

Battery Flight Acceptance Requirements for Lithium-ion Cells and Batteries

1. Introduction

This document describes the testing requirements for Lithium-Ion cells and batteries to determine if they are acceptable for flight. The requirements stated in this document are based on JSC EP-5 *Flight Acceptance Tests for Lithium-ion Cells and Battery Packs for Small Satellite Systems*.

2. Definitions and Acronyms

Words/ Acronyms	Definition
Battery	A single or set of cells either in series or parallel (may be 1 cell or more cells) to give ideal voltage/ current rating
C	The discharge rate that is equal to the capacity of the battery in amp-hours divided by 1 hour.
Cell	A single Lithium ion cell
DPA	Destructive Physical Analysis
OCV	Open Circuit Voltage

Note: For all of these procedures, it is expected that all test values (temperature included) are recorded to their corresponding battery / cell serial number. Serialize all cells/ batteries before testing. Pictures shall be taken whenever possible.

3. Reporting

Provide a test report to document the results of the battery testing. The report should include:

- Test set-up
- Test conductor name
- Date of test
- Pictures of test set-up
- Test data for each cell/battery tested
- Measurement data as recorded for each cell
- Pictures of cells/battery during testing
- Summary of test results
- Signature of responsible manager

4. Physical and Electrochemical Characteristics

4.1 Visual Inspection

Inspect batteries for any deformations such as scrapes, bulges, or dents. Record any findings in a table with the corresponding battery's serial number.

4.2 Measurements of Physical Properties

- a) The length, width, and height need to be measured and recorded. Length, width, and height are defined as the following:
 - Length: The horizontal length of the battery with the serial number upright.
 - Width: The vertical length of the battery with the serial number upright.
 - Height: The smallest dimension.

Measurements should be recorded with .1mm precision.

- b) Record the mass of each battery with a .1g precision.

4.3 Electrochemical Characteristics

- a) Measurement of Open Circuit Voltage

Measure the Open Circuit Voltage (OCV) using a multimeter and record the value for each of the batteries. Measurements should be recorded with .1 V precision.

- b) Measurement of Closed Circuit Voltage

Ensure that the battery is at least charged to 4.0V before proceeding. After setting up the programmable load to a constant current of 1.875A, load the battery and wait for 30 seconds before recording the Closed Circuit Voltage.

5. Charge Cycling Data Procedures

The Charge Cycling Data Procedures include the following cycles in this order: Charge, Discharge, Charge, Discharge, and Charge. Record relevant data for all of these cycles. The temperatures for these cycles should also be recorded and a 10 minute rest period should be provided between charge and discharge.

- a) **Charge** the batteries to 4.2V using a current of $C/2$. Then hold the batteries at a constant 4.2V until the current drops below 50 mA.
- b) **Discharge** the battery pack at a rate of $C/2$ until the voltage drops to 3.0V.
- c) Repeat charge cycling procedures until cycling is completed.

Note: If the MOSFET does not reset for any of the following procedures, discard the cells.

6. Cell Overcharge Procedures

- a) Overcharge batteries to 5.0V with a current of $1C$.
- b) Record the voltage at which the protection activates and the MOSFET opens the circuit.
- c) Discharge the batteries at a rate of $C/5$ and record voltage at which MOSFET closes the circuit.

d) Complete a charge/ discharge cycle as specified in Section 5 and record the capacity.

7. Cell Overdischarge Procedures

- a) Overdischarge the batteries at a 1C rate to 0V.
- b) Record the voltage at which the MOSFET opens the circuit.
- c) Charge the pack at rate of C/5 and record the voltage at which the MOSFET resets itself.
- d) Complete a charge/ discharge cycle specified in Section 5 and record the capacity.

8. External Battery Short Procedures

Externally short the circuit pack using a 10 milliOhm load and hold it for 3 hours (recording the temperature of the battery every 5 minutes). Record the current at a rate greater than 1 kHz for the first 3 seconds of the test, and record the current at the time the MOSFET disconnects the circuit.

After the External Short procedure, charge the batteries at C/5 current to determine the voltage at which the MOSFET resets itself. The pack should then go through one discharge/ charge cycle. Record the capacity.

9. Circuit Schematic Analysis.

Provide the protection circuitry schematic and a description of how it works.

10. Vibration Testing Procedures

Record the OCV for each battery before vibration testing and between each axis of vibration. Vibration testing should follow the spectrum as specified in Table 1 for 1 minute on each axis.

Frequency (Hz)	ASD (G2/Hz)	dB/OCT	Grms
20.00	0.028800	*	*
40.00	0.028800	0.00	0.76
70.00	0.072000	4.93	1.43
700.00	0.072000	0.00	6.89
2000.00	0.018720	-3.86	9.65

Table 1: Vibration Testing Spectrum

Discharge/ charge/ discharge cycle the batteries after the vibration tests and record their capacities. The pass/ fail criteria requires that there shall be less than 0.1% change in the OCV and less than 5% change in capacity before and after vibration tests and throughout the remainder of the battery testing procedures.

11. Vacuum Testing Procedures

- a) The length, width, and height need to be measured and recorded. Length, width, and height are specified in Section 3.2a. Measurements should be recorded with .1mm precision.
- b) Obtain and record the mass of each battery. Measurements should be recorded with .1g precision.
- c) Measure the voltage of all batteries and record the values. If any batteries are not fully charged, charge the battery before continuing.
- d) Place fully charged batteries into the vacuum chamber at atmospheric pressure and pull vacuum at approximately 8 psi/ minute. Maintain vacuum (approximately 0.1 psia) for 6 hours. Re-pressurize the chamber to ambient at a rate of 9 psi/minute.
- e) Visually inspect the battery for leaks, deformations, or bulges. Record any findings.
- f) Obtain measurements of the length, width, and height of the post-vacuum tested batteries. The pass/ fail criteria requires that there shall be less than a 20% change from original dimensions.
- g) Obtain and record the mass of each battery. The pass/ fail criteria requires that there shall be less than 0.1% change in mass.
- h) Discharge/ charge/ discharge cycle the batteries and record the capacity. The pass/ fail criteria requires that there shall be less than 0.1% change in the OCV and less than 5% change in the capacity before and after vacuum testing.