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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This advisory circular (AC) provides manufacturers, installers, and operators with an acceptable means, but not the only means, of compliance with title 14, Code of Federal Regulations (14 CFR), sections 23.2525, 25.1353, 27.1353, 29.1353 and additional commonly-issued requirements related to the design, installation, operation, and maintenance of rechargeable lithium batteries and battery systems on aircraft. Additionally, the installation of the battery and/or battery system will require regulatory compliance with the regulations referenced in Table 2-1 of this AC.

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

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CHAPTER 1. INTRODUCTION

1.1 Purpose.

This AC provides manufacturers and installers with an acceptable means, but not the only means, of compliance with title 14, Code of Federal Regulations (14 CFR) 23.2525, 25.1353, 27.1353, 29.1353 and additional commonly-issued requirements related to the design, installation, operation, and maintenance of rechargeable lithium batteries and battery systems on aircraft.

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

1.2 Applicability.

1.2.1 The guidance provided in this AC is for manufacturers, modifiers, foreign regulatory authorities, Federal Aviation Administration (FAA) type certification engineers, and the Administrator's designees.

1.2.2 **This is a guidance document that contains a means and method of compliance that has been reviewed and accepted by the FAA. Its content is not legally binding in its own right and will not be relied upon by the Department as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance document is voluntary only. Nonconformity will not affect rights and obligations under existing statutes and regulations.**

1.2.3 The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as "should," "may," and "must" are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. If the FAA becomes aware of circumstances in which following this AC would not result in compliance with the applicable regulations, the FAA may require additional substantiation as the basis for finding compliance.

1.3 Cancellation.

This revision cancels AC 20-184, *Guidance on Testing and Installation of Rechargeable Lithium Battery and Battery Systems on Aircraft*, dated October 15, 2015.

1.4 Scope.

1.4.1 Chapter 2 of this AC applies to the certification of installed lithium batteries on aircraft approved pursuant to 14 CFR parts 23, 25, 27, and 29 for—

- Type certificates (TCs),
- Amended type certificates (ATCs),
- Supplemental type certificates (STCs),

- Amended supplemental type certificates (ASTCs), and
- Parts manufacturer approvals (PMAs).

Note: The guidance in Chapter 2 also applies to the installation approval of installed lithium batteries on aircraft in accordance with the field approval process using FAA Form 337, *Major Repair and Alteration (Airframe, Powerplant, Propeller, or Appliance)*, for major repairs and major alterations.

1.4.2 Chapter 3 of this AC provides guidance on maintenance and operational considerations for lithium batteries on aircraft.

1.5 Rechargeable Lithium Batteries Covered in this AC.

1.5.1 Lithium batteries are installed in various aircraft types and serve various purposes. Lithium batteries are different sizes, chemistries, and produced under different manufacturing processes. They also have different levels of complexity. Some benefits of lithium batteries include weight savings, high-energy density per unit volume, relatively constant voltage during discharge, and a long shelf life. Because of their high-energy content and potential thermal instability, lithium batteries can present hazards if improperly designed, manufactured, tested, used, and or stored. Some of the uses for lithium batteries on today's aircraft include, but are not limited to:

- Emergency lighting;
- Cockpit voice recorders, flight data recorders, and underwater locator beacons;
- Main batteries for standby or emergency power;
- Auxiliary power units (APUs) or main starting batteries; and
- Special functions batteries (such as flashlights, electronic equipment, life vests, safety equipment, avionics equipment, communications equipment, and emergency medical equipment).

1.5.2 Lithium batteries have certain failure and operational characteristics, as well as maintenance requirements, that differ significantly from nickel-cadmium and lead-acid rechargeable batteries. The introduction of lithium batteries into aircraft raises some concern about associated battery monitoring systems (such as temperature or state of charge), and such systems will be evaluated and tested regarding the expected extremes in the aircraft-operating environment. Lithium batteries typically have different electrical impedance characteristics than lead-acid or nickel-cadmium batteries. Other components of the aircraft electrical system should be evaluated regarding these characteristics as a system.

1.6 Background.

1.6.1 The proposed use of lithium batteries for equipment and systems on aircraft has prompted the FAA to review the adequacy of its guidance.

1.6.2 The users of lithium battery technology, from aircraft operators to personal computer users, consumer electronics manufacturers, and the electric vehicle industry, have noted safety problems with lithium batteries. These conditions may result from overcharging, over-discharging, flammability of cell components, and internal cell defects. In general, lithium batteries are significantly more susceptible to internal failures that can result in self-sustaining increases in temperature and pressure (that is, thermal runaway) than nickel-cadmium or lead-acid batteries.

1.6.2.1 **Overcharging.**

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

1.6.2.2 **Over-discharging.**

Discharge of some types of lithium batteries beyond a certain voltage (typically 2.4 volts per cell) 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 simple voltage measurements commonly available to the flightcrew when checking battery status. This is a problem shared with nickel-cadmium batteries. Additionally, over-discharging has the potential to lead to an unsafe condition such as a loss of battery capacity that may not be detected by the battery management system.

1.6.2.3 **Flammability of Cell Components** (such as electrolytes and insulators)

Unlike nickel-cadmium and lead-acid batteries, rechargeable lithium batteries use electrolytes, insulators, and other materials that are flammable. These materials can serve as a source of fire.

1.6.2.4 **Internal Cell Defects.**

Undetected internal defects within a battery have the potential to cause an internal short circuit, which may lead to an unsafe condition such as an uncontrolled thermal runaway of the battery. These internal defects may not become apparent until long after the battery is in service.

CHAPTER 2. INSTALLATION OF RECHARGEABLE LITHIUM BATTERIES ON AIRCRAFT

2.1 Certification Process.

This chapter provides certification guidance for the installation of rechargeable lithium batteries on aircraft. This AC can be used as a means of compliance to the requirements established as applicable in the certification program. Applicants should coordinate their certification program with the responsible certification branch (formerly aircraft certification office (ACO) branch) as described in FAA Order 8110.4, *Type Certification*, through the certification project notification (CPN) process, FAA Order 8110.48, *How to Establish the Certification Basis for Changed Aeronautical Products*, or in FAA Order 8110.42, *Parts Manufacturer Approval Procedures*.

2.2 Acceptable Means of Compliance for Installation Approval.

2.2.1 Certification Plan.

As part of the certification program as described in Order 8110.4, prepare a certification plan describing all aspects of showing compliance for the installation of lithium batteries on the aircraft. The FAA recommends submitting the certification plan early in the certification process by providing the following items at a minimum:

- Project description and schedule,
- System description, including a description of the aircraft system interfaces and any aircraft system modifications made to accommodate the aircraft battery system installation,
- System safety assessment,
- Certification basis and means of compliance, including itemized methods of compliance to all applicable requirements, special conditions, and safety objectives,
- Communication and coordination of the test plan(s),
- Conformity plan,
- Instructions for Continued Airworthiness (ICA), and
- Compliance and substantiation documentation.

Note: FAA Order 8110.4 provides directions on how to address the above provisions of a certification plan.

2.2.2 Compliance Checklist.

2.2.2.1 Rechargeable lithium battery installations must support all failure conditions identified in the system safety assessment. Therefore, all applicable airworthiness regulations referenced in Table 2-1, at the applicable amendment level, need to be assessed if the design contains or will contain a lithium battery installation. The installations should also meet the guidance in this chapter.

Table 2-1. Typical Airworthiness Regulations Concerning Lithium Battery Installations

14 CFR	Subject Matter
Section 21.50(b)	*Instructions for continued airworthiness and manufacturer's maintenance manuals having airworthiness limitations sections.*
Section 23.2210	*Structural design loads.*
Section 23.2230	*Limit and ultimate loads.*
Section 23.2235	*Structural strength.*
Section 23.2250(a)	*Design and construction principles.*
Section 23.2265	*Special factors of safety.*
Section 23.2270	*Emergency conditions.*
Section 23.2315(a)	*Means of egress and emergency exits.*
Section 23.2320(c)	*Occupant physical environment.*
Section 23.2325	*Fire protection.*
Section 23.2330	*Fire protection in designated fire zones and adjacent areas.*
Section 23.2335	*Lightning Protection*
Section 23.2440	*Powerplant fire protection.*
Section 23.2500	*Airplane level systems requirements.*
Section 23.2525	*System power generation, storage, and distribution.*
Section 23.2600	*Flightcrew interface.*
Section 23.2605	*Installation and operation.*
Section 23.2610	*Instrument markings, control markings, and placards.*
Section 23.2620	*Airplane flight manual.*

14 CFR	Subject Matter
Sections 25/27/29.301	*Loads.*
Sections 25/27/29.303	*Factor of safety.*
Sections 25/27/29.305	*Strength and deformation.*
Sections 25/27/29.307	*Proof of structure.*
Section 25.581	*Lightning protection.*
Sections 27/29.610	*Lightning and static electricity protection.*
Sections 25/27/29.785	*Seats, berths, litters, safety belts, and harnesses.*
Sections 25/27/29.787(b)	*Cargo and baggage compartments.*
Sections 25/27/29.831	*Ventilation.*
Sections 25/27/29.853	*Compartment interiors.*
Section 25.856(a)	*Thermal/Acoustic insulation materials.*
Sections 25/27/29.863	*Flammable fluid fire protection.*
Section 25.869	*Fire protection: systems.*
Section 25.903(d)	*Turbine engine installations.*
Sections 25/27/29.1301	*Function and installation.*
Sections 25/27/29.1309/23.2510	*Equipment, systems, and installations.*
Sections 25/27/29.1316	*Electrical and electronic system lightning protection.*
Sections 25/27/29.1317/23.2520	*High-intensity Radiated Fields (HIRF) Protection.*
Section 25.1322	*Warning, caution, and advisory lights.*
Sections 27/29.1322	*Flightcrew alerting.*
Sections 25/27/29.1351	*Electrical systems and equipment, general.*
Sections 27/29.1353	*Energy storage systems.*
Sections 25/29.1355	*Distribution system.*
Sections 25/27/29.1357	*Circuit protective devices.*
Section 29.1359	*Electrical system fire and smoke protection.*
Sections 25/29.1363	*Electrical system tests.*
Section 27.1365	*Electric cables.*
Section 27.1367	*Switches.*
Sections 25/29.1431	*Electronic equipment.*
Sections 23/25/27/29.1529	*Instructions for Continued Airworthiness.*

14 CFR	Subject Matter
Sections 25/27/29.1541	*Markings and Placards, General.*
Sections 27/29.1559	*Limitations placard.*
Sections 25/27/29.1581	*Flight Manual, General.*
Sections 25/27/29.1583	*Operating limitations.*
Sections 25/27/29.1585	*Operating procedures.*
Part 25 subpart H	*Electrical Wiring Interconnection Systems (EWIS).*

2.2.2.2 Additional compliance requirements (beyond those listed in Table 2-1) pertaining to lithium batteries include:

2.2.2.2.1 Part 23.

The FAA amended its airworthiness standards for part 23. Amendment 23-64 became effective on August 30, 2017. See Appendix G of this AC for specific guidance regarding rechargeable lithium battery installation in part 23 airplanes.

