Deviation Request ETSO-C142b#4 for an ETSO approval for CS-ETSO applicable to Non-rechargeable lithium cells and batteries (ETSO-C142b)
Consultation Paper

1 Introductory Note

The hereby presented deviation requests shall be subject to public consultation, in accordance with EASA Management Board Decision No 7-2004 as amended by EASA Management Board Decision No 12-2007 products certification procedure dated 11th September 2007, Article 3 (2.) of which states:

"2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency."

2 ETSO-C142b#4 Non-rechargeable lithium cells and batteries

2.1 Summary of Deviation

Deviates from RTCA DO-227A by deleting the requirement and test for cell polarity reversal to fulfil the future RTCA DO-227B currently under evolution led by the RTCA SC-235 working group.

2.2 Original Requirement

RTCA DO-227A

2.2.1.2.2 Cell Polarity Reversal

Requirements:

a. At the upper operational temperature, a depleted cell shall not rupture, experience thermal runaway, leak, or vent when exposed to the maximum continuous current specified by the cell manufacturer or 10% under the maximum current threshold of any embedded protective devices as described in Section 2.4.1.2.2. Venting is permissible through the designed vent port.

b. Should a cell leak or vent through other than the designed vent port during the test this failure may be mitigated at the battery or End Item level. The need for higher-tier mitigations (cell to battery or battery to End Item) shall be reported.

2.4.1.2.2 Cell Polarity Reversal Test

This test is to be performed using the previously-discharged 15 sample cells at three different temperatures. Five of these 15 cells will be tested at -20°C, another five cells will be tested at 23°C, and the final five cells will be tested at 55°C. In all 15 cases, this test will immediately follow the assessment of cell condition after the cell discharge current test, and will use the same discharge current and cell temperatures. This test provides a method of showing compliance with requirement 2.2.1.2.2.

Test Procedure:

a. Maintain the connections of the sample cells to the DC power supply with connection polarity as indicated in Figure 2-7.

b. If the sample cells contain no protective devices, the test current shall be the maximum continuous current specified by the cell manufacturer. If the sample cells contain protective devices, set the test current to just below (by no more than 10 percent) the current at which any protective device will activate during the cell polarity reversal test. The power supply shall be voltage-limited to represent an additional cell in series with the test sample (i.e., 3 volts for a 3 volt cell).

c. The duration of the cell reverse polarity test is defined as C/I, where "C" is the rated capacity of the sample in amp-hours and "I" is the test current in amps. In other words, current will pass through the depleted cell in the discharge direction until the nominal capacity of an additional cell has been conducted. The duration and profile of the reverse charge portion of this test sequence is illustrated in figure 2-8 between time step 4 and time step 10.

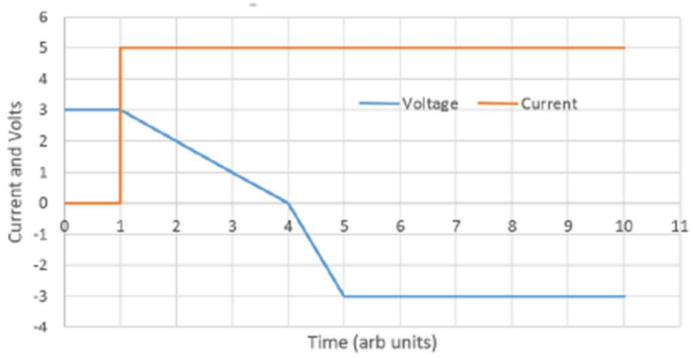

Figure 2-8: Typical Current / Voltage diagram vs time for a cell driven into polarity reversal. After the cell capacity is depleted to zero volts (time step 4) and the cell becomes resistive, the voltage across the cell will rapidly be driven negative by continued current from the power supply.

Evaluation Criteria

Observe the sample cells for 24 hours after completion of the test and examine each sample to determine if it meets the criteria of Table 2-3.

Reportable Items:

a. Compliance with Table 2-3 criteria.

b. The chamber temperature, cell temperature, voltage and current data as a function of time, in plotted and tabulated formats. Voltage and current data shall be collected at a rate of five samples per second. Temperature data may be collected at the same rate or once per second.

c. Document any incidences of post-test warning or appearance changes.

2.4.4 Test samples and Test sequences

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The order of testing described in the figure below illustrates the required sequence of tests for the starting set of test articles (cells, batteries, or End Items) and the number of samples to be employed in each test. The test articles, samples, and test hardware shall be maintained under configuration control throughout the test series.

