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MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR NICKEL-CADMIUM, NICKEL METAL-HYDRIDE, AND LEAD-ACID BATTERIES

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Prepared by:
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FOREWORD

This document was prepared by RTCA Special Committee 211 (SC-211). It was approved by the RTCA Program Management Committee on December 2, 2009.

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- Developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and

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1 INTRODUCTION

Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries of a number of different, sizes, and construction details are widely used today. Among their desirable characteristics are high energy density per unit weight and per unit volume, high cell voltage (Lead-Acid), relatively constant voltage during discharge (NiCd), good low-temperature performance and long shelf life. Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries provide power for aircraft engine or Auxiliary Power Unit (APU) starting and other equipment including avionics and emergency and standby systems. Because of their high energy content, they can present hazards if improperly designed, tested, used, or stored.

1.1 Purpose

The purpose of this document is to provide guidance on the construction, certification, production and use of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid battery on aircraft. This guidance is provided to the designers and manufacturers of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries, aircraft designers and manufacturers, and users within the aviation community. This document contains minimum operational performance standards for rechargeable Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries to be used as power sources on aircraft.

Compliance with these standards is recommended as a means of assuring that the battery will perform its intended function(s) safely under conditions normally encountered in routine aeronautical operations. Any regulatory application of this document is the sole responsibility of the cognizant government agencies.

These standards cover the chemical composition, cell size, cell construction, interconnection of the cells into batteries, venting, operational and storage environments, packaging, handling, test, storage and disposal of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries installed separately or in avionics equipment aboard aircraft. Its further purpose is to provide aircraft designers, and aircraft equipment designers with information on the performance characteristics and operating and environmental limitations of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries.

It is the responsibility of the aircraft and equipment designers and manufacturers to insure that the battery operating environmental limits defined in this document will not be exceeded during the intended use of the batteries and equipment on the aircraft.

1.2 References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to apply.

ANSI/ASQC M1-1996: American National Standard for Calibration Systems
IEC 60952-1 Aircraft Batteries, Part 1: General test requirements and performance levels
IEC 60952-2 Aircraft Batteries, Part 2: Design and construction requirements

IEC 60952-3 Aircraft Batteries, Part 3: Product standard and verification
RTCA DO-160: Environmental conditions and test procedures for airborne equipment
ISO-9000 Quality management principles
Title 14 Code of Federal Regulations for Aeronautics and Space, 1, I, 1-59 Federal Aviation Administration, Department of Transportation

Part 23 Airworthiness Standards – Normal Utility, Acrobatic, and commuter category Airplanes

Section 23-1301 Function and installation, 23-1309 Equipment, systems, and installations, and 23-1353 Electrical equipment and installations including Advisory Circular 23.1309-1C

Part 25 Airworthiness Standards: Transport Category Airplanes

Sect ion 25-1301 Function and installation, 25-1309 Equipment, systems, and installations, and 25-1353 Electrical equipment and installations including Advisory Circular 25.1309-1A

Part 27 Airworthiness Standards: Normal Category Rotorcraft

Section 27-1301 Function and installation, 27-1309 Equipment, systems, and installations, and 27-1353 Electrical equipment and installations including Advisory Circular 27 - 1A

Part 29 Airworthiness Standards: Transport Category Rotorcraft

Section 29-1301 Function and installation, 29-1309 Equipment, systems, and installations, and 29-1353 Electrical equipment and installations including Advisory Circular 29 - 2C

Part 21 Certification Procedures for Products and Parts

Section 21.303 – Replacement and Modification Parts
Section 21.143 – Quality Control Data Requirement - Prime Manufacturer

1.3 Scope

This document contains test, performance and safety evaluation requirements for secondary Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries. Guidance is also provided on design, test, safety, handling, storage, and disposal of these items. This document defines levels of severity of battery testing to enable battery manufacturers to qualify their products in accordance with their intended use. Equipment designers and manufacturers in turn can select batteries whose safety and performance have been demonstrated at levels appropriate to the battery environment within the equipment and to the required performance.

The object of this standard is to define test procedures for the evaluation, comparison and qualification of batteries and to state minimum operational performance standards (MOPS) for airworthiness. Additional requirements shall apply if specified in the design documentation or designated by the Design Authority.

1.3.1 Power Sources

The intended application of batteries described in this document is as power sources for aircraft equipment or instrumentation and emergency devices including emergency lighting, and engine or APU starting when required.

1.4 Regulatory Issues

Regulation of equipment installed in aircraft, and component parts of that equipment, are the responsibility of the Federal Aviation Administration (FAA). In the case of equipment installed in aircraft at the time of manufacture of the aircraft, the aircraft's Type Certificate (TC) specifies the approved aircraft type design including any battery equipment. Amendments, Supplemental Type Certificates (STC) and Part Manufacturer Approval (PMA) may be approved subsequent to the original issue of a TC. It is also possible to obtain FAA regional or field approval for modification or addition of equipment mounted in aircraft. It is to note that although PMA is acceptable for a complete OEM battery replacement, **it is not acceptable for individual cells**. Providing PMA for individual cells can result in intermixing cells from different manufacturers, this practice **is not permitted** per 1.5.1.2 (b).
The distinction should be noted as to whether equipment containing Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries are installed as part of the aircraft's equipment or are carried as cargo: in the former case, the FAA regulates, and in the latter case, regulation is by the Office of Hazardous Materials Transportation.

1.5 General Requirements

Proper integration of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries into aviation-related equipment requires cooperation between the battery supplier, aircraft designer, and the avionic equipment designer. Only through this cooperative exchange of the aircraft performance requirements and the battery's capabilities and limitations can an effective pairing of aircraft, avionics equipment and battery be realized.

Overall, the stated requirements and guidelines contained in this document are generic in nature, and serve only as a baseline for the design and test for specific battery and equipment pairings. Below are general requirements pertinent to the safety, quality control, configuration control, qualification, storage, shipping, and disposal of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid aircraft batteries.

1.5.1 Safety

Safety is the prime consideration in the use of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries on aircraft. The education of installers and end users and personnel involved in the assembly, handling, installation, maintenance and disposal of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries as to their special characteristics is a necessary safety element. Extreme care must be taken in the handling, shipping, and storage of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid Aircraft Batteries. Safety concerns include the possibility of fire, explosion, corrosive nature of the electrolyte and the venting of toxic or flammable gases.
See Appendix A for additional Safety Guidelines

1.5.1.1 Safety Philosophy

Aircraft designers must insure that operational parameters and the environment in which the battery is to be used are not more severe than that to which it has been designed and tested. Operation at discharge rates and temperatures exceeding design limits, improper maintenance, and improper storage may result in dangerous battery failure. Additionally, the improper application of batteries may compromise the safety of the aircraft by it not being capable of delivering adequate power during an emergency to support aircraft essential loads for the design duration.

Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries and the aircraft equipment for which they are the power source must be designed such that no single failure in either can cause a safety hazard to the passengers or crew of the aircraft.

1.5.1.2 Factors Influencing Safety

The battery application and design should be such to avoid the occurrence of short-circuiting of the battery and its components. The battery shall be constructed to minimize ignition sources inside the battery. The battery should be constructed of self extinguishing materials.

Installers and users of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries must be informed that cells and batteries other than those authorized/approved for a particular application must not be substituted even though they may be of the same physical dimensions, capacity, and voltage.

Safe use of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries involves more than battery selection and testing. Other design and operation factors can have a similar impact on safe use. For example:

a) **Multiple Batteries -** In general, the use of a single battery is preferred over the use of a number of batteries in series and/or parallel. However, in many aircraft applications due to either handling requirements (weight) or space restriction separation in more than one battery case may be necessary.

b) **Mixing of Cells or Batteries –** Mixing of cells or batteries from different manufacturers is not an acceptable practice. Cells or batteries of different capacities in series connection will result in the lower capacity battery(ies) being driven into deep discharge (forced discharge). Cells or batteries may have different capacities because they have different designs, manufacturing processes or storage, use or age histories. Therefore, mixing cells or batteries with different part numbers, made by different manufacturers or from different sources, **shall not be allowed**. **Refer to the OEM maintenance manuals for proper replacement of each manufacturer's cells within a battery.**

c) **Battery Polarity -** Installing one or more batteries incorrectly, with the battery output terminals reversed, will result in the reversed battery being charged by others in the circuit during discharge and discharged by the charging system during charge.

d) **Exposed Terminals -** Batteries should be designed and/or packaged in such a way as to prevent short circuits, and assure proper battery installation. Leaving battery output terminals or leads exposed may result in external short-circuiting of the battery during shipping, handling, testing and installation. Terminals of batteries should be covered with non-conductive protective device to avoid any possibility of shorting during handling, shipping, and storage. Aircraft vibration and/or contact oxidation may result in poor electrical connections. Proper connector design and maintenance procedures are necessary.

e) **High Terminal Voltage –** Batteries supplying 50 Volts or above present a personal safety hazard due to the possibility of lethal shock and must be placarded to clearly indicate the hazard.

These examples are only a few of many design features that should be considered to assure reliability and safety.

1.5.2 Manufacturing Standards

Manufacturing standards, including applicable quality standards such as ISO-9000 series, configuration control, source inspection and aircraft manufacture or user's choice of either lot acceptance testing or Statistical Process Control (SPC) and 100 % testing should be defined at the inception of a new program**.**

The aircraft designer, avionics equipment designer, and battery user should then ensure that the selected Nickel-Cadmium or Lead-Acid battery manufacturer adhere to an acceptable quality system as a means of ensuring that the cell or battery conform to specified requirements.

1.5.3 Application Design Review and Verification

A design review by supplier and purchaser must be utilized to ensure that the product will meet all requirements. There should be an application design review including both the designers of the Nickel-Cadmium or Lead-Acid batteries and avionics equipment designer that the batteries are intended to power. The manufacturer of the airframe in which the battery powered equipment is to be used should be included in the design review and verification. The following topics should be considered:

a. Electrical requirements

b. Environmental requirements

c. Battery and equipment testing

d. Determine the effect of cell or battery venting with regard to installation

e. Pre-installation bench checks

f. Battery replacement

g. Shipping, storage, handling, and disposal.

1.5.4 Quality

1.5.4.1 Quality Control

The importance of reliability and safety in aircraft applications of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries demands an effective quality control system to be followed by the battery manufacturer. The quality system followed should be established through a dialogue between the concerned parties. ISO 9000 and 14 CFR Part 21.303(h) can be utilized; however, the requirements of CFR 14 Part 21.143 are applicable.

The uses of techniques such as Statistical Process Control (SPC) or Statistical Quality Control (SQC) have proven effective in battery manufacture and are recommended. Lot acceptance testing of each production run should also be required or (SPC) and 100 % testing, particularly in cases where manufacture is not a continuous process.