2.2.2.2.2 Part 25.

The FAA determined that rechargeable lithium batteries are novel and unusual with the state of technology, considering when part 25 was codified, particularly 25.1353. Therefore, typically, the FAA requires SCs for rechargeable lithium battery installations on transport category airplanes. Appendix C of this AC provides typical rechargeable lithium battery SCs for transport airplanes. Unless these SCs are issued on the specific airplane model being modified, the SCs do not apply to that specific airplane model. The FAA must issue SCs on rechargeable lithium batteries for a specific project. Appendix D of this AC provides an acceptable means of compliance to these rechargeable lithium battery SCs.

Note: Prior to August 2016, the FAA issued SCs with slightly different numerical ordering and wording than the SCs in Appendix C of this AC. The method of compliance in Appendix D of this AC is also applicable to those SCs. Appendix E of this AC correlates the method of compliance in Appendix D of this AC to those SCs issued, prior to August 2016.

2.2.2.2.3 Parts 27/29.

In the case of rotorcraft, see Appendix F of this AC for means of compliance.

2.3 Test Requirements.

2.3.1 Environmental Test Requirements.

To ensure continuous safe function in the installed environments as required by 14 CFR 23.2525, 25.1353, 27.1353, and 29.1353, applicants proposing designs that incorporate lithium battery systems must address environmental qualification standards outlined in:

- RTCA DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment*.
- RTCA DO-311A, *Minimum Operational Performance Standards for Rechargeable Lithium Battery (Systems)*.

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

- Equipment configuration,
- Installation-specific environment encountered on in-service platforms,
- Duration of exposure periods,
- Geographical locations, and
- Frequency of environmental occurrences alone or in combination with other approved systems.

If the applicant wishes to use this AC to show compliance, it must be followed unless an alternate means of deviation is proposed and accepted by the FAA

2.4 **Means of Compliance Testing and Validation.**

Follow the guidance in Appendices D, E, F, and G of this AC to show compliance to the requirements and means of compliance for part 23, 25, 27, and 29 aircraft.

2.4.1 Ground and Flight Test Requirements for Installed Lithium Batteries.

2.4.1.1 If the FAA requires ground and/or flight tests, per the compliance checklist in the certification plan, then the applicant should perform tests to demonstrate the lithium battery systems and the systems in which they are installed will perform as intended in the aircraft.

2.4.1.2 If the FAA requires ground and/or flight tests, per the compliance checklist in the certification plan, then the applicant should perform the tests to demonstrate the lithium battery systems and the systems in which they are installed will not have any adverse effect on the aircraft.

2.4.1.3 If the FAA requires Electromagnetic Interference/Radio Frequency Interference (EMI/RFI) test, per the compliance checklist in the certification plan, then the applicant should perform the electromagnetic compatibility test described in AC 20-190, *Aircraft Electromagnetic Compatibility Certification,* to determine that the installation of the lithium battery does not have any adverse effect on aircraft systems and that the

aircraft systems do not have any adverse effect on the lithium battery. This will demonstrate that the battery system functions as designed during normal aircraft operations.

2.5 **System Safety Assessment.**

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

2.5.1 Perform a system safety assessment to show compliance with §§ 25/27/29.1309 and 23.2510 and all applicable SCs with respect to lithium batteries. 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:

- The levels of hazard associated with installation and use of the lithium batteries.
- Whether the installation design assurance level of lithium batteries is appropriate for performance and safety requirements based on location and intended function.
- No interference due to any failures of the lithium batteries.
- System separation and zonal analysis.
- Impact on flightcrew for normal and non-normal operation.
- Impact of emergency procedure during egress.
- Protection against fire, smoke, and electrical shock hazards.
- Other safety analysis appropriate to the system being installed.
- Statement of compliance for each requirement (SCs or SOs, as appropriate).

2.5.2 Coordinate your assessment with the responsible certification branch 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.

2.6 **Software.**

To ensure intended function and safe operation of the software when showing compliance with §§ 25/27/29.1301/1309/23.2505/2510 and all other applicable regulations, all lithium batteries that use software should comply with RTCA DO-178C, *Software Considerations in Airborne Systems and Equipment Certification*, or equivalent, for the appropriate design assurance level. You can find additional guidance in the following ACs referenced in Appendix A.

- AC 20-115D, *Airborne Software Development Assurance Using EUROCAE ED-12( ) and RTCA DO-178C( )*;
- AC 23.1309-1E, *System Safety Analysis and Assessment for Part 23 Airplanes*;
- AC 25.1309-1B, *System Design and Analysis*;
- AC 27-1B, *Certification of Normal Category Rotorcraft*; and
- AC 29-2C, *Certification of Transport Category Rotorcraft*.

2.7 **Complex Electronic Hardware.**

All lithium battery hardware that contain complex electronic hardware should comply with the most recent revision of RTCA DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*, or AC 20-152A, *Development Assurance for Airborne Electronic Hardware for compliance to 23.1353/2525, 25.1353, 27.13553, and 29.1353*.

2.8 **State of Charge.**

Lithium batteries not maintained at a high enough state of charge degrade at a significantly higher rate. Additionally, overcharging of individual cells could lead to thermal runaway.

2.9 **Flammability.**

2.9.1 Unlike nickel-cadmium and lead-acid cells, rechargeable lithium batteries use electrolytes and other materials that are flammable. This material can serve as a source of fuel for an external fire if a cell failure occurs. Lithium batteries have the potential to ignite spontaneously or experience thermal runaway, which involves an uncontrolled temperature and pressure increase, resulting in propagation to adjacent cells.

2.9.2 Pursuant to §§ 23.2325, 23.2330, 25/27/29.853, 25/27/29.863, and 25.869, aircraft battery equipment must meet the flammability requirements that ensure the protection of structure and critical systems. Test the materials to ensure they meet applicable certification requirements.

2.9.3 The DOT/FAA/AR-00/12, *Aircraft Materials Fire Test Handbook*, Chapters 1 through 10 and Chapter 15 describe an acceptable method of compliance with 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*.

2.10 **Instructions for Continued Airworthiness.**

During the certification process of the lithium batteries (battery and/or installation), complete the ICA in accordance with the following:

- Section 21.50(b);
- Sections 23/25/27/29.1529;
- Section 25.1729;
- Parts 23/27/29 Appendix A,
- Part 25 Appendix H; and
- FAA Order 8110.54A, *Instructions for Continued Airworthiness, Responsibilities, Requirements, and Contents* (or most recent revision).

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

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

2.10.3 The ICA, in accordance with the applicable regulations referenced in paragraph 2.10, must contain an "Airworthiness Limitations" section. Pursuant to §§ 43.16 and 91.403, the "Airworthiness Limitations" section is FAA-approved and specifies maintenance requirements, unless the FAA has approved an alternative program.

2.10.4 When a lithium battery installation is proposed, the ICA should also include at least the following information:

- Specifics of the lithium battery installation, including individual component part numbers and any other unique installation requirements,
- Electrical wiring diagrams/schematics, electrical equipment drawings,
- Maintenance instructions, basic control and operation, testing, servicing, maintenance schedule, inspection, troubleshooting, removing parts, replacing parts, repairs, special tools, fixtures, equipment, and component manual information when appropriate (reference paragraph 3.10.6), and
- Configuration control and storage instructions.

2.11 ICA Recommended Manufacturer's Maintenance and Inspection Requirements.

The ICA, in accordance with the applicable regulations referenced in paragraph 2.10, 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 when installed in the aircraft. The ICA must contain:

2.11.1 Operating instructions and equipment limitations in an installation manual (Type Certification) or a supplemental installation maintenance manual (Supplemental Type Certification).

2.11.2 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.

2.11.3 Maintenance requirements for measurements of battery capacity at appropriate intervals to ensure the battery whose function is required for safe operation of the aircraft will perform its intended function when installed in the aircraft.

2.11.4 Scheduled servicing information to replace batteries at the manufacturer's recommended replacement interval.

2.11.5 Maintenance and inspection requirements for a visual check of the battery and/or charger degradation.

2.11.6 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.

2.11.7 The ICA, in accordance with the applicable regulations referenced in paragraph 2.10, must contain instructions to replace batteries based on the original equipment manufacturer (OEM) maintenance manual. Replacement of individual cells within lithium batteries must be approved by the OEM and the FAA. Do not mix cells from different manufacturers within a lithium battery, unless an alternate means proposed by the OEM and approved by the FAA exists.

CHAPTER 3. MAINTENANCE AND OPERATIONAL CONSIDERATIONS FOR LITHIUM BATTERY SYSTEMS

3.1 Introduction.

Lithium batteries can be hazardous if not maintained and handled properly. This chapter provides guidance for maintenance considerations for aircraft lithium batteries. Maintenance requirements are part of the ICA that must comply with 14 CFR part 21.50 and to the applicable 23/25/27/29.1529 section. This AC has appendices that include further relevant references to assist in compliance (i.e. recording pertinent maintenance data to document the service life of the lithium battery and battery system to ensure the airworthiness of the battery system and aircraft).

3.2 Aircraft Battery Maintenance.

Manufacturer procedures for maintenance should be followed because maintenance and inspection requirements for aircraft lithium batteries vary based on the type of chemical technology and physical construction of the battery. 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 (refer to § 43.13 for additional requirements):

3.2.1 Lithium Battery Chemistry.

The electrolyte used in lithium batteries can be a highly reactive substance and care must be observed in maintaining the lithium batteries in accordance with both the OEM maintenance manual and the applicable regulations referenced in Table 2-1.

3.2.2 Age Management.

To determine the life and age of the installed lithium battery, record the 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 manufacturer.

3.2.3 State of Charge.

State of charge of the lithium battery is determined by the cumulative effect of charging and discharging the battery. In a normal electrical charging system, the generator or alternator restores a battery to full charge during a flight of 60 to 90 minutes regardless of use before flight. However, safeguards must be implemented to ensure the aircraft does not begin flight with a battery not sufficiently charged to accomplish its intended function of continued safe flight and landing of the aircraft in accordance with the applicable regulations referenced in Table 2-1. (See Appendix E, Note 1, for the definition of “sufficiently charged”.)

3.2.4 State of Health.

Determine the state of health of the lithium battery by recording the following:

- Length of time the battery has been installed and in service.

- The State of Charge of the battery. The output of this function may be used for dispatch or maintenance purposes.

- Any activation of temporary safety devices such as resettable fuses or positive temperature coefficient (PTC) if present in the design.

3.2.5 Mechanical Integrity.

In accordance with the applicable regulations referenced in Table 2-1, and to ensure proper mechanical integrity, the battery must be inspected to ensure it is free of any physical damage before use. Then the battery must be installed, and connected properly. The buildup of explosive gases can be avoided by incorporating positive battery venting for the battery and battery compartment 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 the specified performance. The venting system should account for specific installation requirements of the aircraft.

3.2.6 Reliability of Charging/Monitoring Systems.

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

3.2.7 Shop-Level Maintenance Procedures.

In accordance with the applicable regulations referenced in Table 2-1, shop procedures must follow the manufacturer's recommendations (refer to § 43.13 for additional requirements).

