 23, 25, 27, AND 29

Special Condition Requirement #1:

Safe cell temperatures and pressures must be maintained during any foreseeable charging or discharging condition and during any failure of the charging or battery monitoring system not shown to be extremely remote. The rechargeable lithium battery installation must preclude explosion in the event of those failures.

The intent of this SC requirement:

The cells within the lithium battery system shall be designed to minimize the impact of self-sustained, uncontrolled increases in cell temperature or pressure, as a result of any foreseeable charging or discharging condition. The probability of this event must be shown to be extremely remote (1 event in 10 million ($1x10^{-7}$) flight hours). It must preclude explosion in the event of any failure.

Special Condition Requirement #2:

Design of the rechargeable lithium batteries must preclude the occurrence of self-sustaining, uncontrolled increases in temperature or pressure.

The intent of this SC requirement:

The lithium battery system shall be designed to minimize the impact of self-sustained, uncontrolled increases in temperature or pressure, as a result of any failure within the battery. The probability of impact must be extremely improbable (1 event in 1 billion ($1x10^{-9}$) flight hours).

Special Condition Requirement #3:

No explosive or toxic gases emitted by any rechargeable lithium battery in normal operation, or as the result of any failure of the battery charging system, monitoring system, or battery installation which is not shown to be extremely remote, may accumulate in hazardous quantities within the aircraft.

The intent of this SC requirement:

The battery system shall not emit any explosive or toxic gases, smoke, or fluids during normal operation except through designed venting provisions.

Battery systems shall be capable of containing or safely relieving the maximum pressure buildup that can occur under worst-case failure conditions. If the battery system is not capable of containing the maximum pressure, then the appropriate provisions shall be included to safely relieve pressure from the battery. Emissions shall only escape through designed pressure relief provisions.

Hazardous emissions may be flammable, explosive, corrosive, or toxic in certain concentrations. The installer should work with the manufacturer to quantify and mitigate the effects of hazardous emissions. Ensure that the aircraft installation is compatible with the emissions and temperatures that the battery or battery system may generate during any failure condition.

Accommodate any venting provisions on the battery or battery system as applicable. Provide containment of electrolyte leakage, toxic or explosive gases, and debris as applicable.

The probability of this failure must be shown to be extremely remote (1 event in 10 million ($1x10^{-7}$) flight hours).

Special Condition Requirement #4:

Installations of rechargeable lithium batteries must meet the requirements of Title 14 of the Code of Federal Regulations (14 CFR) 23/25/27/29.863(a) through (d) for parts 23, 25, 27, and 29.

The intent of this SC requirement:

Internal and external materials of the rechargeable lithium battery and battery system shall meet the applicable certification flammability requirements of the installation. They must meet the requirements of §§ 23/25/27/29.863(a) through (d).

Special Condition Requirement #5:

For Part 23:

No corrosive fluids or gases that may escape from any rechargeable lithium battery may damage surrounding structure or any adjacent systems, equipment, or electrical wiring of the airplane in such a way as to cause a major or more severe failure condition, in accordance with § 23.1309(c) and applicable regulatory guidance.

The intent of this SC requirement:

There shall be no damage to surrounding structure or any adjacent systems, equipment, or electrical wiring from the fluids or gases emitted from the battery. The design assurance level (DAL) must meet the requirement of § 23.1309(c) and any other applicable airworthiness regulations.

For Part 25:

No corrosive fluids or gases that may escape from any rechargeable lithium battery may damage surrounding structure or any adjacent systems, equipment, or electrical wiring of the airplane in such a way as to cause a major or more severe failure condition, in accordance with § 25.1309(b) and applicable regulatory guidance.

The intent of this SC requirement:

There shall be no damage to surrounding structure or any adjacent systems, equipment, or electrical wiring from the fluids or gases emitted from the battery. The DAL must meet the requirement of § 25.1309(b) and any other applicable airworthiness regulations.