The use of a Failure Analysis/Corrective Action System to analyze and correct the causes of failures that may occur during manufacture, in testing, or in the field, is also recommended.

1.5.4.2 Configuration Control

After qualification, the manufacturer shall maintain configuration control on all parts, processes and materials to insure consistent performance. All design changes shall be processed in accordance with 14 Code of Federal Regulation (CFR) 21.611.

Change is defined as any modification to:

a) Drawing lists
b) Outline drawings
c) Manufacturing drawings
d) Master Parts List or Bill of Materials
e) Processes and Specifications
f) Acceptance Test Procedures, Functional Test Requirements, or Test Instruction Sheets Agreement
g) Software (if any)
h) Identification Markings
i) Installation Instructions and Limitations

1.5.4.3 Re-Qualification

When considering change(s) in configuration, design, materials, production location, or processes that might affect the safety or performance of a previously qualified cell or battery, the changes must be re-qualified prior to permanent incorporation of the change(s). The re-qualification shall consider each element of the Qualification Test Procedure through analysis or retest. The results of the analysis and/or retest shall be documented and forwarded to the certificate/approval holder of the previously qualified cells or batteries.

1.5.5 Storage, Shipping and Disposal

This standard includes design considerations and proper procedures for the storage, shipping, handling, and disposal of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries.

1.5.5.1 Storage

Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries should be stored in a dry and well-ventilated area and should not normally be kept in the same area as flammable materials. Humidity or temperature control is not necessary in most instances but for maximum shelf life the temperature should be below 30ºC. Generally, exposure to temperatures above 50ºC should be kept to a few days in any year. Storage temperatures above 70ºC are to be avoided. Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries should not be stored in the same location/facility due to possible contamination.

Proper battery storage depends on the battery chemistry. Some batteries should be stored shorted, some completely discharged while others require an occasional recharge to obtain their maximum storage life. Aircraft manufacturers and users should consult the battery manufacturer for proper battery storage.

1.5.5.2 Shipping

The transport as cargo of some Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries is regulated. The appropriate regulations of each country should be consulted before transporting Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries.

1.5.5.3 Disposal

The proper disposal of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries is a matter of concern to battery producers, consumers and governmental bodies. Manufacturers Material Safety Data Sheets (MSDS) should be consulted for relevant information. Batteries should be recycled or sent to the Manufacturer for recycling in accordance with all applicable Federal, State and Local regulations for the particular system being used.

1.5.6 Testing

The purpose of Qualification Testing is to demonstrate that Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries meet the design performance and safety requirements of these standards.

1.5.7 Application

The use of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries as power sources in aircraft and aircraft avionics equipment must be clearly defined for a particular application. Specifically designed Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries shall be used only for the intended application until qualified for the requirements of other applications. Previous qualification for a similar requirement in most cases does not constitute suitability for use. Before considering a previously approved battery for a new application, the specifying engineer should evaluate product specification differences. Many devices with similar requirements have subtle differences that will warrant at least a partial retest to assure proper safety and performance.

1.6 Design Consideration

1.6.1 General Construction Requirements

The battery shall be manufactured in such a manner as to be uniform in quality and shall be free from defects that will affect life, functioning, and appearance. Batteries shall not have loose contacts, poor or improper molding or fabrication, damaged or improperly assembled contacts, peeling, flaking or chipping of plating or finish, mechanical damage due to testing environments, nicks or burrs of metal parts of surfaces, nor improper or incorrect marking. A visual examination to requirements shown in Table I upon delivery prior to testing and following testing will determine if the batteries meet the Workmanship requirements

Table 1-1 Workmanship Requirements

Number	Description	Inspection Method
1	Electrical contact surfaces obstructed by insulation compounds.	Visual
2	Pitting or blow holes on the external cell container.	Visual
3	Electrolyte leakage.	Visual
4	Location and polarity of terminals not as specified.	Visual
5	Terminal and identification markings not as specified.	Visual
6	Terminal seals missing or defective.	Visual
7	Corrosion.	Visual
8	Particles of foreign material.	Visual
9	Welds containing blow holes, cracks, or slag inclusions.	Visual
10	Burrs on battery container or cover.	Visual
11	Improper color on outside of container and cover.	Visual

1.6.2 Corrosion Prevention

All exposed metal surfaces of the cells, inter-cell connectors, and associated hardware shall be electrolyte resistant.

1.7 Electrical Bonding

Where metallic hold downs are used, provision shall be made to provide a bare conductive surface on all hold down bars, brackets, or attachment points, for electrical bonding with the airframe unless detailed otherwise in the design documentation. This may be accomplished by leaving part of the hold down bar uncoated or by spot facing the coating to bare metal in the area(s) where the aircraft hold-down device(s) contact the battery.

1.8 Dissimilar Metals

Where dissimilar metals are used in intimate contact, suitable protection against galvanic corrosion shall be applied.

1.9 Venting Arrangements

The design of all vented batteries should employ a method of fresh air dilution of the gases generated during overcharge. The purging system may be either by natural ventilation or by assisted ventilation.

In natural ventilation, the battery container and/or cover should have sufficient holes or louvers to ensure gas dissipation in still air. Such holes or louvers should be designed to prevent access by foreign objects.

For Assisted ventilation, the liberated gases from all the cells should pass into a venting chamber, having ports for the purging air. There are two preferred methods of achieving a purging airflow:

(a) The entry of air into the battery is via an entry housing with a non-return valve. The air is taken from the battery by a pipe connection;

(b) The air is taken to and from the battery by pipe connections and the direction of ventilation is immaterial.

1.10 Marking

1.10.1 Battery Marking

The manufacturer's marking and labeling on the battery exterior shall contain the following minimum information in a legible and durable form:

1. Manufacturer's name
2. Manufacturer's type or part number
3. Modification numbers or letters
4. Nominal battery voltage
5. Rated capacity
6. Battery polarity
7. Chemical system (e.g. nickel-cadmium or lead-acid)
8. Manufacturer's serial number
9. Number of cells (as required)
10. Max continuous discharge rate (Amps) (as applicable)

Additional markings requirements may be specified in the procurement document.

1.10.2 Cell Marking

In the case of removable cells, each cell will be clearly and indelibly inscribed with the following information:

a) Manufacturer's name
b) Date of manufacture or batch or serial number
c) Chemical system or recycling information in accordance with national legislation.

1.10.3 Polarity Marking

The battery container body or electrical main connector shall be clearly and durably marked. Individual cells or monoblocks will bear clear polarity markings.

1.11 Design Life

The design life established by the battery and aircraft manufacturers shall not be exceeded by users.

Normal flight operations require the battery to be removed for scheduled maintenance. During this maintenance the battery shall meet the minimum requirements for airworthiness established by the battery and aircraft manufacturers or it shall be removed from service.

1.12 Deleted

1.13 Test Considerations

The test procedures and associated limits specified throughout this document are intended for use as the means of demonstrating compliance with the minimum operational performance standards. Alternate test procedures or deviations to specified procedures must be shown to demonstrate equivalent or higher levels of performance and safety. Test units submitted for qualification must be characterized and all data recorded.

The cell or battery is subjected to a succession of different tests as it moves from design, and design qualification into operational use.

1.13.1 Test and Verification Philosophy and Goals

The test philosophy imposed upon Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries has as its main consideration safety, reliability and performance. However, actual performance of any battery will depend on the application in which it is used. Reliability and performance are especially important because of their impact on the safety of the aircraft, passengers and crew.

The test requirements should be regarded as the minimum needed to assure a high degree of confidence in the safety, reliability, and performance of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries. Additional tests or analysis, such as fault-tree analysis, should be used in the safety assessment process, particularly for complex battery and charging systems, or critical applications.

1.13.2 Qualification Test Goals

Qualification tests are a well-defined series of tests to demonstrate that the functional, environmental, safety, reliability, and performance requirements of a cell or battery design are met. The tests are to be conducted according to formal procedures, in a fixed sequence, and the results are to be documented.

1.13.3 Operational Tests

Operational tests specifications are the responsibility of the aircraft, battery, and avionics equipment designers and manufacturers. These test procedures and their associated limits are intended to be conducted by equipment maintenance personnel as one means of ensuring that the equipment is functioning properly and can be reliably used for its intended functions. These procedures should state whether each test might diminish the capacity or the performance of the battery.

1.13.4 Unspecified Tests

Additional tests beyond those specified in this document will be required at the equipment level to demonstrate that the battery will meet the equipment specifications for performance and safety.

1.14 Assumptions for the Determination of Charge and Discharge Values

To provide representative examples, this document utilizes voltage and current values based upon an aircraft electrical system nominally rated at 28 VDC. Additionally, the nominal values for cell voltage are assumed to be 1.2 V per cell for nickel-cadmium and Nickel Metal-Hydride batteries and 2.0V per cell for lead-acid batteries. It is important to note that when using this document to evaluate products designed to operate on an aircraft electrical system other than the nominal 28 VDC, or whose chemical properties are such that the individual cell voltage differs from that stated above, test values shall be adjusted accordingly.

1.15 Instructions for Continued Airworthiness

Each manufacturer shall develop Instructions for Continued Airworthiness in accordance with the requirements of the appropriate regulatory authority. The Instructions for Continued Airworthiness should include, but not limited to, the following information:

a) Maintenance
b) Installation description
c) Basic control and operation
d) Servicing
e) Maintenance Schedule
f) Inspection
g) Troubleshooting
h) Removing and replacing parts
i) Repairs
j) Special Tools, Fixtures and Equipment
k) Component manual
l) Configuration control
m) Storage instructions
n) Airworthiness limitations

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2 ELECTRICAL QUALIFICATION REQUIREMENTS AND TEST PROCEDURES

2.1 Test Conditions and Apparatus

2.1.1 General Test Conditions

If specific test conditions are not defined for a test, the test shall be carried out under the following general test condition:

Air pressure: 85 kPa to 106 kPa (850 mbar to 1060 mbar)

Temperature: 23 °C ± 2 °C

Relative Humidity (RH): not to exceed 70 %

If definite tolerances have not been specified, a deviation of not more than ± 5 % from the given non-electrical values will be permitted.

2.1.2 Measuring Apparatus

The measuring method used for the tests shall be selected to suit the magnitude of the parameters to be measured. The apparatus shall be regularly calibrated and shall have at least the degree of accuracy given below:

2.1.3 Voltage Measurement

The instruments used for measuring voltage shall be voltmeters having an accuracy of Class 0.5 or better, as defined in ANSI/ASQC M1-1996: American National Standard for Calibration Systems. The resistance of the voltmeters shall be at least 5 000 Ω/V.

2.1.4 Current Measurement

The instruments used for current measurement shall be ammeters having an accuracy of Class 0.5 or better, as defined in ANSI/ASQC M1-1996: American National Standard for Calibration Systems. This accuracy class shall be maintained for the assembly of ammeter, shunt and leads.