3.2.8 Aircraft Battery Inspection.

Evidence of impending or failed battery failure can sometimes be detected by a general visual inspection. Manufacturer-recommended inspections should include the following actions:

- Inspect battery terminals and all other connections for evidence of corrosion, pitting, arcing, and burns. Clean as required.
- Inspect the battery for improper installation (loose terminal screws, battery terminal links, or connector).
- Inspect the battery mounting.
- Inspect for evidence of physical damage.

3.2.9 Prior to the installation on aircraft, batteries in a rotable stock (which are parts and components that are easily exchanged between product) must be functionally checked at the battery manufacturer's recommended inspection intervals in accordance with the applicable regulations referenced in Table 2-1. Some failure modes may include degraded charge retention capability or other damage due to prolonged storage.

3.3 **Aircraft Battery Replacement.**

3.3.1 Ensure replacement batteries are in airworthy condition. An airworthy battery is one that has been, conformed, installed and tested on the aircraft as required by the FAA accepted ICA. Refer to the battery manufacturer maintenance manuals for proper maintenance of lithium batteries. Refer to the aircraft maintenance procedures for the replacement of lithium batteries.

3.3.2 The ICA should include the manufacturer's requirements for the mandatory battery replacement schedule (airworthiness limitation section) and periodic maintenance.

3.3.3 The installation process for lithium batteries can vary significantly across different aircraft systems. Always consult the specific aircraft manuals for detailed instructions on how to properly remove and install batteries. This ensures adherence to safety and technical specifications unique to each aircraft model.

3.3.4 Always inspect for corrosion and moisture on battery interfaces when replacing batteries. Failure to do so can lead to serious issues. Corrosion disrupts electrical connectivity, diminishing power efficiency and risking system failures. Moisture increases the risk of short circuits, potentially causing power losses and fire hazards. Ensure these inspections are part of your regular maintenance routine to maintain battery reliability and safeguard against potential safety risks.

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

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

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

3.4 **Aircraft Battery Storage and Handling.**

3.4.1 Following the manufacturer's recommended storage procedures will permit users to achieve the best results from their batteries.

3.4.2 Storage requirements vary with the battery type. Record the date of charging and, if the battery is not used within the manufacturer's recommended interval, service the battery per the manufacturer's recommendation.

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

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

3.4.5 Follow the manufacturer's recommended procedure to prevent electrostatic discharge during storage and handling.

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

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

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

3.4.9 Observe the following precautions when handling lithium batteries:

- Do not store lithium batteries with other hazardous or combustible materials.
- Do not heat or incinerate lithium batteries.
- Do not dispose of lithium batteries with other waste unless allowed by applicable regulations.
- Use special care in handling lithium batteries. Do not open, puncture, crush, disassemble, or subject batteries to physical abuse.

3.4.10 Lithium batteries can be a personal safety hazard due to the possibility of lethal shock and must be labeled to clearly indicate the hazard in accordance with the applicable regulations referenced in Table 2-1.

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

3.4.12 Material Safety Data Sheets must be enclosed with lithium batteries for shipping in accordance with the applicable regulations referenced in Table 2-1.

3.4.13 Always wear protective clothing, including gloves and safety goggles, when handling and disposing of lithium batteries. Proper disposal procedures should be followed to avoid environmental hazards and comply with applicable environmental regulations.

APPENDIX A. RELATED REGULATORY AND ADVISORY MATERIAL

The following regulatory and advisory materials are related to this AC:

A.1 Regulations.

The following 14 CFR regulations are related to this AC. Additional details on regulatory compliance are contained in the appendices of this AC. You can download the full text of these regulations from the eCFR Code of Federal Regulations at http://ecfr.gov. You can order a paper copy from the U.S. Superintendent of Documents, U.S. Government Publishing Office, Washington, D.C. 20401; at Government Publishing Office, by calling telephone number (202) 512-1800; or by sending a fax to (202) 512-2250.

- Part 21, *Certification Procedures for Products and Articles.*
- Part 23, *Airworthiness Standards: Normal Category Airplanes.*
- Part 25, *Airworthiness Standards: Transport Category Airplanes.*
- Part 27, *Airworthiness Standards: Normal Category Rotorcraft.*
- Part 29, *Airworthiness Standards: Transport Category Rotorcraft.*
- Part 43, *Maintenance, Preventive Maintenance, Rebuilding, and Alteration.*
- Part 145, *Repair Station.*

A.2 Advisory Circulars.

The following ACs may be related to the guidance in this AC. You should refer to the latest AC version for guidance, which is available on the Dynamic Regulatory System (DRS) at http://drs.faa.gov/.

- AC 20-115D, *Airborne Software Development Assurance Using EUROCAE ED-12( ) and RTCA DO-178( )*, dated July 21, 2017.
- AC 20-128A, *Design Considerations for Minimizing Hazards caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure*, dated March 25, 1997.
- AC 20-135, *Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria*, dated October 11, 2018.
- AC 20-136B, *Aircraft Electrical and Electronic System Lightning Protection*, dated September 7, 2011.
- AC 20-152A, *Development Assurance for Airborne Electronic Hardware*, dated October 7, 2022.

- AC 20-158B, *The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-intensity Radiated Fields (HIRF) Environment*, dated May 20, 2024.
- AC 20-190, *Aircraft Electromagnetic Compatibility Certification,* dated June 1, 2018.
- AC 21-16G, *RTCA Document DO-160 versions D, E, and F, "Environmental Conditions and Test Procedures for Airborne Equipment"*, dated June 22, 2011.
- AC 23.1309-1E, *System Safety Analysis and Assessment for Part 23 Airplanes*, dated November 17, 2011.
- AC 23-17C, *Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships*, dated November 17, 2011.
- AC 25-16, *Electrical Fault and Fire Prevention and Protection*, dated April 5, 1991.
- AC 25.1581-1, *Airplane Flight Manual*, dated October 16, 2012.
- AC 25.856-1, *Thermal/Acoustic Insulation Flame Propagation Test Method Details*, dated June 24, 2005.
- AC 25.863-1 (Aviation Rulemaking Advisory Committee (ARAC) draft), *Flammable Fluid Fire Protection,*[1] dated mm/dd/yyyy. https://www.faa.gov/sites/faa.gov/files/Draft_AC_25-863-X.pdf
- AC 25.1309-1B, *System Design and Analysis*, dated August 30, 2024.
- AC 25.1322-1, *Flightcrew Alerting*, dated December 13, 2010.
- AC 25.1701-1, *Certification of Electrical Wiring Interconnection Systems on Transport Category Airplanes*, dated December 4, 2007.
- AC 27-1B, *Certification of Normal Category Rotorcraft*, dated June 23, 2023.
- AC 29-2C, *Certification of Transport Category Rotorcraft*, dated June 23, 2023.
- AC 43.13-1B, *Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair*, dated September 8, 1998.
- AC 43.13-2B, *Acceptable Methods, Techniques, and Practices—Aircraft Alterations*, dated March 3, 2008.
- AC 120-16G, *Air Carrier Maintenance Programs*, dated January 4, 2016.
- AC 120-42B, *Extended Operations (ETOPS and Polar Operations)*, dated June 13, 2008.

[1] ARAC draft AC 25.863-1, *Flammable Fluid Fire Protection* https://www.faa.gov/sites/faa.gov/files/Draft_AC_25-863-X.pdf.

A.3 **Form.**

Form 337 is available on the Federal Aviation Administration Forms website at https://www.faa.gov/forms/index.cfm/go/document.list/.

FAA Form 337, *Major Repair and Alteration (Airframe, Powerplant, Propeller, or Appliance)*, dated October 01, 2006.

A.4 **Handbooks.**

The following handbooks are available on the Federal Aviation Administration Fire Safety website at https://www.fire.tc.faa.gov/Reports/reports.asp. You should refer to the latest version for guidance.

- DOT/FAA/AR-00/12, *Aircraft Materials Fire Test Handbook,* dated April 2000.
- DOT/FAA/AR-04/26, *Flammability Assessment of Bulk-Packed, Non-rechargeable Lithium Primary Batteries in Transport Category Aircraft,* dated June 2004.

A.5 **Orders.**

The following orders are available on DRS at http://drs.faa.gov/. You should refer to the latest version for guidance.

- FAA Order 8110.4C, *Type Certification*, dated October 20, 2023.
- FAA Order 8110.42D, *Parts Manufacturer Approval Procedures*, dated October 27, 2023.
- FAA Order 8110.48A, *How to Establish the Certification Basis for Changed Aeronautical Products*, dated July 21, 2017.
- FAA Order 8110.52B, *Type Validation and Post-type Validation Procedures*, dated September 29, 2017.
- FAA Order 8110.54A, *Instructions for Continued Airworthiness Responsibilities, Requirements, and Contents*, dated October 23, 2010.
- TSO C179b, *Rechargeable Lithium Batteries and Systems*, dated March 23, 2018.

A.6 **Industry Documents.**

The following industry documents are related to the guidance in this AC. You can obtain International Electrotechnical Commission (IEC) documents online at https://webstore.iec.ch/en/. You can obtain RTCA documents from RTCA Inc., 1150 18th Street NW, Suite 910, Washington, DC 20036; by completing the Document Order Form and faxing it to (202) 833-9434; or online at RTCA (www.rtca.org). You can obtain SAE International Aerospace Recommended Practice (ARP) documents from SAE Customer Service, 400 Commonwealth Drive, Warrendale, PA, 15096; or online at SAE (//saemobilus.sae.org). You can obtain UL (formerly Underwriters Laboratories)

documents online at https://www.shopulstandards.com/. You should refer to the latest version of the referenced document for guidance.

- IEC 62133-2, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications - Part 2: Lithium systems*, dated February 7, 2017.
- RTCA DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment,* dated December 8, 2010.
- RTCA DO-178C( ), *Software Considerations in Airborne Systems and Equipment Certification*, dated December 13, 2011.
- RTCA DO-254( ), *Design Assurance Guidance for Airborne Electronic Hardware*, dated April 19, 2000.
- RTCA DO-311A, *Minimum Operational Performance Standards for Rechargeable Lithium Battery (Systems)*, dated December 19, 2017.
- SAE ARP4761A, *Guidelines for Conducting the Safety Assessment Process on Civil Aircraft, Systems, and Equipment*, dated December 20, 2023.
- UL 1642, *Lithium Batteries*, dated October 12, 2022.
- UL 2054, *Household and Commercial Batteries*, dated March 10, 2022.