For Part 27:

No corrosive fluids or gases that may escape from any rechargeable lithium battery may damage surrounding structure or any adjacent systems, equipment, or electrical wiring of the rotorcraft in such a way as to cause a major or more severe failure condition, in accordance with § 27.1309(b) and (c), and applicable regulatory guidance.

The intent of this SC requirement:

There shall be no damage to surrounding structure or any adjacent systems, equipment, or electrical wiring from the fluids or gases emitted from the battery. The DAL must meet the requirement of § 27.1309(b) and (c), and any other applicable airworthiness regulations.

For Part 29:

No corrosive fluids or gases that may escape from any rechargeable lithium battery may damage surrounding structure or any adjacent systems, equipment, or electrical wiring of the rotorcraft in such a way as to cause a major or more severe failure condition, in accordance with § 29.1309(b) and applicable regulatory guidance.

The intent of this SC requirement:

There shall be no damage to surrounding structure or any adjacent systems, equipment, or electrical wiring from the fluids or gases emitted from the battery. The DAL must meet the requirement of § 29.1309(b) and any other applicable airworthiness regulations.

Special Condition Requirement #6:

Each rechargeable lithium battery installation must have provisions to prevent any hazardous effect on structure or essential systems caused by the maximum amount of heat the battery can generate during a short circuit of the battery or of its individual cells.

The intent of this SC requirement:

The lithium battery system shall be designed to minimize the impact of self-sustained, uncontrolled increases in temperature or pressure, as a result of cell failures (for example, internal cell short circuit) or a short circuit of the battery. It shall prevent any hazardous effect on adjacent or nearby structures or essential systems during this failure.

Special Condition Requirement #7:

The lithium battery system must have a capability to control the charging rate of the battery automatically, so as to prevent battery overheating or overcharging, and either—

(i) A battery temperature sensing and over-temperature warning system with a means for automatically disconnecting the battery from its charging source in the event of an over-temperature condition, or

(ii) A battery failure sensing and warning system with a means for automatically disconnecting the battery from its charging source in the event of battery failure.

The intent of this SC requirement:

The rechargeable lithium battery or battery system shall have protective features to prevent unsafe conditions during operation.

The monitoring and protective system shall control the charging rate of the battery automatically in order to prevent any overcharging or overheating. This includes automatically disconnect charging when this particular fault occurs.

Special Condition Requirement #8:

Any rechargeable lithium battery installation, the function of which is required for safe operation of the aircraft, must incorporate a monitoring and warning feature that will provide an indication

to the appropriate flight crewmembers whenever the state-of-charge of the batteries has fallen below levels considered acceptable for dispatch of the aircraft.

The intent of this SC requirement:

Any aircraft that uses a lithium battery or battery system whose function is necessary for safe operation shall require the incorporation of a monitoring and warning feature that will provide an accurate indication to the appropriate flight crewmembers whenever the state-of-charge of the batteries has fallen below levels considered acceptable for dispatch of the aircraft.

Special Condition Requirement #9:

The instructions for continued airworthiness required by §§ 23/25/27/29.1529 must contain maintenance requirements to assure that the battery is sufficiently charged at appropriate intervals specified by the battery manufacturer and the equipment manufacturer that contain the rechargeable lithium battery or rechargeable lithium battery system. This is required to ensure that lithium rechargeable batteries and lithium rechargeable battery systems will not degrade below specified ampere-hour levels sufficient to power the aircraft system, for intended applications. The instructions for continued airworthiness must also contain procedures for the maintenance of batteries in spares storage to prevent the replacement of batteries with batteries that have experienced degraded charge retention ability or other damage due to prolonged storage at a low state of charge. Replacement batteries must be of the same manufacturer and part number as approved by the FAA. Precautions should be included in the instructions for continued airworthiness maintenance instructions to prevent mishandling of the rechargeable lithium battery and rechargeable lithium battery systems, which could result in short-circuit or other unintentional impact damage caused by dropping or other destructive means that could result in personal injury or property damage.