2.1.5 Temperature Measurement

The instruments used for temperature measurement shall have an accuracy of ± 1 °C or better.

2.1.6 Time Measurement

The instruments used for time measurement shall be to an accuracy of 0.5 % or better.

2.1.7 Additional Test Equipment

Equipment used shall have a measurement accuracy of 5 % unless otherwise stated.

2.1.8 Mass Test Equipment

Equipment used shall have a measurement accuracy of 0.5% unless otherwise stated.

2.1.9 Charging Method

The battery shall be serviced and charged in accordance with the manufacturer's instructions or using the dedicated charger or as required in the design documentation.

2.1.10 Physical Examination

Prior to the commencement of the electrical and environmental testing, each battery being tested shall be inspected as follows to ensure that they comply with the relevant design:

a. Mass and Dimensions

b. Marking as a minimum as detailed in paragraph 1.10.1

c. Correct warning labels

d. Correct interface connectors

e. Damage to case, lid and interface connectors

f. No signs of corrosion

g. No signs of electrolyte leakage

h. General standards of Workmanship

2.2 Electrical Requirements and Test Procedures

2.2.1 Capacity Tests at the $1I_1$ Rate

Capacity is the total quantity of electricity of a cell or battery, expressed in ampere-hours. The $1I_1$ rate is the current that the battery delivers to give not less than its rated C_1 capacity in 1 hour. This shall be the basis on which all other current ratings are defined

2.2.2 Rated Capacity C1

The minimum capacity, expressed in Ah, obtained from a charged battery when discharged at the $1I_1$ rate to the End Point Voltage (EPV).

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. After standing for not less than 20 h and not more than 24 h at an ambient temperature of 23 °C ± 2 °C it shall be discharged at the $1I_1$ rate to its EPV, maintaining the ambient temperature at 23 °C ± 2 °C during discharge.

Evaluation Criteria

The battery shall deliver a capacity of not less than 100 % of its rated capacity for a period of one hour prior to reaching its EPV.

2.2.3 Capacity at $1I_1$ and -18 °C

The minimum capacity at –18 °C, expressed in Ah, obtained from a charged battery when discharged at the $1I_1$ rate to the End Point Voltage (EPV).

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. After standing for not less than 20 h and not more than 24 h at an ambient temperature of –18 °C ± 2 °C it shall be discharged at the $1I_1$ rate to its EPV, maintaining the ambient temperature at –18 °C ± 2 °C during discharge.

Evaluation Criteria

The capacity shall be recorded and shall not be less than the value stated in the design documentation.

2.2.4 Capacity at $1I_1$ and -30°C

The minimum capacity at –30 °C, expressed in Ah, obtained from a charged battery when discharged at the $1I_1$ rate to the End Point Voltage (EPV).

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. After standing for not less than 20 h and not more than 24 h at an ambient temperature of –30 °C ± 2 °C it shall be discharged at the $1I_1$ rate to its EPV, maintaining the ambient temperature at –30 °C ± 2 °C during discharge.

Evaluation Criteria

The capacity shall be recorded and shall not be less than the value stated in the design documentation.

2.2.5 Capacity at $1I_1$ and 50°C

The minimum capacity at 50 °C, expressed in Ah, obtained from a charged battery when discharged at the $1I_1$ rate to the End Point Voltage (EPV).

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. After standing for not less than 20 h and not more than 24 h at an ambient temperature of 50 °C ± 2 °C it shall be discharged at the $1I_1$ rate to its EPV, maintaining the ambient temperature at 50 °C ± 2 °C during discharge.

Evaluation Criteria

The capacity shall be recorded and shall not be less than the value stated in the design documentation.

2.2.6 Constant Voltage Discharge (high rate batteries only)

Subject the battery to a constant voltage discharge equal to the number of cells multiplied by half their nominal voltage at the following temperatures.

2.2.6.1 Constant Voltage Current at 23 °C

The discharge current expressed in amperes at 23 °C, which the battery delivers at the conclusion of a 15 s power discharge, controlled so as to maintain a constant terminal voltage of half the nominal voltage.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer’s instructions or design documentation. After standing for not less than 20 h and not more than 24 h at 23 °C ± 2 °C it shall be discharged at a rate so as to maintain a constant terminal voltage corresponding to half the nominal voltage for not less than 15s. The discharge load shall be automatically controlled to enable a plot of current against time to be recorded throughout the test.

Evaluation Criteria

The current at 15s shall be designated I_{PR} and the current at 0,3 s shall be designated I_{PP}. The curve generated during this test shall meet or exceed the curve provided in the design documentation.

2.2.6.2 Constant Voltage Current at –18 °C

The discharge current expressed in amperes at -18 °C, which the battery delivers at the conclusion of a 15 s power discharge, controlled so as to maintain a constant terminal voltage of half the nominal voltage.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer’s instructions or design documentation. After standing for not less than 20 h and not more than 24 h at –18 °C ± 2 °C it shall be discharged at a rate so as to maintain a constant terminal voltage corresponding to half the nominal voltage for not less than 15 s. The discharge load shall be automatically controlled to enable a plot of current against time to be recorded throughout the test.

Evaluation Criteria

The curve generated during this test shall meet or exceed the curve provided in the design documentation.

2.2.6.3 Constant Voltage Current at –30 °C

The discharge current expressed in amperes at -30 °C, which the battery delivers at the conclusion of a 15 s power discharge, controlled so as to maintain a constant terminal voltage of half the nominal voltage.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. After standing for not less than 20 h and not more than 24 h at –30 °C ± 2 °C, discharge the battery at a rate so as to maintain a constant terminal voltage corresponding to half the nominal voltage for not less than 15 s. The discharge load shall be automatically controlled to enable a plot of current against time to be recorded throughout the test.

Evaluation Criteria

The curve generated during this test shall meet or exceed the curve provided in the design documentation.

2.3 Rapid Discharge Capacity (for high rate batteries only)

Subject the battery to a rapid discharge rate $10I_1$ or the battery max declared rate of discharge at the following temperatures.

2.3.1 Rapid Discharge Capacity at 23 °C

Minimum Capacity at 23 °C, expressed in Ah, obtained from a charged battery when discharged at the $10I_1$ rate to 10.0 volts or the Manufacturer recommended cutoff voltage.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. After standing for not less than 20 h and not more than 24 h at an ambient temperature of 23 °C ± 2 °C it shall be discharged at a $10I_1$ rate to 10.0 volts or the Manufacturer recommended cutoff voltage.

Evaluation Criteria

The capacity delivered by the battery shall recorded and not be less than the value stated in the design documentation.

2.3.2 Rapid Discharge Capacity at –30 °C

Minimum Capacity at -30 °C, expressed in Ah, obtained from a charged battery when discharged at the $10I_1$ rate to 10.0 volts or the Manufacturer recommended cutoff voltage.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. After standing for not less than 20 h and not more than 24 h at an ambient temperature of –30 °C ± 2 °C, a serviced and charged battery shall be discharged at a $10I_1$ rate to 10.0 volts or the Manufacturer recommended cutoff voltage.

Evaluation Criteria

The capacity delivered by the battery shall be recorded and not be less than the value stated in the design documentation.

2.4 Charge Retention

Minimum Capacity at 23 °C, expressed in Ah, obtained from a charged battery when discharged at the $1I_1$ rate to the EPV following exposure at 23 and 50°C for 28 days.

Test Method

The battery shall be subjected to two separate tests one at each of the two different temperatures defined, each to be undertaken sequentially.
Test temperature:

23 °C ± 5 °C
50°C ± 2°C

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. It shall be discharged according to 2.2.2 and the discharge duration shall be recorded (capacity 1).
It shall be recharged and, with the battery cover on, stored in an open circuit condition at the temperature defined above for a period of 28 days after which it shall be removed from the thermal storage, allowed to stabilize to a temperature of 23 °C ± 5 °C for not less than 20 hours and not more than 24 hours and then discharged at the $1I_1$ rate to its EPV (capacity 2).

Evaluation Criteria

The capacity (capacity 2) and the percentage reduction of capacity (calculated from capacities 1 & 2) shall be recorded and shall comply with the value stated in the design documentation.

2.5 Storage

This test may be demonstrated by similarity to previous results documented by the applicant on their construction and chemistry.
Battery after storage for 24 months at temperate conditions shall not indicate any electrolyte leakage, accept charge, demonstrate charge stability, meet rated capacity requirements, pass duty cycle performance, and recover from deep discharge.

Test Method

A new battery, as supplied by the manufacturer, shall be stored in temperate conditions (20 °C ± 15 °C; humidity less than 70 %) for 24 months. Different storage periods may be specified either by the manufacturer or stated in the design documentation.

Evaluation Criteria

After storage, the battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. It shall then satisfy the test sequence in Table 1 for Test Battery in group V.

2.6 Charge Stability

The Charge Stability test is conducted to establish acceptability of the separator system during high temperature constant potential charging.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. To facilitate temperature measurements of the battery, a thermocouple shall be connected to either an inter-cell or monoblock connector, near to the center of the battery, fitted with any necessary instrumentation and placed in a chamber at 50 °C ± 2 °C for not less than 20 h and not more than 24 h, prior to commencement of the test. The battery shall remain in the chamber for the duration of this test and the airflow, across the working section of the chamber, shall not exceed a speed of 1.5 feet per second.
Discharge the battery at a $6I_1$ rate for 5 min and immediately recharge, using either a constant voltage charge of 28.5 V ± 0.1 V or a dedicated charger for a period of 10 hours.
Record the charging current every second for the first five minutes thereafter record both current and temperature at intervals of ten minutes. The voltage shall be recorded throughout the discharge period.
On completion of charge stand on open circuit for 1 h. Discharge, the battery, at the $1I_1$ rate to its EPV. The battery shall be examined at the end of test for physical damage. No water additions shall be made after the battery has been placed in the chamber.

Evaluation Criteria

During the constant voltage charge, the charging current shall not increase from the minimum value during this period by more than $0,1I_1$ and the temperature of the center section shall not exceed 70 °C. During the discharge at $1I_1$, the battery shall deliver a capacity of not less than 75 % of C_1.
At the end of test, the battery after standing at 23 °C ± 2 °C for not less than 20 h and not more than 24 h, shall meet the requirements of 2.2.2.

2.7 Short-circuit Test

The short-circuit test is conducted to show worst case the extent of battery failure and that the products of that failure are contained within the battery case. This test also provides information on amount of output current that can be delivered to help in sizing wiring and circuit breakers.

Test Method.