APPENDIX B. TERMS AND DEFINITIONS

For purposes of this AC, the following definitions apply:

- **Battery.** One or more electrically connected cells, having positive and negative terminals. A battery may include inter-cell connectors, protective devices, circuitry, and other components.
- **Battery System.** The equipment being qualified that includes a standalone or an embedded battery and may also include additional hardware that is required to comply with standard RTCA DO-311A.
- **Cell.** A single electrochemical unit that exhibits a voltage across its two terminals and is used as a component of a battery.
- **Charged Battery.** A battery that has been fully charged in accordance with the manufacturer's instructions or as defined in the design documentation.
- **Continued Safe Flight and Landing[2].** 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.
- **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 that errors may cause failures if the failures are directly traced to the errors.
- **Redundancy.** The presence of more than one independent means for accomplishing a given function or flight operation.
- **Serviced.** The procedures necessary to prepare and maintain an equipment under test in accordance with the manufacturer's instructions or as defined in the design documentation.
- **Service Life.** The maximum combined storage and installed life of an undischarged cell or battery. Service life cannot be greater than shelf life and 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.
- **Shelf Life.** The maximum period at which an undischarged cell or battery stored under standard conditions retains 80 percent of rated ampere-hour capacity (RTCA DO-311A). The cell/battery manufacturer specifies shelf life.

[2] 14 CFR section 23.2000(b)

APPENDIX C.
TYPICAL RECHARGEABLE LITHIUM BATTERY SPECIAL CONDITIONS FOR TRANSPORT CATEGORY AIRPLANES

C.1 **Typical Rechargeable Lithium Battery SCs Issued After August 2016.**

In lieu of § 25.1353(b)(1) through (4) at amendment 25-123 or § 25.1353(c)(1) through (4) at earlier amendments, each rechargeable lithium battery installation must:

1. Be designed to maintain safe cell temperatures and pressures under all foreseeable operating conditions to prevent fire and explosion.
2. Be designed to prevent the occurrence of self-sustaining, uncontrollable increases in temperature or pressure, and automatically control the charge rate of each cell to protect against adverse operating conditions, such as cell imbalance, back charging, overcharging, and overheating.
3. Not emit explosive or toxic gases, either in normal operation or as a result of its failure, that may accumulate in hazardous quantities within the airplane.
4. Meet the requirements of § 25.863.
5. Not damage surrounding structure or adjacent systems, equipment, or electrical wiring from corrosive fluids or gases that may escape in such a way as to cause a major or more-severe failure condition.
6. Have provisions to prevent any hazardous effect on airplane structure or systems caused by the maximum amount of heat it can generate due to any failure of it or its individual cells.
7. Have a failure sensing and warning system to alert the flightcrew if its failure affects safe operation of the airplane.
8. Have a monitoring and warning feature that alerts the flightcrew when its charge state falls below acceptable levels if its function is required for safe operation of the airplane.
9. Have a means to automatically disconnect from its charging source in the event of an over-temperature condition, cell failure or battery failure.

Note: A battery system consists of the battery; battery charger; and any protective, monitoring, and alerting circuitry or hardware inside or outside of the battery. It also includes vents (where necessary) and packaging. For the purpose of this special condition, a battery and the battery system are referred to as a battery.

APPENDIX D. ACCEPTABLE METHOD OF COMPLIANCE WITH SPECIAL CONDITIONS FOR RECHARGEABLE LITHIUM BATTERIES ON TRANSPORT CATEGORY AIRPLANES

D.1 Acceptable Methods of Compliance with Rechargeable Lithium Battery SCs.

An acceptable method of compliance with the rechargeable lithium battery SCs in Appendix C and related part 25 requirements is provided in paragraphs D.3 and D.4. Applicants who propose the SCs in Appendix C for their project should submit a letter indicating this to the certification branch responsible for their project.

D.2 Issued SCs with Slightly Different Numerical Order and Wording.

Prior to August 2016, the FAA issued SCs with slightly different numerical order and wording than the SCs in Appendix C. The method of compliance in paragraph D.3 is also applicable to those SCs. Appendix E correlates the method of compliance in paragraph D.3 to those SCs issued prior to August 2016.

D.3 Methods of Compliance with SCs.

RTCA DO-311A, *Minimum Operational Performance Standards for Rechargeable Lithium Batteries and Battery Systems,* section 2.1 *General Requirements* provides design requirements and guidelines that are pertinent to designing safe batteries and to meeting part 25 requirements and the SCs. Consider each of these requirements and guidelines when designing cells and batteries. The FAA does not consider Appendix C of DO-311A an acceptable alternate method for battery thermal runaway containment tests (paragraph 2.4.5.5).

D.3.1 SCs 1 and 2 are intended to ensure that the cells and batteries are designed to eliminate the potential for uncontrollable failures. However, a certain number of failures may still occur due to various factors, many of which are beyond the control of the designer. Therefore, these SCs are intended to protect the airplane and its occupants even if a failure occurs.

D.3.2 These SCs are independent of each other. Demonstrating compliance with one of these SCs does not necessarily constitute compliance with the other SCs. The following is an acceptable method of compliance for each of the SCs:

D.3.3 Method of Compliance for SCs 1 and 2.

D.3.3.1 Whereas SC 1 requires that each individual cell within a rechargeable lithium battery be designed to maintain safe temperatures and pressures, SC 2 addresses these same issues but for the entire battery. Special Condition 2 requires that the battery be designed to prevent propagation of a thermal event, such as self-sustained, uncontrollable increases in temperature, or pressure from one cell to adjacent cells.

D.3.3.2 Show that very small button/coin batteries that have less than 2 watt-hours of energy meet UL 1642, UL 2054 or International Electrotechnical Commission (IEC) 62133-2. Show that other batteries meet the requirements in RTCA DO-311A, sections 2.2 *Equipment Requirements – Standard Conditions* (which are applicable according to RTCA DO-311A, section 2.4.2) and 2.3 *Equipment Requirements – Environmental Conditions*. Consider that batteries with less than 2 watt-hours of energy that are not button/coin batteries, or do not meet UL 1642, UL 2054, or IEC 62133-2, to be energy category 2 batteries.

D.3.3.3 Use the test procedures in RTCA DO-311A, section 2.4 *Equipment Test Procedures* to show that the requirements of RTCA DO-311A, section 2.2 are met. Note that RTCA DO-311A, Table 2-2, provides a test matrix that defines which tests are required for each category of battery, along with the order of the testing.

Note: Provide the FAA with the video of the testing conducted for RTCA DO-311A section 2.4.5.5.

D.3.4 Method of Compliance for SCs 3-6.

Paragraphs D.3.4 through D.3.8 provide a method of compliance with SCs 3-6 for button/coin rechargeable lithium batteries that have less than 2 watt-hours of energy and meet UL 1642, UL 2054, or IEC 62133. For other rechargeable lithium batteries, show compliance with SCs 3 – 6 using data related to a worst-case event where all battery cells go into thermal runaway. To accomplish this, use the worst case test data from paragraph D.3.1, Method of Compliance for SCs 1 and 2. If none of those tests produce an event where all battery cells go into thermal runaway, coordinate with the FAA Technical Policy Branch to determine either an acceptable revision to the test method of one of those tests, or an acceptable analysis based on your test data, to obtain data representative of this condition.

D.3.5 Method of Compliance for SC 3.

D.3.5.1 RTCA DO-311A, section 3.2.1 *Hazardous Battery Emissions* discusses potential gas emissions from batteries and their effects. An acceptable method of compliance with SC 3 includes using the tests required under paragraph D.3.2, *Method of Compliance for SCs 3-6,* to demonstrate that all emitted gases are contained or vented overboard (i.e., vented outside the airplane) through designed ports. Paragraph D.4.1, *System Safety Assessment*, of this appendix provides guidance for conducting a system safety assessment for a design that vents these gases overboard.

D.3.5.2 SC 3 does allow explosive and toxic gases to be uncontained and not vented overboard if they do not accumulate in hazardous quantities within the airplane. Consider the gases emitted from not only the cells but also the battery materials (e.g., insulation separators) when demonstrating compliance by this means.

D.3.6 Method of Compliance for SC 4.

D.3.6.1 The amendment level of § 25.863 is determined by § 21.17 or § 21.101, as appropriate. The amendment level is not determined by the issuance or effective date of the SCs.

D.3.6.2 The ARAC draft AC 25.863-1, *Flammable Fluid Fire Protection*[3], gives acceptable guidance on § 25.863. Section 25.863 is a "fail-safe" regulation that requires means to minimize the likelihood of a fire and the resultant hazards if fire does occur.

D.3.6.3 When applying § 25.863 to a battery installation, if required by SC 4, conduct a hazard assessment assuming that a battery failure ignites any resultant flammable fluids or gases, and provide provisions to address the associated hazards. This may result in the need to provide a battery enclosure that vents overboard.

D.3.7 Method of Compliance for SC 5.

Show that if fluid escapes the battery, it is not corrosive or it is managed in a way (e.g., contained, isolated, or vented overboard) to protect the surrounding structure and adjacent systems, equipment, and electrical wiring.

D.3.8 Method of Compliance for SC 6.

D.3.8.1 Show that the effects of heat, and any related effects, from the tests performed under paragraph D.3.4, *Method of Compliance for SCs 3-6,* do not constitute a hazard to the structure or systems of the airplane.

D.3.8.2 If the effects of the heat or any related effects constitute a hazard to the structure or systems of the airplane, design mitigation at the airplane level may be applied to bring the design into compliance with this SC.

D.3.9 Method of Compliance for SC 7.

SC 7 has the same purpose as that of § 25.1309(c), but is specific to the lithium battery, which is to require flightcrew alerting if the failure of a battery installation, in itself or in relation to a system that performs an airplane-level function, could result in "unsafe system operating conditions" as stated in § 25.1309(c). The alert must meet the applicable paragraphs of § 25.1322. The applicant should refer to the current version of AC 25.1309-1B, *System Design and Analysis,* for guidance.

D.3.10 Method of Compliance for SC 8.

[3] ARAC draft AC 25.863-1
https://www.faa.gov/sites/faa.gov/files/Draft_AC_25-863-X.pdf

D.3.10.1 The alert must meet the applicable paragraphs of § 25.1322. Conduct a safety assessment in accordance with § 25.1309 to determine if the flightcrew alert is a warning, caution, or advisory, taking into account all phases of flight.

D.3.10.2 Have a means for the flightcrew and maintenance personnel to determine the battery charge state if the battery's function is required for safe operation of the airplane.

D.3.11 Method of Compliance for SC 9.

Confirm the battery automatically disconnects from its charging source during the tests required by paragraph D.3.4, *Method of Compliance for SCs 3-6,* except for the tests where the protection is already disabled. This is one of the means of preventing the failure conditions discussed in RTCA DO-311A.

D.3.12 Method of Compliance for Very Small Button or Coin Rechargeable Lithium Batteries.

For button/coin rechargeable lithium battery installations that have less than 2 watt-hours of energy, an acceptable method of compliance with SCs 1-6 and 9 is to show these batteries meet UL 1642, UL 2054, or IEC 62133. For very small button/coin rechargeable lithium batteries that do not meet UL 1642, UL 2054, or IEC 62133, show compliance with SCs 3-6 using data related to the worst-case test data from paragraph D.3.1 Method of compliance for SC 1 and 2.

D.4 **Part 25 Compliance.**

Rechargeable lithium battery installations, typically, must comply with applicable SCs and part 25 and part 26 requirements. The following paragraphs provide methods of compliance and other information for pertinent part 25 requirements:

D.4.1 System Safety Assessment.