The intent of this SC requirement:

The ICA shall contain maintenance requirements to assure proper maintenance and operation of the rechargeable lithium batteries and battery system. All the above-mentioned requirements must be addressed including any mandatory requirement listed in the Airworthiness Limitation Section of the ICA, if applicable. Use Order 8110.54 as guidance for the compliance to this requirement.

APPENDIX E. MOC FOR SMALL AND MEDIUM LITHIUM BATTERIES (USING RTCA DO-347 MOPS)

Provide the following information to the applicable Aircraft Certification Office along with your compliance data:

Acceptable Means of Compliance for Special Condition Requirement #1:

a) Provide a list of all design features that show compliance to requirement #1.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date, and test number that show compliance to requirement #1.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

1.5.2 Charging and Discharging Protection

1.5.3 Mitigation of Cell Failure Effects

1.5.5 Flammability

1.6 Design Criteria

1.7 Design Guidelines

2.1 Test Conditions and Apparatus

2.3.7 Short-circuit Test of a Cell

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.10 Insulation Resistance Test

2.3.12 Deep Discharge Test

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.5 Additional Equipment Installation Considerations

Acceptable Means of Compliance for Special Condition Requirement #2:

a) Provide a list of all design features that show compliance with requirement #2.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #2.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

1.5.1 Battery Protective Features

1.5.2 Charging and Discharging Protection

1.5.5 Flammability

1.5.7 Environmental Qualification

1.6 Design Criteria

1.7 Design Guidelines

2.1 Test Conditions and Apparatus

2.3.2 Constant Voltage Discharge Test for High Rate Batteries

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.10 Insulation Resistance Test

2.3.11 Duty Cycle Test for High Rate Batteries

2.3.12 Deep Discharge Test

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.5 Additional Equipment Installation Considerations

3.2 Safety Considerations for Installed Equipment

Acceptable Means of Compliance for Special Condition Requirement #3:

a) Provide a list of all design features that show compliance with requirement #3.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #3.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

1.5.4 Battery Emissions

1.5.5 Flammability

1.5.7 Environmental Qualification

1.6.2 Venting Provisions. For a Small/Medium battery, it is acceptable to vent into the surrounding battery container if meeting the provisions of this section.

2.1 Test Conditions and Apparatus

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.3 Hazardous Battery Emissions

3.1.5 Additional Equipment Installation Considerations

Acceptable Means of Compliance for Special Condition Requirement #4:

a) Provide a list of all design features that show compliance with requirement #4.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #4.

c) Because lithium batteries and battery systems contain high energy which can be a source of flammable fluid, applicants must show compliance with 23/25/27/29.863.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

1.5.5 Flammability

1.5.7 Environmental Qualification

2.6 Environmental Qualification Requirements

Acceptable Means of Compliance for Special Condition Requirement #5:

a) Provide a list of all design features that show compliance with requirement #5.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #5.

c) Because lithium batteries and battery systems contain high energy which can be a source of flammable fluid, applicants must show compliance with 23/25/27/29.863.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

1.5.1 Battery Protective Features

1.5.4 Battery Emissions

1.5.7 Environmental Qualification

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.3 Hazardous Battery Emissions

3.1.5 Additional Equipment Installation Considerations

3.2 Safety Considerations for Installed Equipment

Acceptable Means of Compliance for Special Condition Requirement #6:

a) Provide a list of all design features that show compliance with requirement #6.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #6.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

1.5.1 Battery Protective Features

1.5.2 Charging and Discharging Protection

1.5.5 Flammability

1.5.7 Environmental Qualification

1.6 Design Criteria

1.7 Design Guidelines

2.1 Test Conditions and Apparatus

2.3.2 Constant Voltage Discharge Test for High Rate Batteries

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.10 Insulation Resistance Test

2.3.11 Duty Cycle Test for High Rate Batteries

2.3.12 Deep Discharge Test

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.5 Additional Equipment Installation Considerations