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation and stabilized at 23°C ± 2 °C for not less than 20 h and not more than 24 h. It shall then be connected to a test circuit with an appropriate mating connector

for 60 s. The total resistance of the circuit including the appropriate mating connector shall not exceed 2.0 mΩ.
The current and the terminal voltage shall be measured throughout the test. Peak current and last recorded current are to be recorded.

Evaluation Criteria

All debris or fragmentation shall be contained within the battery casing and there shall be no subsequent ignition of gases within the battery.
Peak current and last recorded current are to be reported. If the battery becomes open circuit, the time at which the open circuit occurred shall be documented. The current just prior to this and the physical condition of the battery after the test shall be reported.

Evaluation Criteria

All debris or fragmentation shall be contained within the battery casing and there shall be no subsequent ignition of gases within the battery.
Peak current and last recorded current are to be reported. If the battery becomes open circuit, the time at which the open circuit occurred shall be documented. The current just prior to this and the physical condition of the battery after the test shall be reported.

2.8 Charge Acceptance

Included in this test are optional requirements for low temperature assessment (either –18 °C or –40 °C), which shall be undertaken where internal heaters are fitted to batteries. The ambient temperature test shall be carried out regardless of whether the battery contains internal heaters or not.

2.8.1 Ambient Temperature (23°C)

Charge acceptance of batteries checks the ability of the chemistry to accept charge at 23°C. This assures that energy removed from the battery during ground and start operations can be returned to the battery in a reasonable amount of time so it can provide emergency services.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer’s instructions or design documentation. It shall be discharged in accordance with 2.2.2 and the discharge duration shall be recorded. It shall be recharged in accordance with the battery manufacturer’s instructions or design documentation. It shall then be discharged at the $1I_1$ rate for 50 % of the duration of the previous discharge test. The battery shall stand for not less than 20 h and not more than 24 h and then be charged at a constant voltage of 28,5 V ± 0,1 V or using a dedicated charger for 1,0 ± 0,05h. A curve of current as a function of time shall be recorded for a period of 1 h.
Immediately after charging, the battery shall be discharged at $1I_1$ to its EPV.

Evaluation Criteria

The capacity shall be recorded and shall be not less than the value declared by the manufacturer or as stated in the design documentation.

2.8.2 Low Temperature (for Batteries Containing Internal Heaters)

2.8.2.1 Charge and Discharge Test at –18 °C

Charge and Discharge Test at -18° C of batteries checks the ability of the chemistry to accept charge with internal heaters and that the internal heaters are properly sized. This assures through the application of heater blankets that energy removed from the battery during ground and start operations can be returned to the battery in a reasonable amount of time so the battery can provide emergence services.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation and then placed in a test chamber at –18 °C ± 2 °C for not less than 20 h and not more than 24 h. While at this test temperature, the battery shall be discharged at the $1I_1$ rate to its EPV.
Within 5 min with the battery still in the –18 °C environment, charge it at a constant voltage of 28.5 V ± 0,1 V or using its dedicated charger for 0.5 h ± 3 min. A curve of current as a function of time shall be recorded. The battery heater circuit shall be energized at its specified power during the entire 0.5 h charge. At the end of the 0.5 h charge, disconnect power from the heater circuit. Immediately following charge, remove the battery from the test chamber and discharge it at $1I_1$ to its EPV.

Evaluation Criteria

The capacity shall be recorded and shall not be less than the value of the previous discharge or as stated in the design documentation.

2.8.2.2 Charge and Discharge Test at –40 °C

Charge and Discharge Test at -40° C of batteries checks the ability of the chemistry to accept charge with internal heaters and that the internal heaters are properly sized. This assures through the application of heater blankets that energy removed from the battery during ground and start operations can be returned to the battery in a reasonable amount of time so the battery can provide emergence services.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation and placed in a test chamber at –40 °C ± 2 °C for not less than 20 h and not more than 24 hours. While at this test temperature, the battery shall be discharged at the $1I_1$ rate to its EPV.
Within 5 min and with the battery still in the –40 °C environment, charge it at a constant voltage of 28,5 V ± 0,1 V or using its dedicated charger for 1,0 h ± 3 min. A curve of current as a function of time shall be recorded. The battery heater circuit shall be energized during the entire 1.0 h charge. At the end of the 1.0 h charge, disconnect power from the heater circuit.
Immediately after completing the 1.0 h charge, remove the battery from the –40 °C environment and place in a 23 °C± 2 °C environment. Within five min, discharge the battery at the $1I_1$ rate to its EPV.

Evaluation Criteria

The capacity shall be recorded and shall not be less than the value of the previous discharge or as stated in the design documentation.

2.9 Insulation Resistance and Dielectric Strength

To assess insulation resistance both of the following tests shall be carried out.

2.9.1 Insulation Resistance

Measurement in Mega-ohms the resistance to current leakage through the insulating materials used in the battery. Conducted for personnel safety and power reliability.

Test Method

The value of the insulation resistance shall be measured with 250 V D.C. between the positive output terminal and the usual points for the installation and attachment of the casing.

Evaluation Criteria

The minimum value of the insulation resistance shall be 0.25 MΩ but after cleaning and drying the minimum value shall be 10 MΩ.

2.9.2 Dielectric Strength

Dielectric Strength is the demonstration of the ability of an insulator to withstand potential difference without passing an electric current. Conducted for personnel safety and power reliability.

Test Method

The battery shall be stabilized at 23 °C ± 5 °C for not less than 20 h and not more than 24 h. Apply an A.C. voltage, rms value 1500 V, frequency 50 Hz ± 10 Hz, for 1 min. between each battery terminal and case (or its attachments if insulated).

Evaluation Criteria

There shall be no arcing or insulation breakdown.

2.10 Duty Cycle Performance (for engine start batteries only)

Simulated engine or APU starts and charge cycling is conducted to determine the ability of the battery to perform its intended function, and accept charge without performing maintenance for a preset number of cycles.

Test method

The following test shall then be carried out at an ambient temperature of 23 °C ± 5 °C. The battery may be externally cooled throughout the test. To assist cooling the cover of batteries fitted with removable covers may be removed.

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. During the test the temperature of the battery shall be measured as close as possible to the center of its mass; either on one of the inter-cell connectors or secured to the monoblock surface.

A duty cycle consists of the following sequence:

a) The battery shall be discharged through a fixed resistor for 20 s. The value of the resistor (in ohms) shall be equal to 1.15 times the nominal battery voltage divided by its rated value of I_{PR} (5.5) or as declared in the design documentation. The nominal battery voltage is defined as the number of cells times 1.2 V for nickel-cadmium or 2.0 V for lead-acid batteries. The resistance shall not vary by more than ± 5% through the test.
b) After standing on open circuit for 2 min it shall again be discharged through the resistor for 20 s.
c) The battery shall then be charged using a dedicated charger or at a constant voltage of 28.5 V ± 0,1 V (for a nominal 24 volt battery and adjusted pro rata for batteries of other nominal voltages) for 60 min. ± 2 min. The constant voltage supply shall have a current rating of at least $8I_1$.
d) The battery shall then stand on open circuit for not less than 1 h and not more than 2 h.

The duty cycle (sequence a) to d)) shall be repeated 50 times unless directed otherwise in the design documentation. No water addition is permitted during these cycles.
The battery shall be immediately discharged at the $1I_1$ rate recording the duration to its EPV.
The battery shall then be serviced and charged in accordance with the battery manufacturer's instructions or design documentation.
The battery shall then be discharged at the $1I_1$ rate recording the duration to its EPV.
Repeat the procedures above to provide a minimum total of 100 duty cycles.

Evaluation Criteria

The battery shall meet the specification if:

a) The minimum battery terminal voltage achieved during the discharge at (a) above shall be not less than 13 volts (for a nominal 24 volt battery and adjusted pro rata for batteries of other nominal voltages);
b) The temperature in the center of the battery shall not exceed 60 °C;
c) The current during constant voltage charge reduces to and remains below 0.2 I_1 during the test;
d) The duration of the discharge at the $1I_1$ rate, immediately after the last charge of the cycling test, is not less than 48 min (80 % of C_1)
e) The water replenishment, where applicable, per cell during servicing does not exceed the manufacturer's recommendations;
f) The insulation resistance between cells and case before servicing is not less than 0.25 MΩ at a voltage of 250 V D.C.;
g) After servicing and charging the duration of the discharge at the $1I_1$ rate is not less than 54 min (90 % of C_1);
h) Dimensional distortion remains within specified limits;
i) No cracking of cases or covers of either cells or batteries occurs.

2.11 Water Consumption Test

This test is designed for vented Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries to which water can be added. Measurement of mass change in grams associated with continuous constant voltage charge. This helps to establish the battery water addition (maintenance) cycle.

Test Method

A rated capacity test shall be carried out on a serviced and charged battery in accordance with 2.3.1. The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation.

The battery shall be weighed prior to commencement of the test and after the completion of each 500 h. The battery is required to complete a minimum of 2000 h.

The battery shall be subjected to a charge at a constant voltage of 28,5 V ± 0,1 V at a temperature of 23 °C ± 5 °C. The test shall continue for 2000 h or until the maximum weight loss, commensurate with safe operation, as declared by the manufacturer, has been reached.

Evaluation Criteria

The total number of hours on charge and the resultant weight loss shall be recorded.

2.12 Cyclic Endurance (for all batteries)

The Cyclic Endurance Test is conducted to determine the number of cycles that can be performed without performing maintenance to rebalance the capacity for nickel cadmium and nickel metal hydride, and to determine the cycle life for lead-acid batteries.

Test Method.

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation and subjected to 4 sets of 24 shallow discharge cycles followed by 1 deep discharge cycle or until the battery fails to meet the requirement below. External cooling is permitted.

Each shallow cycle shall consist of a discharge at the $1I_1$ rate for 10 min, followed by a charge at 28.5 V ± 0,1 V or with a dedicated charger for 2 h, and a stand for 1 h.

Each deep cycle shall consist of a discharge at the $1I_1$ rate for 48 min, followed by a charge at 28.5 V ± 0,1 V or with a dedicated charger for 2 h, and a stand for 1 h.

Evaluation Criteria

During each discharge the voltage shall not fall below 0,9 V per cell for nickel-cadmium batteries or 1,5 V per cell for lead-acid batteries.
The manufacturer shall declare the number of cycles satisfactorily completed.

2.13 Deep Discharge Test

To establish the performance of the battery and its ability to recover from a deep discharge, the following test shall be applied:

Test Method

This test shall be carried out at 25 °C ± 5 °C. A battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation.

Discharge the battery at the $1I_1$ rate (in accordance with 2.2.2), to determine its capacity (capacity 1). Apply a 1 Ω ±10% resistor between the positive and negative terminals of the battery. The resistor shall remain connected for two weeks. Remove the resistor circuit and leave the battery to stand in the discharged condition for a further two weeks.