D.4.1.1 Although these SCs require specific functionalities and capabilities and address certain critical failure modes of rechargeable lithium batteries and their installations, the applicant must also meet the requirements of §§ 25.1301, 25.1309, and 25.1709, when applicable, in addition to these SCs. To date, in-service experience has shown that rechargeable lithium battery thermal/pressure runaway conditions are not extremely improbable. Assume such failures could occur sometime during the life of the battery installation when demonstrating compliance with § 25.1309 except for button/coin batteries that have less than 2 watt-hours of energy and meet UL 1642, UL 2054, or IEC 62133. For button/coin batteries that have less than 2 watt-hours of energy and meet UL 1642, UL 2054, or IEC 62133, use the data from one of these UL or IEC standards to support demonstrating compliance with § 25.1309. For other rechargeable lithium batteries, use the worst-case data indicated in paragraph D.3.2, Method of

Compliance for SCs 3 – 6, to support demonstrating compliance with § 25.1309.

D.4.1.2 As part of showing compliance with § 25.1309, the applicant is to demonstrate that particular risks, such as identified in SAE ARP4761A, *Guidelines and Methods for Conducting Safety Assessment Process on Civil Airborne Systems and Equipment*, an uncontained rotor burst, tire debris, fire, lightning, or bird strike will not compromise continued safe flight and landing. The applicant is to consider the effects of particular risks—both internal and external—to rechargeable lithium battery installations. For example, the applicant is to consider the effects of particular risks on any containment and venting provisions for a rechargeable lithium battery.

D.4.1.3 Application of § 25.1309(b) and (c) may result in required periodic maintenance actions or flightcrew alerting features. For example, an over-temperature warning system may be necessary to allow the flightcrew to manage potentially unsafe system operating conditions. Provide rationale for alerting requirements (or for why an alert is not needed) in the system safety assessment of the battery installations to demonstrate compliance with § 25.1309(c). Such alerts, if provided, must meet § 25.1322. Refer to AC 25.1309-1B, *System Design and Analysis*; AC 25.1322-1, *Flightcrew Alerting*; AC 25.1581-1 *Airplane Flight Manual;* and AC 25.1701-1, *Certification of Electrical Wiring Interconnection Systems on Transport Category Airplanes,* for further guidance.

Note: In addition to the current AC 25.1309-1B, the FAA has allowed the use of ARAC recommended AC 25.1309-1 B, if the applicant receives an equivalent level of safety finding to §§ 25.1301 and 25.1309 in accordance with FAA Policy Statement PS-ANM100-00-113-1034.

Note: Venting toxic and explosive gases from a rechargeable lithium battery failure through designed ports that lead outside of the airplane is a method of compliance with SC 3 as discussed in paragraph D.3.3 Method of Compliance for SC 3. In this case, consider the hazards of exposure of these gases to ground personnel, air conditioning in-take and engine in-take in accordance with § 25.1309.

D.4.2 Section 25.1353 Electrical Equipment and Installations.

The SC states that it applies to all rechargeable lithium battery installations in lieu of § 25.1353(b)(1) through (4) at amendment 25-123 or § 25.1353(c)(1) through (4) at earlier amendments. This statement does not relieve an applicant from demonstrating compliance to the other paragraphs of § 25.1353.

D.4.3 Section 25.1529 ICA.

Include in the ICA the following to comply with § 25.1529:

D.4.3.1 A requirement to only replace rechargeable lithium batteries with batteries from the same manufacturer with the same part number, or to obtain a new FAA approval for installing a different battery. Refer to the battery original equipment manufacturer maintenance manual.

D.4.3.2 Procedures to ensure that each rechargeable lithium battery has not:

1. Experienced degraded charge retention ability or other damage during storage.
2. Been damaged from environmental or physical impacts such as mechanical shock, vibration, heat, and possible abuses encountered during storage, transportation prior to their installation, or maintenance activities on or around them.

D.4.3.3 Precautions to prevent mishandling of replacement rechargeable lithium batteries prior to their installation, which could result in short-circuit or other unintentional damage.

Note: Acceptable procedures for paragraph D.4.3.2 item 2 may include a quality control process for packaging, storing, maintaining, and transporting rechargeable lithium batteries, including directions to report dropped or damaged batteries.

D.4.4 Section 25.1729 ICA; Electrical Wiring Interconnection Systems (EWIS).

EWIS maintenance and inspection tasks required by § 25.1729 are to ensure that EWIS components associated with rechargeable lithium batteries are sufficient to prevent degradation of any EWIS component that is designed and installed to support compliance with these SCs.

D.4.5 Sections 25.903(d) and 25.1309 Uncontained Engine or APU Rotor Failures.

D.4.5.1 As part of showing compliance with § 25.1309, the FAA expects the applicant to demonstrate that a foreseeable event originating from outside of a rechargeable lithium battery, such as an uncontained rotor burst, will not impact the airworthiness of the aircraft preventing continued safe flight and landing. An applicant may propose fail-safe design features that encase and safely vent the hazardous byproducts of a failure originated from within the battery to show compliance with the rechargeable lithium battery SC. However, a rotor failure could defeat such safety features depending on the location of the battery installation. If an applicant proposes to install a rechargeable lithium battery in a rotor burst zone, the applicant must ensure the means of compliance to the SC remain effective considering potential rotor failures that could damage the battery.

D.4.5.2 Regarding compliance to § 25.903(d)(1) turbine engine rotor failures, AC 20-128A, *Design Considerations for Minimizing Hazards caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure*, provides guidance on fragmentation characteristics and the boundaries of the locations in which applicants are expected to evaluate the effects of impact damage following an uncontained rotor burst. If an applicant proposes to install a rechargeable lithium battery in a rotor burst zone, the applicant must assess the rotor-burst-induced damage to the battery to show compliance with § 25.903(d)(1) in conjunction with showing compliance with the rechargeable lithium battery SC. In this case, provide a proposed method of compliance to the FAA. Alternatively, locate the battery outside of the rotor burst zone.

D.5 Hazard Mitigations for Large Battery System Thermal Runaway Conditions.

Airplanes requiring high-capacity batteries may increase the severity level and adverse effects resulting from a battery thermal runaway condition, or any other hazards. As stated earlier, using RTCA DO-311A, including articles approved under TSO-C179b, is an accepted approach for addressing the thermal runaway aspects of rechargeable lithium battery installations. All applicable airworthiness regulations must be addressed and complied with. RTCA DO-311A and TSO-C179b provide a testing standard and article-level approval that requires additional integration and mitigation strategies in order to fully comply with the applicable airworthiness regulations on the aircraft. The FAA outlines the following guidance in Section D.6 to address verification aspects of lithium battery thermal runaway conditions for RTCA DO-311A, section 2.4.5.5. All other tests within RTCA DO-311A are applicable as stated in the industry consensus standard.

Note: Due to the significance of technical and regulatory issues regarding Hazard Mitigations for Large Battery System Thermal Runaway Conditions (D.5), coordination with the FAA is required.

D.6 Battery Thermal Runaway Containment Test (RTCA DO-311A, Section 2.4.5.5).

Coordinate as soon as possible with the FAA on the proposed design methodology.

D.6.1 RTCA DO-311A, section 2.4.5.5 describes the test methods for battery thermal runaway containment that are designed to force the entire battery into a thermal runaway state. This may not be feasible for very large high-capacity systems (e.g., systems used for propulsion applications). To address the feasibility of very large high-capacity battery system testing, this section of the AC defines a module or sub-pack as a battery system divided into smaller configurations to help in testing and validating the safety implication of the battery system. The battery and battery system can be designed into several smaller modules or sub-packs. Each module has an assembly of cells electrically connected and enclosed in a single enclosure. Each sub-pack has an assembly of electrically connected modules that is enclosed by a single enclosure. The

venting design of the sub-pack, module, and cells needs to be considered in the mitigation strategy.

D.6.2 To successfully comply with the requirement of RTCA DO-311A, section 2.4.5.5 test, it is acceptable to use a modularized/sub-pack battery system design.

APPENDIX E. CORRELATION OF TRANSPORT CATEGORY AIRPLANE METHOD OF COMPLIANCE TO SPECIAL CONDITIONS ISSUED PRIOR TO AUGUST 2016

Prior to August 2016, the FAA issued SCs with slightly different order and wording than the SCs in Appendix C. The method of compliance in Appendix D is also applicable to those SCs. The intent of this appendix is to correlate the method of compliance in Appendix D to those earlier SCs.

E.1 Rechargeable Lithium Battery SCs Issued Before August 2016:

In lieu of the requirements of § 25.1353(c)(1) through (c)(4) at amendment 25-113, all rechargeable lithium batteries, and battery systems on [airplane model] must be designed and installed as follows:

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.
2. Design of the rechargeable lithium batteries must preclude the occurrence of self-sustaining, uncontrolled increases in temperature or pressure.
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 not shown to be extremely remote, may accumulate in hazardous quantities within the airplane.
4. Installations of rechargeable lithium batteries must meet the requirements of § 25.863(a) through (d).
5. 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.
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.
7. Lithium battery installations must have a system to control the charging rate of the battery automatically, designed to prevent battery overheating or overcharging, and,
    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.

8. Any rechargeable lithium battery installation, the function of which is required for safe operation of the airplane, 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 airplane.
9. The instructions for continued airworthiness required by § 25.1529 must contain maintenance requirements to ensure 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 rechargeable lithium batteries and rechargeable lithium battery systems will not degrade below specified ampere-hour levels sufficient to power the airplane systems 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 batteries or other destructive means that could result in personal injury or property damage.

Note 1: 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.

Note 2: These special conditions are not intended to replace § 25.1353(c) in the certification basis of the [airplane model]. These special conditions apply only to rechargeable lithium batteries and lithium battery systems and their installations on [airplane model]. The requirements of § 25.1353(c) remain in effect for batteries and battery installations on [airplane model] that do not use lithium batteries.

E.2 The Following Provides Correlation Between the Method of Compliance in Appendix D to the SCs Issued Before August 2016:

- Method of Compliance for Pre-August 2016 SCs 1 and 2. Appendix D, section D.3.1, *Method of Compliance for SCs 1 and 2,* provides a method of compliance.
- Method of Compliance for Pre-August 2016 SC 3. Appendix D, sections D.3.2, *Method of Compliance for SCs 3 – 6,* and D.3.3, *Method of Compliance for SC 3,* provide a method of compliance.