3.2 Safety Considerations for Installed equipment

Acceptable Means of Compliance for Special Condition Requirement #7:

a) Provide a list of all design features that show compliance with requirement #7.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #7.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

1.5.1 Battery Protective Features

1.5.2 Charging and Discharging Protection

1.7.2 Built-In-Test.

1.7.3 Prevention from Back Charging

2.3.12 Deep Discharge Test

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.5.1 Software

2.5.2 Hardware

2.6 Environmental Qualification Requirements

Acceptable Means of Compliance for Special Condition Requirement #8:

a) Provide a list of all design features that show compliance with requirement #8.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #8.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

2.3.1 Rated Capacity Test

2.3.4 Charge Retention Test

2.3.5 Shelf Life Test

2.3.6 Float Life Test

2.3.10 Insulation Resistance Test

2.3.12 Deep Discharge Test

2.5.1 Software

2.5.2 Hardware

3.1.1 Warning System

Acceptable Means of Compliance for Special Condition #9:

a) Provide a copy of the ICA.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-347 document design and test sections:

1.5.6 Instructions for Continued Airworthiness

2.3.4 Charge Retention Test

2.3.5 Shelf Life Test

2.3.6 Float Life Test

APPENDIX F. MOC FOR LARGE LITHIUM BATTERIES AND BATTERY SYSTEMS (USING RTCA DO-311 AND SOME TESTS OF DO-347 MOPS)

Provide the following information to the applicable Aircraft Certification Office along with your compliance data:

Acceptable Means of Compliance for Special Condition #1:

a) Provide a list of all design features that show compliance to requirement #1.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #1.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following DO-311 and listed RTCA DO-347 test:

RTCA DO-311 sections

1.5.2 Precautions during charging and discharging

1.5.3 Prevention of Thermal Runaway

1.5.6 Charging and Protection

1.5.10 Design of Protection Circuits

2.3.15 Duty Cycle Performance (for engine start batteries only)

RTCA DO-347 sections

1.5.2 Charging and Discharging Protection

1.5.3 Mitigation of Cell Failure Effects

1.5.5 Flammability

1.6 Design Requirements

1.7 Design Guidelines

2.1 Test Conditions and Apparatus

2.3.7 Short-circuit Test of a Cell

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.10 Insulation Resistance Test

2.3.12 Deep Discharge Test

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.5 Additional Equipment Installation Considerations

Acceptable Means of Compliance for Special Condition #2:

a) Provide a list of all design features that show compliance with requirement #2.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #2.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-311 and selected section of DO-347 document design and test sections:

RTCA DO-311 sections

1.5.2 Precautions during charging and discharging

1.5.3 Prevention of Thermal Runaway

1.5.6 Charging and Protection

1.5.10 Design of Protection Circuits

2.3.15 Duty Cycle Performance (for engine start batteries only)

2.3.18 Overcharge with Protection Enabled Test

RTCA DO-347 sections

1.5.1 Battery Protective Features

1.5.2 Charging and Discharging Protection

1.5.5 Flammability

1.5.7 Environmental Qualification

1.6 Design Criteria

1.7 Design Guidelines

2.1 Test Conditions and Apparatus

2.3.2 Constant Voltage Discharge Test for High Rate Batteries

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.10 Insulation Resistance Test

2.3.11 Duty Cycle Test for High Rate Batteries

2.3.12 Deep Discharge Test

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.5 Additional Equipment Installation Considerations

3.2 Safety Considerations for Installed Equipment

Acceptable Means of Compliance for Special Condition #3:

a) Provide a list of all design features that show compliance with requirement #3.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #3.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following RTCA DO-311 and selected section of DO-347 document design and test sections:

RTCA DO-311 sections

1.5.2 Precautions during charging and discharging

1.5.3 Prevention of Thermal Runaway

1.5.6 Charging and Protection

1.5.10 Design of Protection Circuits

1.9.6 Vent Mechanism

2.3.15 Duty Cycle Performance (for engine start batteries only)

2.3.18 Overcharge with Protection Enabled Test

RTCA DO-347 sections

1.5.4 Battery Emissions

1.5.5 Flammability

1.5.7 Environmental Qualification

1.6.2 Venting Provisions

2.1 Test Conditions and Apparatus

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.3 Hazardous Battery Emissions