Charge the battery in accordance with the battery manufacturer's instructions or design documentation. Carry out a Capacity Discharge Test ($1I_1$) in accordance with 2.2.2 (capacity 2).

Evaluation Criteria

The battery shall have passed this test if the capacity 2 is equal to or greater than 90 % of the capacity 1 or as stated in the design documentation

2.14 Induced Destructive Overcharge.

WARNING: Attention is drawn to the possible risk of fire or explosion involved in performing this test.

The Induced Destructive Overcharge Test is conducted to determine the effects of the battery going into thermal-run-away. Simulates conditions that could occur if one or more cells were to short and charger failed to shut off. This determines the safety of the battery.

Test Method

To establish the performance of the battery and its ability to recover from a deep discharge, the following test shall be applied:

Test Method

The battery shall be charged and serviced in accordance with the battery manufacturer's instructions or design documentation.

It shall be mounted by its normal method of mounting.

It shall then be further charged, using a constant voltage power supply, at a minimum of 3V per cell for lead-acid and 1.8V for nickel-cadmium and nickel metal-hydride with the capability of supplying a current of at least $8I_1$ Amperes to the point of total battery failure.

The charging source shall not be removed until the battery voltage and charge current have stabilized for at least one hour.

Throughout the test, record the battery terminal voltage, charging current and the battery temperature.

Evaluation Criteria

The following shall be reported:

a) Any evidence of flame from the battery within 3h following termination of the final charge;
b) Effectiveness of the battery containment case to contain all debris resulting from any explosion during or after the test;

c) Any escape of electrolyte from the battery case.

2.15 Electrical Emissions

Batteries, which contain active electronic components, shall be tested to the requirements of DO-160. The manufacturer shall declare, whether the battery contains any active components.

3 ENVIRONMENTAL QUALIFICATION REQUIREMENTS AND TEST PROCEDURES

3.1 Vibration

The battery shall be subjected to random vibration per section 8 of RTCA/DO-160. The method of mounting, orientation and vibration spectrum applied during vibration assessment shall replicate that used in the application. The details below are designed for the majority of applications, specific requirements shall be included in the design documentation. This test demonstrates minimum operational performance for batteries for all aircraft types. Since batteries service life is limited in comparison to the service life of the aircraft, vibration requirements may be tailored to meet the requirements of the application and to account for the limited operational life of the battery system.

3.1.1 Battery Mounting

The battery shall be mounted with the base of the battery in a horizontal plane irrespective of the axis of vibration (Figure 1). Unless otherwise specified it shall be secured directly onto the vibration table by its nominal method of mounting. Electrical connection to the battery shall be made via the battery connectors.

3.1.2 Random Vibration Test (Section 8 of RTCA/DO-160)

The Random Vibration Test is intended to provide a laboratory means of verifying the safety of batteries under conditions representative of those which may be encountered in actual aeronautical operations. Values shown are for minimum airworthiness and should be tailored to those that the battery will see in the actual aircraft based on its location.

Test Method

3.1.2.1 Initial Resonance Search

An initial resonance search test using sinusoidal vibration shall be carried out with a sweep rate of 0,5 octave per minute, using the following conditions:

5 Hz to 54 Hz (0,5 mm constant displacement amplitude)
54 Hz to 2000 Hz (6 g constant acceleration amplitude)

The sweep shall be carried out along each of three mutually perpendicular axes and throughout the search the frequencies at which any equipment malfunction or mechanical resonance occur shall be noted.

3.1.2.2 Vibration Test

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation.
Perform the Standard Vibration Procedure of sub clause 8.2.1, vibration test requirement of 8.3 of DO-160. Subject the battery to the Random Test Procedure of sub clause 8.5.2.

Subject the battery to the vibration test curve C (4.12 grms), of Figure 8.1.

The vibration shall be applied to the battery in each of its three major orthogonal axes for 1.0 h ± 1 min per axis.

During vibration the battery shall be charged in the same manner as it would normally be charged when installed in the aircraft and shall be discharged at the $1I_1$ rate for 10 min prior to beginning each axis.
Temperature sensors and/or switches shall be monitored during vibration tests to demonstrate that there is no erroneous operation.

The battery voltage and current shall be continuously recorded such that variation or interruption of the output can be detected.

The battery shall comply with the Rapid Discharge capacity test at 23°C.

Evaluation Criteria

When subjected to random Vibration Test the battery shall comply with the following;

a) No battery cell or component shall show dimensional distortion beyond specified limits or cracking of cases or covers of either cells or batteries.
b) There shall be no interruption of output and no irregular variation of voltage or current.
c) There shall be no mechanical failure of any part, electrolyte leakage or spillage of electrolyte at any time during the test or venting of gasses containing entrained electrolyte (except during charge of vented batteries).
d) The minimum value of the insulation resistance shall be 0.25 MΩ but after cleaning and drying the minimum value shall be 10 MΩ. There shall be no breakdown of insulation, stripping of metal plating from any component part, corrosion of metal parts, or loosening of protective coating from the battery container or cover or deterioration of battery identification markings.
e) The battery shall deliver a minimum of 80% of the Rapid Discharge Capacity rating declared by the manufacturer or required by the design documentation.

3.2 Deleted

3.3 Operational Shock and Crash Safety (Section 7 of RTCA/DO-160)

3.3.1 Operational Shock

The Operational Shock Test is intended to provide a laboratory means of verifying the safety of batteries under conditions representative of those that may be encountered in actual aeronautical operations**.**

Test Method

Perform the Operational Shock Test Procedure of sub clause 7.2.1 of RTCA/DO-160. All shock pulses shall be of saw tooth configuration. The battery shall be fully charged prior to the shock test. Shock the battery in all orientations except do not shock in the suspended upside down position. While subjecting the battery to the shocks, discharge the battery at the 0.5 I_1 rate; and, after each shock, check for any failure, electrically or mechanically. No resilient mounting shall be provided. The operational test (impulse) acceleration peak value shall be as shown in the table below.

Operational Peak Value (g)	Crash Safety Peak Value (g)	Nominal Saw tooth Duration
6	20	11 milliseconds

Evaluation Criteria

The battery shall be examined for physical damage resulting from the shock test and there shall be no damage to the battery or leakage of electrolyte from the battery.

3.3.2 Crash Safety (Section 7 of RTCA/DO-160)

The Crash Safety Test is intended to provide a laboratory means of verifying the safety of batteries under conditions representative of those that may be encountered in actual aeronautical operations. This test assures that battery attachment method will not allow the battery to come adrift during hard landing or crash landing harming the passengers.
Both the impulse and sustained test procedures shall be performed.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation and subjected to the Crash Safety

Test Procedure 1 of sub clause 7.3 of RTCA/DO-160. The battery shall not be shocked in the suspended upside down position.
Test Procedure 2 of sub clause 7.3 of RTCA/DO-160. The battery shall not be shocked in the suspended upside down position.

Evaluation Criteria

The battery shall meet all mechanical requirements specified in sub clause 7.3.1 of the RTCA/DO-160. In addition, no leakage of electrolyte from the battery is allowed. After the shocks are completed, the battery shall be subjected to the rapid discharge capacity at 23 °C of 2.3.1 and must deliver that declared by the manufacturer or required by the design documentation.

3.4 Explosion Containment (Section 9 of RTCA/DO-160)

WARNING: Extreme caution shall be exercised when carrying out this test, to prevent injury in the event that the explosion is not contained.

The Explosion Containment Test is conducted to determine the effectiveness of the case to the ignition of hydrogen in the battery that might occur if a cell were to short or the charger malfunction and overcharging the battery to a gassing state.
This test shall be used instead of the test required by section 9 of RTCA/DO-160.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. It shall be mounted by its nominal method of mounting and with no forced ventilation, shall be overcharged with a current of 0.5 I_1. After not less than 5 min at this current, the gases within the outer casing of the battery shall be ignited by a suitable method.

Evaluation Criteria

All debris or fragmentation shall be contained within the casing and there shall be no subsequent ignition of the battery after power is removed.

3.5 Temperature and Altitude

3.5.1 Altitude

The Temperature and Altitude Test is intended to provide a laboratory means of verifying the safety of batteries under conditions representative of those that may be encountered in actual aeronautical operations.

Test Method.

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation, placed in the altitude chamber and connected to the external supplies. It shall be subjected to two cycles at ambient temperature as follows:

Reduce the absolute pressure over 15 min to 55,000 feet.
Discharge the battery at 5 I_1 for 5 min.
Charged at a constant 28,5 V or using the dedicated charger for a period of 3 h
Return the pressure of the test area over 15 min

After standing for not less than 20 h and not more than 24 h on open circuit at 23 °C ± 2 °C, the battery shall be subjected to the rated capacity test of clause 2.3.1.

Evaluation Criteria

The battery shall meet the capacity requirement of clause 2.3.1. It shall not exhibit deformation of the case, lid, cell containers or insulators outside of the tolerances defined. It shall not show evidence of abnormal heating, including the connector area. It shall not exhibit cracking of the case, cell containers and components, displacement or obstruction of the venting arrangement. It shall not exhibit deterioration of the surface protection.

3.5.2 Rapid Decompression

The rapid decompression test is conducted to assure that seals and vent bands will quickly adjust pressure and reseal without allowing large amounts of electrolyte to be pulled from the battery and that the battery cells and monoblocks are not cracked during a condition when the aircraft looses internal pressurization.

Test Method (Section 4, paragraph 4.6.2 DO-160)

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation, placed in the altitude chamber and connected to the external supplies.
Adjust the absolute pressure to and equivalent altitude of 8,000 ft (2,300 m) MSL and allow the equipment to stabilize. Reduce the absolute pressure to the equivalent of the maximum operational altitude of 55,000 feet. This reduction in pressure shall take place in 15 seconds. Maintain this reduced pressure for at least 10 minutes or as specified in the procurement specification.

Evaluation Criteria

Determine compliance with the design documentation during the period at maximum operating altitude.

3.6 Temperature Shock

The Temperature Shock Test is intended to provide a laboratory means of verifying the effectiveness of seals, components, and dissimilar materials used in the batteries under extreme temperature conditions representative of those which may be encountered in actual aeronautical operations.

Test Method

a) The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation.
b) The battery shall then be placed in temperature chamber at 85 °C ± 2 °C for 4.25 h ± 0.25 h.
c) At the conclusion of this time period, the item shall be transferred, within 5 min, to a cold chamber with an internal chamber temperature of –55 °C ± 2 °C.
d) The battery shall be exposed to this temperature for 4.25 h +/- 0.25 h.
e) At the conclusion of this time period, the test item shall, within 5 min be returned to the high temperature chamber maintained at 85 °C ± 2 °C.
f) The battery shall be exposed to this temperature for 4.25 h +/- 0.25 h.
g) Repeat for a total of 3 cycles.
h) The battery shall be removed from the temperature chamber and allowed to stand at 23 C±2°C for not less than 20 h and not more than 24 h.
i) Discharge the battery in accordance with clause 2.3.1.