- Method of Compliance for Pre-August 2016 SC 4. Appendix D, sections D.3.2, *Method of Compliance for SCs 3 – 6* and D.3.4, *Method of Compliance for SC 4,* provide a method of compliance.
- Method of Compliance for Pre-August 2016 SC 5. Appendix D, sections D.3.2, Method of Compliance for SCs 3 – 6 and D.3.5, *Method of Compliance for SC 5*, provide a method of compliance.
- Method of Compliance for Pre-August 2016 SC 6. Appendix D, sections D.3.2, *Method of Compliance for SCs 3 – 6* and D.3.6, *Method of Compliance for SC 6,* provide a method of compliance.
- Method of Compliance for Pre-August 2016 SC 7. Section D.3.1, *Method of Compliance for SCs 1 and 2* demonstrates that rechargeable lithium batteries are designed to prevent overheating and overcharging. Section D.3.9, *Method of Compliance for SC 9,* provide additional applicable guidance.
- Method of Compliance for Pre-August 2016 SC 8. Appendix D, section D.3.8, *Method of Compliance for SC 8,* provides applicable guidance.
- Method of Compliance for Pre-August 2016 SC 9. SC 9 contains specific requirements related to ICAs that must be met. Section 25.1529 is another independent, applicable regulation. Section D.4.3, *Section 25.1529 Instructions for Continued Airworthiness (ICA),* applies to § 25.1529.

APPENDIX F. REGULATIONS AND METHOD OF COMPLIANCE FOR RECHARGEABLE LITHIUM BATTERIES FOR ROTORCRAFT

The method of compliance provided in this appendix is to establish an approach to show compliance for rechargeable lithium batteries and their installation on rotorcraft. This AC is also intended to ensure, as required by §§ 27/29.601, 27/29.1309, and 27/29.1353, that the installation does not present a hazard to the rotorcraft and its occupants.

F.1 Regulatory Basis From Part 27 at Amendment 27-51 and Part 29 at Amendment 29-59.

F.1.1 Regulations 27/29.601 require that the design must not have features or details that experience has shown to be hazardous or unreliable.

F.1.2 Regulations 27/29.863 require a means of minimizing the probability of ignition of flammable fluids or vapors that might leak from flammable liquid sources and the resultant hazards in the event of ignition.

F.1.3 Regulations 27/29.1301 require that each system is appropriate for its intended function and is labeled and installed according to its limitations and function.

F.1.4 Regulations 27/29.1309 state that required systems must perform their intended function under any foreseeable operating conditions; systems must be designed to prevent hazards to the rotorcraft in the event of a probable malfunction or failure.

F.1.5 Regulations 27/29.1353 require in part that energy storage systems must be designed and installed to maintain safe cell temperatures and pressures so that no explosive or toxic gases can accumulate in hazardous quantities, and that corrosive fluids or gases cannot damage surrounding structures or essential systems.

F.1.6 Regulations 27/29.1529 require that the ICA be prepared.

F.2 Advisory Circulars.

- AC 27-1B, *Certification of Normal Category Rotorcraft*.
- AC 29-2C, *Certification of Transport Category Rotorcraft.*

F.3 Industry Document.

RTCA DO-311A, *Minimum Operational Performance Standards for Rechargeable Lithium Batteries and Battery Systems.*

F.4 **Part 27/29 Regulations.**

The following regulations are identified as critical for safe installation of rechargeable lithium batteries. Each rechargeable lithium battery installation must show that the following are met:

F.4.1 Sections 27/29.1353(a).

Energy storage systems must provide automatic protective features for any conditions that could prevent continued safe flight and landing.

F.4.2 Sections 27/29.1353(b).

Energy storage systems must not emit any flammable, explosive, or toxic gases, smoke, or fluids that could accumulate in hazardous quantities within the rotorcraft.

F.4.3 Sections 27/29.1353(c).

Corrosive fluids or gases that escape from the system must not damage surrounding structures, adjacent equipment, or systems necessary for continued safe flight and landing.

F.4.4 Sections 27/29.1353(d).

The maximum amount of heat and pressure that can be generated during any operation or under any failure condition of the energy storage system or its individual components must not result in any hazardous effect on rotorcraft structure, equipment, or systems necessary for continued safe flight and landing.

F.4.5 Sections 27/29.1353(e).

Energy storage system installations required for continued safe flight and landing of the rotorcraft must have monitoring features and a means to indicate to the pilot the status of all critical system parameters.

Note: An energy storage system consists of individual battery cell(s), a battery assembly, and any protective monitoring and alerting circuitry or hardware inside or outside of the battery. It may also include vents (when necessary) and packaging. For the purpose of this guidance, a battery and battery system are referred to as a battery.

F.5 **Method of Compliance.**

The following method of compliance is acceptable to ensure that the battery complies with §§ 27/29.1353(a) through §§ 27/29.1353(e) discussed in the paragraphs above.

F.5.1 RTCA DO-311A, *Minimum Operational Performance Standards for Rechargeable Lithium Batteries and Battery Systems,* section 2.1 *General Requirements* provides design requirements and guidelines that are pertinent to designing safe batteries and to meeting parts 27/29 applicable requirements and the regulations shown in paragraph F.4 above. Section 2.2, *Equipment Requirements – Standard Conditions*, defines the minimum functional requirements for battery cells, batteries, and end items. Each

subsection in section 2.2 references a specific test procedure found in section 2.4. Test procedures and evaluation criteria specifically for cells, batteries, and end items are outlined in section 2.4 corresponding to each of the functional and safety requirements. Test conditions are defined in section 2.3. Consider each of these requirements and guidelines when designing cells and batteries.

F.5.2 Sections 27/29.1353(a) are intended to ensure that the cells and batteries are designed to eliminate the potential for uncontrollable failures. However, a certain number of failures will still occur due to various factors, many of which are beyond the control of the designer. Therefore, these regulations, as a whole, are intended to protect the rotorcraft and its occupants even if a failure occurs.

F.5.3 These regulations are independent of each other. Demonstrating compliance with one of these regulations does not constitute compliance with the other regulations. An acceptable method of compliance for each regulation is as follows:

F.5.4 Method of Compliance for §§ 27/29.1353(a).

F.5.4.1 Sections 27/29.1353(a) require that the cell and battery be designed to prevent propagation of a thermal event, such as self-sustained, uncontrollable increases in temperature or pressure from one cell to adjacent cells.

F.5.4.2 Show that the batteries meet the requirements in RTCA DO-311A, sections 2.2, *Equipment Requirements – Standard Conditions* (which are applicable according to RTCA DO-311A, section 2.4.2) and 2.3 Equipment Requirements – Environmental Conditions. Consider that batteries with less than 2 watt-hours of energy that are not button/coin batteries, or do not meet UL 1642, UL 2054, or IEC 62133-2, to be energy category 2 batteries. Use the test procedures in RTCA DO-311A, section 2.4, *Equipment Test Procedures,* to show that the requirements of RTCA DO-311A, section 2.2 are met. Note that RTCA DO-311A, Table 2-2 provides a test matrix that defines which tests are required for each category of battery, along with the order of the testing.

F.5.4.3 Provide the FAA with the video of the testing conducted for RTCA DO-311A section 2.4.5.5.

F.5.5 Method of Compliance for §§ 27/29.1353(b).

F.5.5.1 Sections 27/29.1353(a) require that the cell and battery be designed to prevent propagation of a thermal event, such as self-sustained, uncontrollable increases in temperature or pressure from one cell to adjacent cells.

F.5.5.2 An acceptable means of complying with §§ 27/29.1353(b) includes using the tests required under §§ 27/29.1353(a) to demonstrate that all emitted

gases are contained or vented overboard (i.e., vented outside the rotorcraft) through designed ports. If the design has ports to vent gases overboard, show that there are means to protect ground personnel from exposure to these gases and to prevent re-ingestion, for example through engine in-take or air conditioning in-take, in accordance with §§ 27/29.1301 and 27/29.1309. The applicant should refer to the current AC 27-1B and AC 29-2C for guidance on §§ 27/29.1309.

F.5.5.3 Sections 27/29.1353(b) allow explosive and toxic gases to be uncontained and not vented overboard if they do not accumulate in hazardous quantities within the rotorcraft. Consider the gases emitted from not only the cells but also the battery materials (e.g., insulation separators) when demonstrating compliance by this means.

F.5.5.4 While each paragraph of section(s) 27/29.1353 needs to be evaluated specifically, it may be possible to use the results of testing conducted for §§ 27/29.1353(a) for compliance to §§ 27/29.1353(b). Therefore, if there were gases emitted from the end item (RTCA DO 311A, Category C) during the testing of RTCA DO-311A, section 2.4.5.5 in compliance with §§ 27/29.1353(a), the emitted gases must be collected and evaluated for the volume and constituents of the gas. This would provide the ability to evaluate the dissipation and hazard level of these emissions in the location in which the end item is installed.

F.5.6 Method of Compliance for §§ 27/29.1353(c).

Show that if fluid escapes the battery during testing of regulations 27/29.1353(a), it is not corrosive or it is managed in a way (e.g., contained, isolated, or vented overboard) to protect the surrounding structure and adjacent systems, equipment, and electrical wiring of the rotorcraft.

F.5.7 Method of Compliance for §§ 27/29.1353(d).

F.5.7.1 Show that the effects of the heat, and any related effects, from the tests performed under §§ 27/29.1353(a) do not constitute a hazard to the structure or systems of the rotorcraft necessary for operations, maintenance and continued safe flight and landing.

F.5.7.2 If the effects of the heat or any related effects constitute a hazard to the structure or systems of the rotorcraft, design mitigation at the aircraft level may be applied to bring the design into compliance with regulations 27/29.1353(d).

F.5.8 Method of Compliance for §§ 27/29.1353(e).

F.5.8.1 Sections 27/29.1353(e) require flightcrew alerting to monitor features and have a means to indicate to the pilot of critical system parameters, which may otherwise lead to an unsafe operating condition. Flightcrew alerting is

required if a battery installation failure affects continued safe flight and landing. The effect of the battery failure on other systems that perform functions required for safe flight and landing must also be considered. The alert must meet the applicable paragraphs of §§ 27/29.1301 and 27/29.1309. The applicant should refer to the current AC 27-1B and AC 29-2C for guidance on compliance to §§ 27/29.1322, 27/29.1301 and 27/29.1309.

F.5.8.2 The following are examples of means for flightcrew or maintenance personnel to determine the battery charge state, which is a critical system parameter:

1. A manually activated system (e.g., push button) that displays the available charge of each battery unit.
2. An automatic system that records the available charge of each battery unit on an appropriate interval and makes it available to maintenance personnel before the next flight.
3. Physical access that allows a maintenance person to measure the battery charge state.

Note: The above means are acceptable only if the ICA includes a requirement for a person to check the battery charge state within an interval that will ensure sufficient charge for the entire flight, considering the worst-case scenario, and to replace the battery when the charge is not sufficient.

F.5.8.3 After completing all the required test and validation, based on the method of compliance for each regulation, provide a summary of all the evaluation criteria and reportable items listed in each test.

F.5.9 Method of Compliance for Very Small Rechargeable Lithium Batteries Less Than 2 Watt-Hours.

Compliance to UL 1642, UL 2054, or IEC 62122 is an acceptable method of compliance to show §§ 27/29.1353(a) through §§ 27/29.1353(e) are met for very small button/coin-sized rechargeable lithium batteries installations with less than 2 watt-hours of energy.

F.5.10 Part 27/29 Compliance.

Rechargeable lithium battery installations must satisfy each means of compliance identified in this AC and all applicable part 27/29 requirements. The following provides methods of compliance and other information related to compliance to part 27/29 requirements.