3.1.5 Additional Equipment Installation Considerations

Acceptable Means of Compliance for Special Condition #4:

a) Provide a list of all design features that show compliance with requirement #4.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #4.

c) Applicants must show compliance with 14 CFR 23/25/27/29.863 because lithium batteries and battery systems contain high energy which can be a source of flammable fluid.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following DO-311 and listed RTCA DO-347 test:

RTCA DO-311 sections

1.5.3 Prevention of Thermal Runaway

1.5.6 Charging and Protection

1.5.10 Design of Protection Circuits

1.9.6 Vent Mechanism

RTCA DO-347 sections

1.5.5 Flammability

1.5.7 Environmental Qualification

2.6 Environmental Qualification Requirements

Acceptable Means of Compliance for Special Condition 5:

a) Provide a list of all design features that show compliance with requirement #5.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #5.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following DO-311 and RTCA DO-347 document design and test sections:

RTCA DO-311 sections

1.5.3 Prevention of Thermal Runaway

1.5.6 Charging and Protection

1.5.10 Design of Protection Circuits

1.9.6 Vent Mechanism

RTCA DO-347 sections

1.5.1 Battery Protective Features

1.5.4 Battery Emissions

1.5.7 Environmental Qualification

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.3 Hazardous Battery Emissions

3.1.5 Additional Equipment Installation Considerations

3.2 Safety Considerations for Installed Equipment

Acceptable Means of Compliance for Special Condition #6:

a) Provide a list of all design features that show compliance with requirement #6.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #6.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following DO-311 and listed RTCA DO-347 test:

RTCA DO-311 sections

1.5.3 Prevention of Thermal Runaway

1.5.6 Charging and Protection

1.5.10 Design of Protection Circuits

1.9.6 Vent Mechanism

RTCA DO-347 sections

1.5.1 Battery Protective Features

1.5.2 Charging and Discharging Protection

1.5.5 Flammability

1.5.7 Environmental Qualification

1.6 Design Criteria

1.7 Design Guidelines

2.1 Test Conditions and Apparatus

2.3.2 Constant Voltage Discharge Test for High Rate Batteries

2.3.8 Short-circuit Test with Protection Enabled

2.3.9 Short-circuit Test with Protection Disabled

2.3.10 Insulation Resistance Test

2.3.11 Duty Cycle Test for High Rate Batteries

2.3.12 Deep Discharge Test

2.3.13 Overcharge Test with Protection Enabled

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.6 Environmental Qualification Requirements

3.1.5 Additional Equipment Installation Considerations

3.2 Safety Considerations for Installed Equipment

Acceptable Means of Compliance for Special Condition #7:

a) Provide a list of all design features that show compliance with requirement #7.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #7.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following DO-311 and listed RTCA DO-347 test:

RTCA DO-311 sections

1.5.3 Prevention of Thermal Runaway

1.5.6 Charging and Protection

1.5.7 Warning System.

1.5.10 Design of Protection Circuits

1.9.6 Vent Mechanism

2.3.18 Overcharge with Protection Enabled Test

RTCA DO-347 sections

1.5.1 Battery Protective Features

1.5.2 Charging and Discharging Protection

1.7.2 Built-In-Test

1.7.3 Prevention from Back Charging

2.3.12 Deep Discharge Test

2.3.14 Overcharge Test with Protection Disabled

2.3.15 Thermal Runaway Containment Test

2.5.1 Software

2.5.2 Hardware

2.6 Environmental Qualification Requirements

Acceptable Means of Compliance for Special Condition #8:

a) Provide a list of all design features that show compliance with requirement #8.

b) Provide a list of all analysis and test(s), including but not limited to the standards document number, revision, release date and test number that show compliance to requirement #8.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following DO-311 and listed RTCA DO-347 test:

RTCA DO-311 sections

1.5.3 Prevention of Thermal Runaway

1.5.6 Charging and Protection

1.5.7 Warning System.

1.5.10 Design of Protection Circuits

1.9.6 Vent Mechanism

RTCA DO-347 sections

2.3.1 Rated Capacity Test

2.3.4 Charge Retention Test

2.3.5 Shelf Life Test

2.3.6 Float Life Test

2.3.10 Insulation Resistance Test

2.3.12 Deep Discharge Test

2.5.1 Software

2.5.2 Hardware

Acceptable Means of Compliance for Special Condition #9:

a) Provide a copy of the ICA.

Note: The electrical wiring interconnection systems (EWIS) maintenance and inspection tasks required by § 25.1729 must ensure that EWIS components associated with the batteries and battery systems are sufficient to detect degradation of any EWIS component that is designed and installed to support compliance with special condition items numbers 1 through 8.

Note: The term “sufficiently charged”' means that the battery will retain enough of a charge, expressed in ampere-hours, to ensure that the battery cells will not be damaged. A battery cell may be damaged by lowering the charge below a point where the battery experiences a reduction in the ability to charge and retain a full charge. This reduction would be greater than the reduction that may result from normal operational degradation.

As an example for lithium battery and battery systems acceptable means of compliance including but not limited to the following DO-311 and listed RTCA DO-347 test:

RTCA DO-311 sections

1.12 Instructions for Continued Airworthiness

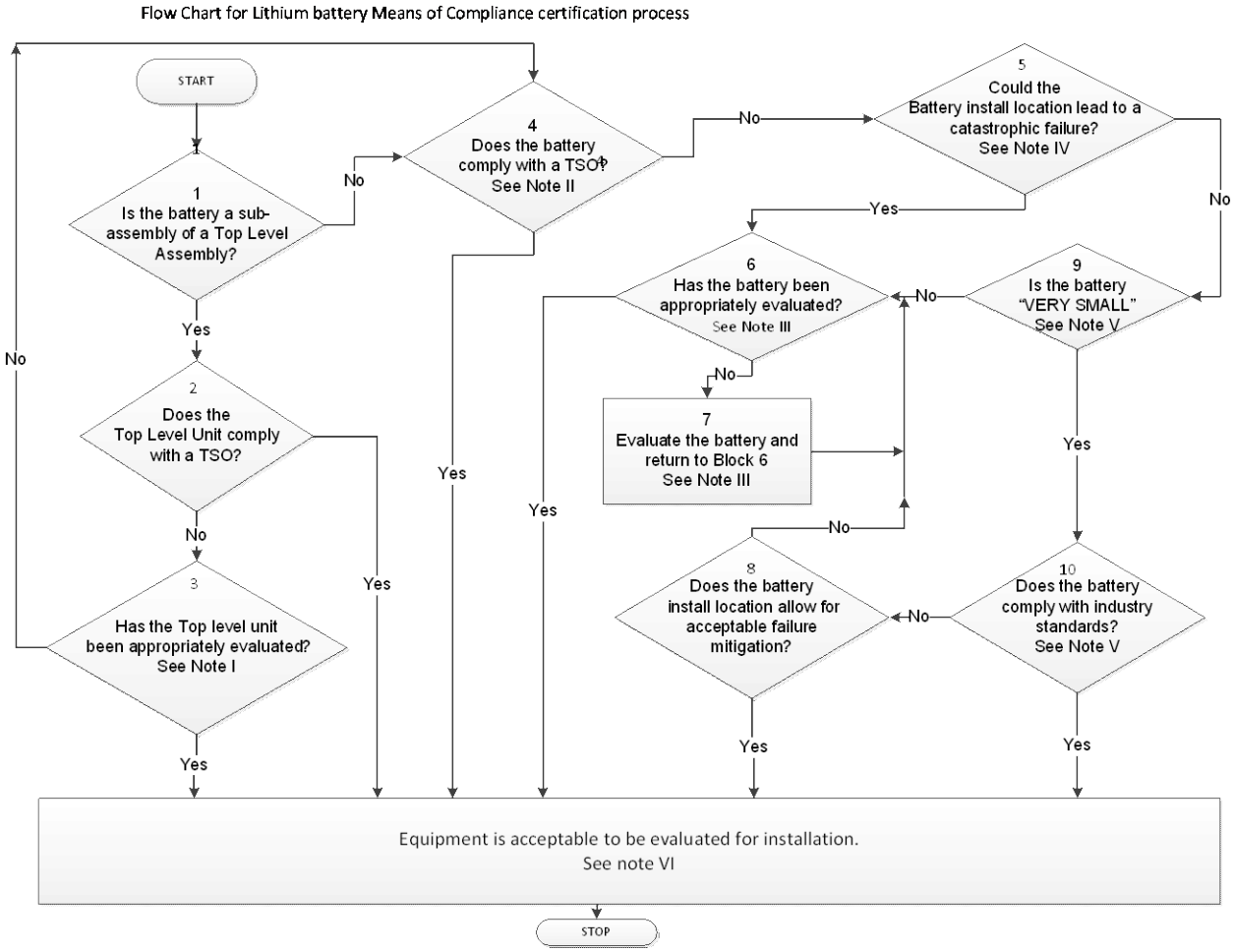
RTCA DO-347 sections

2.3.4 Charge Retention Test

2.3.5 Shelf Life Test

2.3.6 Float Life Test

APPENDIX G. FLOW CHART FOR LITHIUM BATTERY MEANS OF COMPLIANCE CERTIFICATION PROCESS.



Notes:

I. Has the Top Level Unit been FAA conformed (see FAA Form 8120-10 and Order 8110-4 Appendix 4), and successfully tested per appropriate standards such as DO-311, DO-347, DO-160, DO-178 and DO-254 (or equivalent)? Has any regulatory compliance been accomplished for the Top Level Unit?

II. Has the battery successfully completed any TSO MPS testing? Does it have an FAA TSO, such as TSO-C179a?

III. Has the battery been FAA conformed and successfully tested per appropriate standards such as DO-311, DO-347, DO-160, DO-178 and DO-254? Has any regulatory compliance been accomplished on the battery?

IV. Is there a Functional Hazard Assessment, System Safety Assessment and or failure Modes and Effects Analysis accomplished? If so, is the Hazard Assessment catastrophic?

V. The battery size is defined by Table 1-1 on page 3 of the RTCA document DO-347. See page 33 Section 2.8 of RTCA document DO-347 for industry standards.

VI. The equipment must be evaluated for installation requirements. If the equipment has a TSO, the tests under the TSO MOPS can be used for compliance to the airworthiness regulations (Test Report must be provided). When there is a delta between the test accomplished under the TSO and the installation requirement based on criticality and location on aircraft only the delta tests, if any, need to be tested in order to comply with the airworthiness regulations.

APPENDIX H. ADVISORY CIRCULAR FEEDBACK INFORMATION

If you have comments or recommendations for improving this advisory circular (AC), or suggestions for new items or subjects to be added, or if you find an error, you may let us know by using this page as a template and 1) emailing it to 9-AWA-AVS-AIR500-Coord@faa.gov or 2) faxing it to the attention of the AIR Directives Management Officer at 202-267-3983.

Subject: (insert AC number and title) Date: (insert date)

Comment/Recommendation/Error: (Please fill out all that apply)

An error has been noted:

Paragraph _____

Page _____

Type of error (check all that apply): Editorial:----- Procedural-----

Conceptual____

Description/Comments:_____
_____
_____

Recommend paragraph _____ on page _____ be changed as follows:
(attach separate sheets if necessary)

_____

In a future change to this advisory circular, please include coverage on the following subject:
(briefly describe what you want added attaching separate sheets if necessary)

_____

Name: _____