Evaluation Criteria

a) No battery cell or component, when subjected to Temperature Variation (Shock) shall show dimensional distortion beyond specified limits or cracking of cases or covers of either cells or batteries.
b) There shall be no mechanical failure of any part, electrolyte leakage or spillage of electrolyte at any time during the test or venting of gasses containing entrained electrolyte (except during charge of vented nickel-cadmium batteries).
c) The minimum value of the insulation resistance, shall be 0,25 MΩ but after cleaning and drying the minimum value shall be 10 MΩ. There shall be no breakdown of insulation, stripping of metal plating from any component part,

corrosion of metal parts, or loosening of protective coating from the battery container or cover or deterioration of battery identification markings.

3.7 Fungus Resistance (Section 13 of RTCA/DO-160)

This test shall be undertaken to assess the fungal resistance of the battery components. This test may be omitted provided it can be demonstrated that the battery materials contain no fungal nutrients.

Test Method.

Per Section 13.0 of RTCA/DO-160

Evaluation Criteria

No battery or cell components shall support fungal growth determined from inspection following the Fungus Test of Section 13 of RTCA/DO-160.

3.8 Humidity (Section 6 of RTCA/DO-160)

The Humidity Test is intended to provide a laboratory means of verifying the safety of batteries under conditions representative of those that may be encountered in actual aeronautical operations.

Test Method.

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation and subjected to the Humidity Test, Section 6.0 of RTCA/DO-160. Batteries shall be classified as "Category A" equipment.

The battery shall be inspected for corrosion and any physical/mechanical damage, within 2,0 h after the cycles are completed.

The battery shall also be subjected to the Rapid discharge capacity at 23 °C (clause 2.3.1).

Evaluation Criteria

The battery capacity at the end of the Rapid discharge capacity shall be no less than that declared by the manufacturer or required by the design documentation. The battery shall not show:

a) Corrosion of any parts,
b) Physical/mechanical failure of any part,
c) Cracking of cases or covers of either cells or batteries,
d) Breakdown of insulation, stripping of metal plating from any component part, or loosening of protective coating from any battery part.

3.9 Fluid Contamination

3.9.1 General

Subject samples of those materials used for the outer surfaces of the battery and any other material within the battery, which may be exposed to the environment (or subject a complete battery, if more convenient) to either the spray test (3.10.1.1) or the immersion test (3.10.1.2).
The test fluids and the respective test temperature shall be selected from ISO 7137. The manufacturer shall declare the range of sustainable fluids. Additional fluids shall be identified in the design documentation.

3.9.1.1 Spray Test (Section 14 of RTCA/DO-160)

Test Method

Spray the battery or materials under test with the appropriate fluid one or more times per day as necessary to maintain a wetted condition for a minimum of 24 h. If it is difficult to maintain a wetted condition then the immersion test (6.10.1.2) shall be used. The spray shall be a fine mist maintained at the temperatures defined in ISO 7137 and shall be directed toward every major surface, seal and connectors of the battery or material under test.
Following the 24 h period and without removing the excess fluid, the test specimen shall be placed in an appropriate chamber and subjected to a constant temperature of + 65 °C for a minimum of 160 h. At the end of this period the test specimen shall be returned to ambient room conditions for a minimum of 2 h.

Note: *If the battery or materials are to be tested to more than one class of contaminating fluid, it shall normally be tested with each fluid separately. However simultaneous testing is permitted if required by the product standard. Fluids shall not be pre-mixed prior to spraying and the order of application shall be as specified in the equipment technical specification unless noted in the equipment technical specification, the total exposure time for simultaneous application of fluids shall be the same as the exposure time for a single fluid.*

Evaluation Criteria

Following the 2 h period of test, the battery or materials tested shall then be examined and the results of the test shall assure that the materials exposed during the test will protect the battery from deleterious effects of exposure to the applied fluids.

3.9.1.2 Immersion Test

Test Method.

Immerse the battery or materials under test in the appropriate fluid for a minimum of 24 h. The fluid temperature shall be maintained at the temperatures defined in ISO 7137 and shall cover the test specimen completely.
Following the 24 h period remove the test specimen, place in an appropriate chamber and subject it to a constant temperature of + 65 °C for a minimum of 160 h. At the end of this period the test specimen shall be returned to ambient room conditions for a minimum of 2 h.

Evaluation Criteria

Following the 2 h period of test, the battery or materials tested shall then be examined and the results of the test shall assure that the materials exposed during the test will protect the battery from deleterious effects of exposure to the applied fluids.

Precautions, Since many contaminants may have flash points within the test temperature range, care shall be taken to ensure that adequate safety measures are taken to limit the possibility of fire or explosion. If the immersion test is carried out on a battery, care shall be taken to ensure that the temperature of the fluid does not exceed the maximum design temperature of the battery as defined by the battery manufacturer.
Some contaminants may themselves or in combination with other contaminants or with the test sample, be toxic. Due consideration shall be given to this possibility before commencing the tests.
Some fluids may be electrically conductive. When the tests are being carried out on a complete battery, suitable precautions shall be taken during exposure to the fluids.
Additional test fluids shall be as defined in the design documentation, each sample being subjected to one fluid only. The test temperature shall be 23 °C ± 5 °C.
At the end of the test period, the sample or battery shall show no signs of physical damage, deterioration or leakage.

3.10 **Salt Spray** (only applicable where the battery installation is subject to a salt atmosphere, see DO-160 Category S)

The Salt Spray Test is intended to provide a laboratory means of verifying the safety of batteries under conditions representative of those that can be encountered in actual aeronautical operations.

Test Method.

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation and subjected to the Salt Spray Test, Section 14.0 of RTCA/DO-160 for Category S equipment. The battery shall be placed in the chamber and exposed to the salt spray for a period of 48 (+1,0, -0,0) h. Within 4,0 h after the exposure period, the battery shall be inspected for corrosion and any physical/mechanical damage. The battery shall also be subjected to the Rapid discharge capacity at 23 °C of 2.5.1.

Evaluation Criteria

The battery capacity at the end of the Rapid discharge capacity shall be no less than that declared by the manufacturer or required by the design documentation. The battery shall not show:

a) Corrosion of any parts,
b) Physical/mechanical failure of any part,
c) Cracking of cases or covers of either cells or batteries,
d) Breakdown of insulation, stripping of metal plating from any component part, or loosening of protective finish.

3.11 **Physical Integrity at High Temperature (85 °C)**

The Physical Integrity Test at High Temperature is a non-operating test that checks the integrity of materials and seals in the battery to ambient temperatures the battery will see while setting on the tarmac.

Test Method.

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. Place the battery in a temperature chamber at a minimum of 85°C for 16 h. Remove the battery from the 85°C environment.
Stabilize the battery at room ambient conditions and inspect.

Evaluation Criteria

The battery shall not show:

a) Dimensional distortion beyond specified limits;
b) Cracking of cases or covers of either cells or batteries;
c) Mechanical failure of any part;
d) Electrolyte leakage or spilling of electrolyte at any time during the test;
e) Breakdown of insulation, stripping of metal plating from any component part, corrosion of metal parts, or loosening of protective coating from the battery container or cover;
f) Deterioration of battery identification markings.

3.12 Electrolyte Resistance

This test applies to the accessories (shims, heater blankets, harness assemblies, temperature sensors, electronic components, seals and parts bearing markings) either separate or assembled. It shall be performed on representative accessories or samples.

Test Method.

1. Flooded electrolyte batteries:

Before the test the sample shall be measured for dimensional compliance and its mass shall be determined to within ± 0,1%.

Completely immerse the sample in an appropriate container with a lid, containing electrolyte at a density of 1,3 ±0.03 g/cm^3 (when measured at 20°C) for a period of 7 days at a temperature of 65 ± 2°C. Do not immerse the output connectors.

After exposure, rinse, wipe and dry for 2 h at between 32 °C and 36°C.

2. Valve regulated batteries (limited electrolyte)

Before the test the sample shall be measured for dimensional compliance and its mass shall be determined to within 0,1%.

Using the spray test procedure from DO-160, Fluid Susceptibility Test, apply a solution of electrolyte at a density of 1.3 ± 0.03 g/cm^3 (when measured at 20°C) for a period of 24 hours at a temperature of 65 ± 20°C. Do not spray output connectors.

After exposure, rinse, wipe and dry for 2 h at between 32°C and 36°C.

Evaluation Criteria

The seals shall continue to function.
The seals and shims shall not hinder assembly.
Variations in mass and dimensions shall not exceed 2%.

There shall be no corrosion, any abnormal deposit, or alteration of markings.

Harness assemblies and heaters: There shall be no electrolyte leakage paths changing the resistance values of the harness components.

3.13 Thermal Sensors

Temperature sensors and/or switches shall be monitored during temperature and vibration tests to demonstrate that there is no erroneous operation.

Test Method.

Validation of temperature sensor or switch operation shall be performed by putting component into a thermal chamber and elevating temperature.

Evaluation Criteria

a) Temperature Switch: At temperature of activation the switch shall open or close as specified by design.
b) Temperature Sensor: Upon elevation of temperature an ohmmeter shall be used to verify resistance as specified by design.

3.14 Component Qualification Tests

To assess the components of the battery the following test shall be applied as appropriate.

3.14.1 Vent Valve Test

3.14.1.1 For Vented Nickel-Cadmium Vent Valves

The vent valve test is conducted to assure that the vent bands on the vent valves open at the proper pressure range to avoid pressure buildup and cracking of cell cases which results in insulation resistance failure of the battery which is considered a safety issue.

Test Method

This test shall be performed first at ambient temperature and then at –30°C after two days of stabilization at this temperature, on at least three valves, using an adapter supplied with compressed air at variable pressure up to 100kPa.
The internal pressure shall be raised gradually to 70kPa then returned to 0kPa.

Evaluation Criteria

The valve shall be open at or bellow 70kPa and closed at or below 14kPa

3.14.1.2 For Vented Lead-Acid Vent Valves

The vent valve shall be installed in the top of a test fixture having an internal volume of 350 ± 15 cc. The test fixture shall be approximately cubic or a circular cylinder with a diameter equal to the height. A pressure gauge shall be installed in the fixture. The fixture shall be connected through a valve to a source of compressed air which, when the valve is open, shall maintain a pressure of 65 ± 3kPa in the fixture whether the valve is open or closed. The box shall be airtight except for the opening for the vent valve, pressure gauge, and supply air valve.