F.5.10.1 System Safety Assessment.

Although these hazard conditions require specific functionalities and capabilities and address certain critical failure modes of rechargeable

lithium batteries and their installations, the applicant must also meet the requirements of §§ 27/29.1301, 27/29.1309, and 27/29.1353. To date, in-service experience has shown that rechargeable lithium battery thermal/pressure runaway conditions are not extremely improbable. Assume such failures could occur sometime during the life of the battery installation when demonstrating compliance with §§ 27/29.1309. Application of §§ 27/29.1309 may result in required periodic maintenance actions or flightcrew alerting features. For example, an over-temperature warning system may be necessary to allow the flightcrew to manage potentially unsafe system operating conditions. Provide rationale for alerting requirements (or for why an alert is not needed) in the system safety assessment of the battery installations to demonstrate compliance with §§ 27/29.1309. Such alerts, if provided, must meet §§ 27/29.1322.

F.5.10.2 The ICA should include the following provisions to comply with § 27/29.1529:

1. Maintenance requirements to replace each rechargeable lithium battery within an interval that will ensure there is sufficient charge to power equipment.
2. A requirement to only replace rechargeable lithium batteries with batteries from the same manufacturer with the same part number or to obtain a new FAA approval for installing a different battery. Refer to the battery Original Equipment Manufacturer's maintenance manual.
3. Procedures to ensure that each rechargeable lithium battery has not:

   (a) Experienced degraded charge retention ability or other damage during storage.

   (b) Been damaged from environmental or physical impacts such as mechanical shock, vibration, heat, and possible abuses encountered during storage, transportation prior to their installation or maintenance activities on or around them.

   (c) Precautions to prevent mishandling of replacement rechargeable lithium batteries prior to their installation which could result in short-circuit or other unintentional damage.

Note: Acceptable procedures for paragraph F.5.11.2(3) above may include a quality control process for packaging, storing, maintaining, and transporting rechargeable lithium batteries, including reporting of dropped or damaged batteries.

F.5.10.3 Uncontained Engine or APU Rotor Failures: § 29.1309.

As part of showing compliance with § 29.1309, the FAA expects the applicant to demonstrate that a foreseeable event originating from outside of a rechargeable lithium battery, such as an uncontained rotor burst, will

not compromise continued safe flight and landing. While you may use failsafe design features that encase and safely vent the hazardous by products of a failure originated from within the battery to show compliance with regulations applicable to rechargeable lithium battery systems, depending on the location of the battery installation, a rotor failure could defeat such safety features. If you propose to install a rechargeable lithium battery in a rotor burst zone, then you must ensure the means of compliance to the regulations remains effective, considering potential rotor failures that could damage the battery.

F.5.10.4 Turbine Engine Rotor Failures: § 29.903(d)(1).

AC 20-128A provides guidance on fragmentation characteristics, and the boundaries of the locations in which applicants are expected to evaluate the effects of impact damage, following an uncontained rotor burst. If you propose to install a rechargeable lithium battery in a rotor burst zone, then you must assess the rotor-burst-induced damage to the battery in your plan for showing compliance with § 29.903(d)(1), in conjunction with complying to regulations applicable to the rechargeable lithium battery. Clearly state your method of compliance in your response to this section of the AC. Alternatively, the battery must be located outside of the rotor burst zone.

F.5.11 Hazard Mitigations for Large Battery System Thermal Runaway Conditions.

Note: Due to the significance of technical and regulatory issues, coordinate as soon as possible with the FAA.

F.5.11.1 Aircraft requiring high-capacity batteries may increase the severity level and adverse effects resulting from a battery thermal runaway condition, or any other hazards. As stated earlier, using RTCA DO-311A, including articles approved under TSO-C179b, is an accepted approach for addressing the thermal runaway aspects of rechargeable lithium battery installations. All applicable airworthiness regulations must be addressed and complied with. RTCA DO-311A and TSO-C179b, provide a testing standard, and article-level approval that requires additional integration and mitigation strategies to fully comply with the applicable airworthiness regulations on the rotorcraft.

F.5.11.2 In addition, the FAA outlines guidance in F.5.12 to address verification aspects of lithium battery thermal runaway conditions for the RTCA DO-311A section 2.4.5.5. All other tests within RTCA DO-311A are applicable as stated in the industry consensus standard.

F.5.12 Battery Thermal Runaway Containment Test (RTCA DO-311A, section 2.4.5.5).

Note: Coordinate as soon as possible with the FAA on the proposed method of compliance for this section.

F.5.12.1 RTCA DO-311A, section 2.4.5.5 describes the test methods for battery thermal runaway containment that are designed to force the entire battery into a thermal runaway state. This may not be feasible for very large high-capacity systems (e.g., systems used for propulsion applications). To address the feasibility of very large high-capacity battery system testing, this section of the AC defines a module or sub-pack as a battery system divided into smaller configurations to help in testing and validating the safety implication of the battery system. The battery and battery system can be designed into several smaller modules or sub-packs. Each module has an assembly of cells electrically connected and enclosed in a single enclosure. Each sub-pack has an assembly of electrically connected modules that is enclosed by a single enclosure. The venting design of the sub-pack, module, and cells need to be considered in the mitigation strategy.

F.5.12.2 To successfully comply with the requirement of the RTCA DO-311A section 2.4.5.5 test, it is acceptable to use a modularized/sub-pack battery system design.

APPENDIX G. INSTALLATION OF RECHARGEABLE LITHIUM BATTERIES FOR SMALL AIRPLANES

G.1 **Applicability.**

G.1.1 Regulations applicable to installing rechargeable lithium batteries that provide power to small airplanes are §§ 23.2005, 23.2010, 23.2325(g), 23.2410, 23.2500, 23.2505, 23.2510, 23.2525, 23.2605, and 23.1529, Appendix A, at amendment 23-64. If the means and methods of compliance referenced in this AC are accomplished with no deviations and coordinated with the FAA, the development of an issue paper is not necessary. Additional requirements may be necessary after assessing the installation, application, location, and operating environment.

G.1.2 The applicant must meet the current requirements of part 23 at amendment 23-64 in the areas of change for the rechargeable lithium battery installation, and may use means and methods in this AC on certification projects[4] with an original certification basis prior to amendment 23-64, so long as they are not contrary to any special conditions already part of the certification basis.

G.1.3 This appendix does not address compliance to applicable crashworthiness and survivable emergency landing requirements with respect to the rechargeable lithium battery.

G.2 **Means of Compliance with Safety Objectives.**

The applicant must comply with the following SOs, including all other applicable airworthiness regulations, when using the means of compliance in this AC for the installation of rechargeable lithium batteries.

G.2.1 SO 1: Be designed to maintain safe cell temperatures and pressures under all foreseeable operating conditions to prevent fire and explosion.

G.2.2 SO 2: Be designed to prevent the occurrence of self-sustaining, uncontrollable increases in temperature or pressure, and automatically control the charge rate of each cell to protect against adverse operating conditions, such as cell imbalance, back charging, overcharging, and overheating.

G.2.3 SO 3: Not emit explosive or toxic gases, either in normal operation or as a result of its failure, that may accumulate in hazardous quantities within the airplane.

G.2.4 SO 4: Meet the requirements of § 23.2325(g) regarding areas where flammable fluids or vapors might escape by leakage.

[4] Including TCs, STCs, ATCs, and ASTCs.

G.2.5 SO 5: Not damage surrounding structure or adjacent systems, equipment, components, or electrical wiring from corrosive or any other fluids or gases that may escape in such a way as to cause a major or more-severe failure condition.

G.2.6 SO 6: Have provisions to prevent any hazardous effect on airplane structure or systems caused by the maximum amount of heat it can generate due to any failure of it or its individual cells.

G.2.7 SO 7: Have a failure sensing and warning system to alert the flightcrew if its failure affects safe operation of the airplane.

G.2.8 SO 8: Have a monitoring and warning feature that alerts the flightcrew when its charge state falls below acceptable levels if its function is required for safe operation of the airplane.

G.2.9 SO 9: Have a means to disconnect from its charging source in the event of an over-temperature condition, cell failure, or battery failure.

G.3 **Method of Compliance with Safety Objectives.**

G.3.1 RTCA DO-311A provides data used to demonstrate that rechargeable lithium battery installations meet the means of compliance SOs when using this AC for compliance.

G.3.2 RTCA DO-311A section 2.1, *General Requirements,* provides design requirements and guidelines that are pertinent to designing safe batteries and meeting part 23 requirements and the means of compliance SOs. Consider each of these requirements and guidelines when designing cells and batteries.

G.3.3 RTCA DO-311A, sections 1.4, 1.5, 1.6, and all of section 2.1 provide guidelines and general requirements that are pertinent to designing and installing safe lithium batteries on aircraft.

G.3.4 SOs 1 and 2 are intended to ensure that the cells and battery are designed to eliminate the potential for uncontrollable failures. However, a certain number of failures will still occur due to various factors beyond the control of the designer. Therefore, the means of compliance SOs, as a whole, are intended to protect the airplane and its occupants if failure occurs.

G.3.5 The following method of compliance must be used to comply with the means of compliance in G.2 above. Means of compliance SOs are independent of each other. Demonstrating compliance with one of these SOs does not constitute compliance with the other SOs.

G.3.5.1 **SO 1:** Designed to maintain safe cell temperatures and pressures under all foreseeable operating conditions to prevent fire and explosion.

Method of Compliance with SO 1:

1. Show that batteries meet the requirements in RTCA DO-311A, sections 2.2, *Equipment Requirements – Standard Conditions* (which are applicable according to section 2.4.2) and section 2.3, *Equipment Requirements – Environmental Conditions*.
2. Use the test procedures in section 2.4, *Equipment Test Procedures,* to show that the requirements of section 2.2 are met.

G.3.5.2 **SO 2:** Designed to prevent the occurrence of self-sustaining, uncontrollable increases in temperature or pressure, and automatically control the charge rate of each cell to protect against adverse operating conditions, such as cell imbalance, back charging, overcharging, and overheating.

Method of Compliance with SO 2:

1. SO 2 addresses the same issues for the entire battery as SO 1 for the individual cell. The battery must be designed to prevent propagation of a thermal event due to any operational or fault conditions, such as self-sustained, uncontrollable increases in temperature or pressure.
2. RTCA DO-311A, section 2.4.2, Table 2-2, provides a test matrix that defines which tests are required for each category of battery, along with the order of the testing.
3. Provide the FAA with the video of the testing conducted for RTCA DO-311A section 2.4.5.5.

G.3.5.3 **SO 3:** Not emit explosive or toxic gases, either in normal operation or as a result of its failure, that may accumulate in hazardous quantities within the airplane.

Method of Compliance with SO 3:

1. RTCA DO-311A, section 3.2.1*, Hazardous Battery Emissions,* discusses potential gas emissions from batteries and their effects. All emitted gases must be contained or vented overboard (i.e., vented outside the airplane) through designed ports.
2. SO 3 does allow explosive and toxic gases to be uncontained and not vented overboard if they do not accumulate in hazardous quantities within the airplane. Consider the gases emitted from not only the cells but also the battery materials (e.g., insulation separators). Provide substantiation to this requirement in terms of analysis and test results. Use the test results of SO 1 and SO 2 for SO 3.
3. An acceptable means of complying with SO 3 includes using the tests required under SO 1 and SO 2 to demonstrate that all emitted gases are contained or vented overboard (i.e., vented outside the aircraft) through designed vent ports. If the design has ports to vent gases overboard, show that there are means to protect ground personnel from exposure to these gases and to prevent re-ingestion, for example

through engine in-take or air conditioning in-take, in accordance with § 23.2510.

4. If there were gases emitted from the end item under RTCA DO 311A Category C during the testing of RTCA DO-311A section 2.4.5.5 in compliance to SO 1 and SO 2, the emitted gases must be collected and evaluated for the volume and constituents of the gas. This would provide the ability to evaluate the dissipation and hazard level of these emissions in the location in which the End Item is to be installed.

G.3.5.4 **SO 4:** Meet the requirements of § 23.2325(g).

Method of Compliance with SO 4:

1. Section 23.2325(g) requires minimizing the likelihood of a fire and the resultant hazards if fire does occur. Both battery electrolyte and any coolant fluid, if present, are considered fluid systems when evaluating § 23.2325(g).
2. Perform a safety assessment to identify and evaluate associated hazards and its severity. Mitigate and minimize all hazards resulting from a battery failure.

G.3.5.5 **SO 5:** Not damage surrounding structure or adjacent systems, equipment, components, or electrical wiring from corrosive or any other fluids or gases that may escape in such a way as to cause a major or more-severe failure condition.

Method of Compliance with SO 5:

1. Show that if fluid escapes the battery, it is not corrosive or it is managed in a way (e.g., contained, isolated, or vented overboard) to protect the surrounding structure and adjacent systems, equipment, components, and electrical wiring.
2. Evaluate test results after conducting tests per RTCA DO-311A, including a system safety assessment for failure conditions. Use test results of SO 1 and SO 2 for SO 5 substantiations. Mitigation at the airplane level may be applied to bring the design into compliance.
3. The intent is to show that if fluid escapes the battery during the testing for compliance to SO 1 and SO 2, it is not corrosive or it is managed in a way (e.g., contained, isolated, or vented overboard) to protect the surrounding structure and adjacent systems, equipment, and electrical wiring.

G.3.5.6 **SO 6:** Have provisions to prevent any hazardous effect on airplane structure or systems caused by the maximum amount of heat it can generate due to any failure of it or its individual cells.

Method of Compliance with SO 6:

1. Show that the effects of heat and any related effects from conducting tests per RTCA DO-311A do not create a hazard to the structure or systems of the airplane. The maximum heat to be considered must be equal to or greater than the heat generated from the worst-case thermal runaway containment test agreed to in this appendix (e.g., tests performed for SO 1 and 2).
2. If the effects of the heat or any related effects constitute a hazard to the structure or systems of the airplane, mitigation at the airplane level may be applied to bring the design into compliance.
3. The temperature of the gases and the enclosure need to be provided. This temperature will help show that the effects of the heat, and any related effects, from the tests performed under SO 1 and SO 2 do not constitute a hazard to the structure or systems of the aircraft.

G.3.5.7 **SO 7:** Have a failure sensing and warning system to alert the flightcrew if its failure affects safe operation of the airplane.

Method of Compliance with SO 7:

1. Ensure adequate flightcrew alerting because failure effects of a battery installation to airplane level functions could result in unsafe system operating conditions.
2. RTCA DO-311A, section 2.1.4.2, *Battery Warning Features*, that discusses warning circuits and signals.

G.3.5.8 **SO 8:** Have a monitoring and warning feature that alerts the flightcrew when its charge state falls below acceptable levels if its function is required for safe operation of the airplane.

Method of Compliance with SO 8:

1. Have a means for the flightcrew and maintenance personnel to determine the battery charge state if the battery's function is required for safe operation of the airplane.
2. Use a system safety assessment to determine the alert level.

G.3.5.9 **SO 9:** Have a means to disconnect from its charging source in the event of an over-temperature condition, cell failure, or battery failure.

Method of Compliance with SO 9:

1. In accordance with the applicable rules listed in paragraph 2.2.2, Table 2-1, the battery must be capable of disconnecting itself from the charging source to prevent failure conditions, including satisfying SO 1 and SO 2.
2. Not applicable to the cases where RTCA DO-311A has protection disabled as a prerequisite for the test.

G.4 **Method of Compliance for Very Small Rechargeable Lithium Batteries Less Than 2 Watt-Hours.**

Compliance to UL 1642, UL 2054, or IEC 62122 is an acceptable method of compliance to show §§ 27/29.1353(a) through §§ 27/29.1353(e) are met for very small button/coin-sized rechargeable lithium batteries installations with less than 2 watt-hours of energy.

G.5 **ICA Required by § 23.1529, Appendix A to Part 23.**

Include the following in the ICA, to comply with § 23.1529, Appendix A to part 23:

G.5.1 Maintenance requirements to replace each rechargeable lithium battery within an interval that will ensure there is sufficient charge to power equipment.

G.5.2 A requirement to only replace rechargeable lithium batteries with batteries from the same manufacturer with the same part number or to obtain a new FAA approval for installing a different battery. Refer to the battery Original Equipment Manufacturer maintenance manual.

G.5.3 Procedures to ensure that each rechargeable lithium battery has not:

- Experienced degraded charge retention ability or other damage during storage.
- Been damaged from environmental or physical impacts such as mechanical shock, vibration, heat, and possible abuses encountered during storage, transportation prior to their installation or maintenance activities on or around them.

G.5.4 Precautions to prevent mishandling of replacement rechargeable lithium batteries prior to their installation that could result in short-circuit or other unintentional damage.

G.6 **Uncontained Engine or APU Rotor Failures: §§ 23.2410 and 23.2510 at Amendment 23-64.**

G.6.1 In general, as part of showing compliance with §§ 23.2410 and 23.2510, the FAA expects the applicant to demonstrate that a foreseeable event originating from outside of a rechargeable lithium battery, such as an uncontained rotor burst, will not compromise continued safe flight and landing. You may use fail-safe design features that encase and safely vent the hazardous byproducts of a failure originated from within the battery to show compliance with the rechargeable lithium battery SOs. Depending on the location of the battery installation, a rotor failure could defeat such safety features. If a rechargeable lithium battery is installed in a rotor burst zone, ensure the means of compliance to the SOs remains effective considering potential rotor failures that could damage the battery.

G.6.2 Regarding compliance to § 23.2410 for turbine engine rotor failures, AC 20-128A, *Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure*, provides guidance on fragmentation

characteristics and the boundaries of the locations in which applicants are expected to evaluate the effects of impact damage following an uncontained rotor burst. For a non-rechargeable lithium battery—except for very small button/coin cells with less than 2 watt-hours of energy that meet UL 1642, UL 2054, or IEC 62133-2—assess the rotor-burst-induced damage to the battery in a plan for showing compliance with § 23.2410 in conjunction with complying with the rechargeable lithium battery SOs. If a rechargeable lithium battery is installed in a rotor burst zone, assess the rotor-burst-induced damage to the battery in a plan for showing compliance with § 23.2410 in conjunction with complying with the rechargeable lithium battery SOs. Clearly state the method of compliance in your response to this section of the AC. Alternatively, the battery is to be located outside of the rotor burst zone.

G.7 Lithium Battery Installed in a Designated Fire Zone (DFZ) (§§ 23.2440 and 23.2510).

G.7.1 Installation in a DFZ should be avoided, but may be acceptable, if the battery location does not create an additional hazard. The external fire threat to the battery when it is located in a DFZ is a 2000°F flame for 15 minutes per AC 20-135, *Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria*. The heat generated by this flame may cause multiple cells to enter thermal runaway along with damage to the battery containment system resulting in uncontrolled fire or explosion.

G.7.2 In accordance with § 23.2440(c)(1) and any other applicable airworthiness regulation references in Table 2-1 of AC 20-184A, the battery must contain or vent any thermal runaway and prevent introduction of additional hazards when exposed to a 2000°F flame for 15 minutes. Test by exposing the battery installation design (including any vents) to a 2000°F flame for 15 minutes per AC 20-135. Ensure no additional hazards are introduced. For all batteries installed in a DFZ, minimize the risk of fire in the DFZ. Some examples are:

G.7.2.1 Directing and venting (if the design includes a vent) any potential flames or flammable material from the battery out of the fire zone. Any vent system included in the design must continue to function in the event of a thermal runaway of the battery, otherwise it must not create an additional hazard from its failure.

G.7.2.2 Using fireproof materials in the construction of the battery installation design.

G.7.2.3 Providing adequate shielding to protect the battery and vent, if any, from direct flames to ensure the battery remains below a temperature that could compromise the thermal runaway containment integrity when exposed to a powerplant fire condition.

G.8 **Hazard Mitigations for Large Battery System Thermal Runaway Conditions.**

Airplanes requiring high-capacity batteries may increase the severity level and adverse effects resulting from a battery thermal runaway condition or any other hazards. Using RTCA DO-311A, including articles approved under TSO-C179b, is an accepted approach for addressing the thermal runaway aspects of rechargeable lithium battery installations. All applicable airworthiness regulations must be addressed and complied with. RTCA DO-311A, as well as TSO-C179b, provide a testing standard and article-level approval that requires additional integration and mitigation strategies in order to fully comply with the applicable airworthiness regulations on the aircraft. The level of acceptable risk will be commensurate with the part 23 level 1, 2, 3, or 4 aircraft. In addition, the FAA outlines guidance in paragraph G.8 to address verification aspects of lithium battery thermal runaway conditions for the RTCA DO-311A, section 2.4.5.5. All other tests within RTCA DO-311A are applicable as stated in the industry consensus standard.

Note: Due to the significance of technical and regulatory issues, coordinate as soon as possible with the FAA.

G.9 **Battery Thermal Runaway Containment Test (RTCA DO-311A, Section 2.4.5.5).**

G.9.1 RTCA DO-311A, section 2.4.5.5, describes the test methods for battery thermal runaway containment that are designed to force the entire battery into a thermal runaway state. This may not be feasible for very large high-capacity systems (e.g., systems used for propulsion applications). To address the feasibility of very large high-capacity battery system testing, this section of the AC defines a module or sub-pack as a battery system divided into smaller configurations to help in testing and validating the safety implication of the battery system. The battery and battery system can be designed into several smaller modules or sub-packs. Each module has an assembly of cells electrically connected and enclosed in a single enclosure. Each sub-pack has an assembly of electrically connected modules that is enclosed by a single enclosure. The venting design of the sub-pack, module, and cells need to be considered in the mitigation strategy.

G.9.2 To successfully comply with the requirement of RTCA DO-311A, section 2.4.5.5 test, it is acceptable to use a modularized/sub-pack battery system design.

Note: Coordinate as soon as possible with the FAA on the proposed design methodology (i.e., modularized/sub-pack battery system design).