The fixture shall be placed in the environment detailed below and tested as described.

a) Opening at 27°C. The vent valve shall be set in the inverted vertical position with the air supply valve open. The vent valve shall be rotated to an angle of 31° and the air supply valve closed. The vent valve shall meet requirement a.

b) Closing at 27°C. The vent valve shall be placed in its normal vertical attitude with the air supply valve open. The vent valve shall be rotated to an angle of 49° and the air supply valve closed. The vent valve shall meet requirement b.

c) Opening at –40°C. The vent valve shall be placed in a temperature chamber at –40C for 2h. With the vent valve in the chamber, the vent valve shall be set in the inverted vertical position with the air supply valve open. The vent valve shall be rotated to an angle of 31° and the air supply valve closed. The vent valve shall meet requirement a.

d) Closing at –40°C. The vent valve shall be placed in a temperature chamber at –40C for 2h. With the vent valve in the chamber, the vent valve shall be placed in its normal vertical attitude with the air supply valve open. The vent valve shall be rotated to an angle of 49° and the air supply valve closed. The vent valve shall meet requirement b.

e) Opening at 60°C. The vent valve shall be placed in a temperature chamber at 60C for 2h. With the vent valve in the chamber, the vent valve shall be set in the inverted vertical position with the air supply valve open. The vent valve shall be rotated to an angle of 31° and the air supply valve closed. The vent valve shall meet requirement a.

f) Closing at 60°C. The vent valve shall be placed in a temperature chamber at 60C for 2h. With the vent valve in the chamber, the vent valve shall be placed in its normal vertical attitude with the air supply valve open. The vent valve shall be rotated to an angle of 49° and the air supply valve closed. The vent valve shall meet requirement b.

Evaluation Criteria

a) When the valve is rotated to the specified angle and the air supply valve is closed, the pressure shall decay at least 95% in 10s.

b) When the valve is rotated to the specified angle and the air supply valve is open, the pressure shall not decay by more than 5% in 2.5m.

c) The vent valve shall meet the requirements of 3.13 Electrolyte Resistance.

3.14.1.2.1 For Valve Regulated Vent Valves (Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid)

The vent valve test is conducted to assure that the vent valves open at the proper pressure range to avoid pressure buildup and cracking of cell cases which results in insulation resistance failure of the battery which is considered a safety issue.

Test Method

This test shall be performed first at ambient temperature and then at –30°C after two days of stabilization at this temperature, on at least three valves, using an adapter supplied with compressed air at variable pressure.

The internal pressure shall be raised gradually to the pressure specified by the battery manufacturer then returned to 0kPa.

Evaluation Criteria

The valve shall operate as specified by the manufacturer.

3.14.1.3 Cell Container Test

3.14.1.4 For Nickel-Cadmium and Nickel Metal-Hydride Cell Containers

The Cell Container test is conducted to assure that the cell cases will operate over the vent valve pressure range without cracking cell cases or causing insulation resistance failure of the battery.

This test shall be performed separately on three firmly connected cells inside the battery case (at ambient temperature).

Test Method.

a) Conditioning. Using an adapter to replace the vent plug and a pressure-reducing device, inject dry air or nitrogen under pressure into the cell. Apply a pressure of 138kPa for 15s.
b) Keep the cell under a pressure of 70kPa for 5 min, during which the cell shall be tilted to rest on all its sides so that electrolyte comes in contact with each side of the lid seal for approximately 1 min.
c) Replace the vent plug and immerse the cell in water so that the joint between the cell container and lid is moistened but not the upper surface (bearing the terminals and valves). Perform a voltage response test, between one terminal and the water, at 500VAC for 1 min.

Evaluation Criteria

a) The cell shall not have deteriorated.
b) There shall be no insulation breakdown.
c) There shall be no spark over.
d) There shall be no break or crack in the cell containers and components, no displacement or obstruction of the venting system, no deterioration in surface protection.

3.14.1.5 For Lead-Acid Battery Containers

The Lead-Acid Battery Container test is conducted to assure that the battery container will operate over the vent valve pressure range without cracking the battery container walls which would result in insulation resistance failure of the battery which is considered a safety issue.

Test Method

a) Sample batteries in the dry and charged condition shall be placed in an oven at 85°C ± 2°C and maintained at this temperature, in the normal upright position, for 6h. At the end of this time they shall be tilted to an angle of 90° from the normal upright position and maintained at the specified temperature in the new position for a period of 5m. At the end of this time they shall be returned to the normal upright position and the surface inspected.

b) While still at 85°C ± 2°C, an internal air pressure of 15.5 ± 2kPa shall be applied to each cell of this battery for 30s. Upon successful completion of this part of the test, stabilize the battery at room temperature, and add electrolyte to the battery. Charge the battery in accordance with the battery manufacturer's instructions or design documentation.

Evaluation Criteria

a) The individual cells shall withstand an internal air pressure of 15.5 ± 2kPa for a minimum of 30 seconds without loss of greater than 1.4kPa at 85°C.

b) The individual cells shall withstand an internal air pressure of 15.5 ± 2kPa for a minimum of 30 seconds without loss of greater than 0.7kPa at 27°C.

3.14.2 Battery Electrolyte Containment Test

This test only applies to batteries which are naturally ventilated types or which have apertures in the case and lid. The Battery Electrolyte Containment Test is conducted to determine the effectiveness of the vent plugs to avoid spillage within the battery cell containers/monoblocs.

Test Method

The battery shall be serviced and charged in accordance with the battery manufacturer's instructions or design documentation. The electrolyte levels shall be checked in accordance with the manufacturer's instruction. The battery shall be secured on a platform which can turn around its two horizontal axis (see figure 1) and submitted to an additional 2 h charge at 28.5 V ± 0.1 V or using a dedicated charger) before the test and shall be charged at this voltage throughout the test.

***Note**: Batteries not charged on the aircraft shall be left on open circuit during the test.*

The battery shall be slowly rocked ten times from side to side through an angle of 60° from the nominal vertical position. The time taken to move from one tilted position through the vertical to the other tilted position shall be more than 20 s and the battery shall remain in each tilted position for at least 5 s.

Evaluation Criteria

Remove the battery case cover and check for electrolyte on top of the cell containers/monoblocs. There shall be no electrolyte present.

3.15 Strength of Connector Receptacle

The Strength of Connector Receptacle test is conducted on receptacles that are formed into the battery case during manufacture. These tests are conducted to assure the connector receptacle does not disconnect during the dynamic aircraft environment.

Test Method

Apply a rotational torque, progressively, parallel to the connector mounting plane, to reach 8 ± 1 N.m at the end of 10 s.
Apply for 10 sec a pulling force of 1100 N minimum, in an axial direction.

Evaluation Criteria

The connections, battery case, insulating components and connector shall show no sign of deformation, displacement or asymmetry of the mounting.

3.16 Handle Strength

The Handle Strength test is conducted to assure that the handles function properly.

Test Method

Each battery handle shall be subjected to a tension load of 1.5 times the battery weight. The tension shall be applied in a vertical upward direction.

Evaluation Criteria

There shall be no damage to the battery or evidence of breaking, bending or cracking of the battery container, cover, handle, handle mounts.

4 QUALITY ASSURANCE REQUIREMENTS

4.1 General Quality Requirements

Quality Assurance is the tool by which the purchaser and supplier requirements are satisfied. The specific requirements are detailed in an appropriate quality assurance standard such as ISO 9000. For this standard the supplier shall have in place a recognized quality assurance scheme approved by a national civil aviation or military authority and shall comply with its requirements for all activities.

4.1.1 Order of Testing

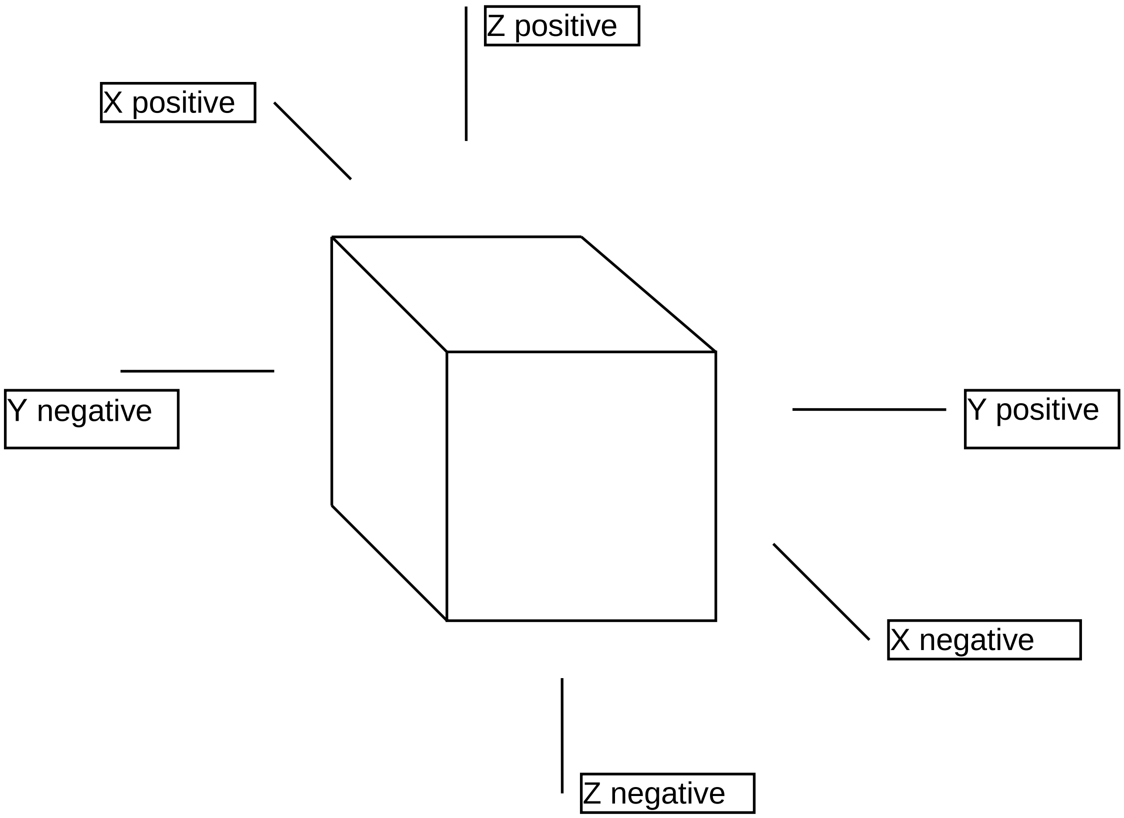
Six batteries shall be used for testing, one for each group and a spare from the same batch. The order of application of the tests shall be that given in Table 4-1.
The spare battery shall be kept in reserve and may be substituted into the program in the event of failure of either the battery or test equipment. If this battery is used, it shall be subjected to all ratings tests through rapid discharge and then may be inserted into the test matrix at the point where the previous sample failed.
Approval will be given by the appropriate authority after satisfactory completion of testing Batteries N°s I, II, III and IV.
Battery N° V results are for information only and will not hold up TSO approval.
Prior test results or analysis by similarity can be substituted for approval for any specific test.
Interim approval may be given by the appropriate authority after satisfactory completion of testing Batteries N°s I, II, III and IV pending full approval after satisfactory completion testing of Battery N° V.

Table 4-1 **Approval Test Schedule**

Test	Clause or sub-clause reference	Battery N°.				
		I	II	III	IV	V
Physical Examination	2.1.10	X	X	X	X	X
Handle Strength	3.16	X				
Strength of Connector Receptacle	3.15	X				
Insulation Resistance and Dielectric Strength	2.9	X	X	X	X	X
Rated Capacity C_1.	2.2.2	X	X	X	X	X
Storage	2.5					X
Capacity at different temperatures	2.2.3, 2.2.4, 2.2.5	X	X	X	X	
Constant Voltage Discharge	2.2.6	X	X	X	X	
Rapid discharge capacity	2.3	X	X	X	X	
Charge acceptance	2.8				X	X
Water Consumption	2.11		X			
Charge retention	2.4				X	

Test	Clause or sub-clause reference	Battery N°.				
		I	II	III	IV	V
Altitude	3.5.1		X			
Rapid Decompression	3.5.2		X			
Charge stability	2.6			X		X
Temperature Shock	3.6			X		
Deep Discharge	2.13		X			X
Humidity	3.8	X				
Salt Spray	3.10	X				
Electrical Emissions	2.15	1	1	1	1	1
Fungus Resistance	3.7	1	1	1	1	1
Fluid Contamination	3.9	1	1	1	1	1
Electrolyte Resistance	3.12	1	1	1	1	1
Thermal Sensors	3.13	1	1	1	1	1
Component Qualification Tests	3.14	1	1	1	1	1
Vibration	3.1				X	
Physical Integrity at High Temp	3.11		X			
Operational Shocks and Crash Safety	3.3		X			
Duty cycle performance	2.10	X				X
Cyclic Endurance	2.12			X		
Induced Destructive Overcharge	2.14		X			
Short-circuit current	2.7	X				
Explosion containment	3.4				X	

Note: 1 to be undertaken on a suitable battery or representative material sample



<u>Figure 1</u> **Vibration Orientation**

<u>Notes:</u>

1. Battery Mounting details to be determined in accordance with the Product Standard or design documentation and shall reflect as close as possible the aircraft installation.

2. Axis of vibration shall be defined in terms of orientation using the connector as the reference to the designated direction given above.

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5 DEFINITION OF TERMS

For the purpose of this standard, the following definitions apply.

$1I_1$ Rate
The current is that which the battery delivers to give not less than its rated C_1 capacity in 1 hour. This shall be the basis on which all other current ratings are defined.

Airworthiness
Is defined as the compliance of a battery or part thereof with all conditions and regulations required by the appropriate Government authorities for their safe operation and performance in an airborne environment.

Ampere-hour:
A unit for the quantity of electricity obtained by integrating current in amperes over time in hours. Used as a measure of battery capacity (abbreviated Ah).

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

Battery System:
Two or more electrically connected batteries that provide power to equipment.

Battery Voltage Assumptions.
The criteria defined in this standard are based upon batteries used on an aircraft electrical system nominally rated at 28V D.C. The nominal values for cell voltage are 1.2 V per cell for nickel-cadmium and nickel metal hydride batteries and 2.0 V per cell for lead-acid batteries.
For applications other than 28V D.C. it is important to note the battery voltages and to adjust the test parameters accordingly dependent upon the number of cells used in the respective battery configuration.

Capacity retention
The fraction of the full capacity available from a battery under specified conditions of discharge after it has been stored for a specific period of time at a specified temperature.

Cell
A single electrochemical unit which exhibits a voltage across its two terminals and is used as a component of a battery.

Charge Acceptance
Willingness of a battery or cell to accept charge. May be affected by cell temperature, charge rate, and state of charge.

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

Charging Current
Current provided to a cell or battery in the direction opposite the flow of current during discharge.

Charge Retention
See Capacity Retention.

Charge Stability
Charge is the conversion of electrical energy, provided in the form of a current from an external source, into chemical energy within a cell or battery. A stable charge is one in which the charge current drops in order to maintain a constant potential in the battery or cell.

Constant Voltage Discharge Current (Ipr)
See Power Rating

Current Values
All current values throughout this standard shall be expressed in amperes (A).
Traditionally certain installers and users of secondary cells and batteries have expressed the current used to charge and discharge cells and batteries as a multiple of the capacity. For example, a current of 20 A used to charge a cell with a rated capacity C (Ah) of 100 Ah would be expressed as C/5 or 0.2 C (A). This method of current designation has been used in all Standards relating to secondary cells and batteries.
This is equally applicable to Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid and therefore the reference current (I_t) shall be expressed as
$(I_t)A = Cn_nAh/1nh$
Where Cn_n is the rated capacity declared by the manufacturer in ampere-hours and n (where n=1) is the time base in hours for which the rated capacity is declared.

Cut-off Voltage
The prescribed voltage for which the usable energy or capacity is calculated for the discharge.

Cyclic Endurance
A cycle is the discharge and subsequent or preceding charge of a secondary battery such that it is restored to its original conditions. Endurance is the measurement of the number of cycles a cell or battery can go without conditioning or performing of maintenance.

Discharge
The operation of a cell or battery in providing electrical current to an external load.

Deep Discharge
Withdraw of at least 80% of the rated capacity of a cell or battery.

Distortion
The change in any dimension of a cell or battery beyond the design tolerances.

Electrode
Conductor in a cell or battery, which contains the active material, through which an electric current passes.

Electrolyte
A medium in which the transport of electrical charge in a cell takes place by the migration of ions between the positive and negative electrodes.

End Voltage
(See cut-off voltage.)

End of Life Capacity - C_1EOL
The minimum capacity, expressed in Ah, expected from a charged battery when discharged at the $1I_1$ rate to the (EPV).
When no longer able to produce this capacity during a one hour discharge prior to reaching the EPV, the battery is said to be at end of life and shall be removed from service.

End Point Voltage (EPV)
Unless otherwise stated, during discharge the battery End Point Voltage (EPV) corresponding to a mean voltage per cell of 1.00 V for nickel-cadmium and nickel metal hydride or 1.67 V for lead-acid batteries.

Energy Density
The energy per unit weight (gravimetric energy density) or per unit volume (volumetric energy density), expressed Wh/kg and Wh/L.

Induced Destructive Overcharge
Overcharge is the forcing of current through a cell or battery after all the active material has been converted to the charged state. In other words, charging continued after 100% state of charge is achieved. Induced destructive is a test conducted to determine worse case what will happen to the cell or battery.

Leakage
Release of liquid or gas from a cell or battery. Leakage is determined by either visual observation or weight loss.

Load
An electrical load is any device which causes electrical flow when connected to the terminals of a cell or battery or the current itself.

Open-circuit Voltage (OCV)
The difference in potential between the terminals of a cell or battery; i.e. voltage under no-load conditions.

Operating Life
The maximum period during cell or battery service life that an undischarged cell or battery will meet specific performance requirements.

Overcharge Endurance
The forcing of current through a cell or battery after all the active material has been converted to the charged state. In other words, charging continued after 100% state of charge is achieved. Endurance measures the amount of time the cell or battery can withstand this condition prior to need for maintenance.

Peak Power Current (Ipp).
The discharge current, which the battery delivers at the conclusion of a 0.3 s power discharge, controlled so as to maintain a constant terminal voltage of half the nominal voltage.

Power Rating (Ipr)
The discharge current, which the battery delivers at the conclusion of a 15 s power discharge, controlled so as to maintain a constant terminal voltage of half the nominal voltage.

Rapid Discharge Capacity

A quantitative term indicating a discharge rate that is usually greater than the C_1 rate.

Rated Capacity (C_1)
The minimum capacity, expressed in Ah, obtained from a charged battery when discharged at the $1I_1$ rate to the End Point Voltage.

Separator
Electronically insulating material intended to prevent the cathode and anode from shorting, but which permits the transport of ions from one electrode to the other.

Service Life
The maximum combined storage and installed life of an un-discharged 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.

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

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

Short Circuit test
A direct connection between the terminals of a cell or battery that provides a near-zero resistance path for current flow. An internal short circuit is a defect or fault within a cell which causes the anode and cathode to come into electrical contact.

Storage
Time from manufacture/activation of battery until it is placed into service in the aircraft.

Vent
A design feature of a cell or battery which activates to relieve excessive internal pressure.

Venting
Release of liquid or gas from a cell designed to prevent the buildup of excessive internal pressure. Observation and weight loss are indicators of venting.

Working Voltage
The typical voltage or range of voltage of a cell or battery during discharge (also called operating voltage or running voltage).

Appendix A

Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid Battery Safety Guidelines

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Appendix A, Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid Battery Safety Guidelines

1.0 GENERAL

a. All personnel who use or handle Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries must be familiar with their properties, safety precautions, handling procedures and disposal requirements.

b. Questions regarding Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid battery disposal should be directed to the appropriate federal, state or local environmental-protection agencies.

c. Questions regarding proper use and limitations of batteries should be directed to the cell, battery or equipment manufacturer.

2.0 HANDLING

a. Observe the following guidelines when handling Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries:

(1) Store batteries in cool, dry, ventilated area.

(2) Control battery fires in accordance with instructions on the Manufacturer's Safety Data Sheet (M.S.D.S.).

(3) Use special care in handling batteries. Make sure they are not punctured, crushed, or otherwise mutilated.

(4) Check batteries prior to use for any leakage or deformity. Do not use if there is any evidence of leakage or self-discharge.

(5) Wear protective clothing before handling and disposing of batteries.

(6) Use batteries only for the application for which they were designed.

(7) Take warning labels seriously. Follow all safety precautions.

b. Observe the following precautions when handling Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries:

(1) Do not store batteries with other hazardous or combustible materials.

(2) Do not heat or incinerate. Do not dispose of batteries with other waste unless allowed by applicable regulations.

(3) Do not open, puncture, crush, disassemble, or subject batteries to physical abuse.

(4) Do not use a Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid battery in any application except the one for which it is intended.

(5) Do not short circuit battery terminals. High currents may lead to excessive heating.

3.0 DISPOSAL

a. Dispose of Nickel-Cadmium, Nickel Metal-Hydride, and Lead-Acid batteries in accordance with all applicable federal, state and local regulations.

b. Insure that batteries are protected from heat, short circuits, compaction, mutilation, or other abusive physical or electrical conditions during storage, use and disposal.

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RTCA Special Committee 197
Rechargeable & Starting Batteries

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