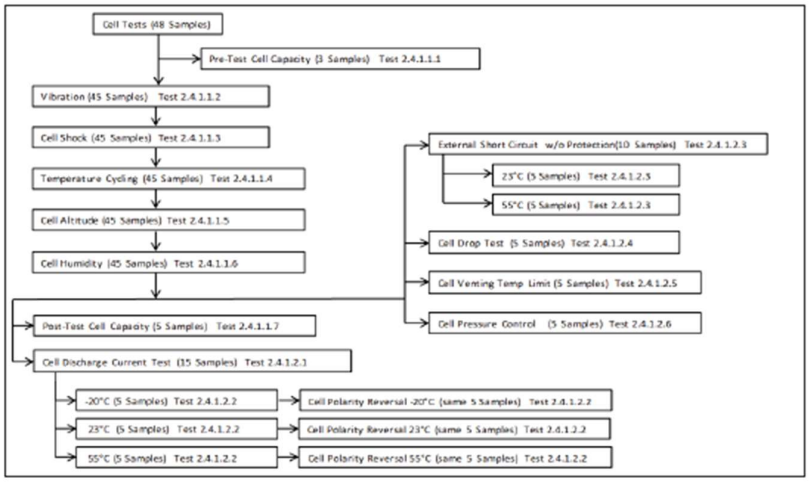

Figure 2-25: Cell Test Sequence

Table 2-3: Cell Test Evaluation Criteria Code: F = Fail, A = Allowable

Test	Requirement Paragraph	Test Paragraph	Leak	Vent	Distort	Fire	Rupture	OCV
Pre-Test Cell Capacity	2.2.1.1.1	2.4.1.1.1	F	F	F	F	F	-
Vibration	2.2.1.1.2	2.4.1.1.2	F	F	F	F	F	F[1]
Shock	2.2.1.1.3	2.4.1.1.3	F	F	F	F	F	F[1]
Temperature Cycling	2.2.1.1.4	2.4.1.1.4	F	F	F	F	F	F[1]
Altitude	2.2.1.1.5	2.4.1.1.5	F	F	F	F	F	F[1]
Humidity	2.2.1.1.6	2.4.1.1.6	F	F	F	F	F	F[1]
Post-Test Cell Capacity	2.2.1.1.7	2.4.1.1.7	F	F	F	F	F	-
Cell Discharge Current	2.2.1.2.1	2.4.1.2.1	F	F	F	F	F	-
Cell Polarity Reversal	2.2.1.2.2	2.4.1.2.2	F[2]	F[2]	A	F	F	-
Cell External Short Circuit	2.2.1.2.3	2.4.1.2.3	F[2]	F[2]	A	F	F	-
Cell Drop	2.2.1.2.4	2.4.1.2.4	F	F	A	F	F	F
Cell Venting Temp Limit	2.2.1.2.5	2.4.1.2.5	A	A	A	F	F	-
Cell Pressure Control	2.2.1.2.6	2.4.1.2.6	A[3]	A[3]	A[3]	F	F	-

1. The change in open circuit voltage during the test shall be less than 2%.
2. This is a failure at the cell level. If used at the battery level, this failure may be mitigated at the battery or end item level. The condition is reportable so that design requirements of higher-level products or assemblies can incorporate the mitigation.
3. The cell shall not leak, vent, or distort below 91°C.

2.3 Industry

The DO-227A standard provides requirements and tests for non-rechargeable lithium batteries. These requirements and tests are organized in three levels: cell, battery and end-item to facilitate various industrial work sharing, so that, for example, a manufacturer A builds an end-item that uses the battery of a manufacturer B that in turns uses cells from a manufacturer C.

While this organization of the standard permits different industrial arrangements, it introduces additional constraints as some failures at one level might be fully mitigated at upper level. Eventually, any end-item product manufacturer must demonstrate compliance to each level supporting the demonstration that the end-item is safe for installation.

At cell level, the 'cell polarity reversal test' that is subject of this deviation intends to cover the possibility of imbalance in a battery, for instance, due to soft shorts within a cell or different internal resistances from cell to cell. This is tested with a single cell connected to a bipolar power supply in order to simulate a battery configuration that contains an imbalanced or discharged cell in series.

However, at battery level, the DO-227A also addresses the same condition of polarity reversal by requiring the battery to also pass, among other tests, a 'battery cell series polarity reversal test' (DO-227A sections 2.2.2.2.1, 2.4.2.2.1, figure 2-26 and table 2-4).

On top of that, at end item level, the manufacturer is expected to show compliance through 'Thermal Runaway Containment Tests' that a thermal runaway condition, which is the worst-case scenario, can be contained within the end-item (DO-227A sections 2.2.3.2.2, 2.4.3.2.2, figure 2-27 and table 2-5).

A polarity reversal failure of a cell (thus at cell level) can be fully mitigated or contained at the battery level or at end-item level, and this being demonstrated by the aforementioned testing at battery and end item levels.

The RTCA Special Committee SC-235 (tasked to produce the DO-227B) has recognized this in its 16th plenary meeting held on the 30th of July 2021. RTCA Paper No. 192-21/SC235-034 meeting summary states that: "*It was suggested that the cell-level polarity reversal test be deleted. The committee, including the FAA and Transport Canada, accepted the inputs from the cell manufacturers and agreed to delete the test. This is acceptable because the reversal hazard is addressed by the battery-level reversal test as well as by the Thermal Runaway test.*"

The above statement from the RTCA Special Committee SC-235 is based on the three following aspects:

- First, the polarity reversal condition is a multi-cell battery condition rather than a single cell level condition: This is ratified by the fact that test setup for a 'Cell Polarity Reversal Test' needs to simulate a battery configuration to reach such condition.
- Second, the polarity reversal condition is not an attribute of a single cell and it cannot happen without connection of an external power supply:
  This was ratified by two cell manufacturers who stated that it is physically impossible for a single cell to enter in a reversed polarity condition on its own.

- Finally, because the polarity reversal hazard is already addressed twice, i.e. by the 'battery cell series polarity reversal test' as well as by the 'Thermal Runaway Containment Tests'.

2.4 Equivalent Level of Safety

An equivalent level of safety is provided by performing the following existing tests at upper levels, which are mandatory for ETSO authorization:

- The **'Battery Cell Series Polarity Reversal Test'** (DO-227A sections 2.2.2.2.1, 2.4.2.2.1, figure 2-26 and table 2-4) ensures that the potential appearance of a cell polarity reversal condition of a cell when it is used in a battery configuration (which is the real use case for the cells) can be contained at battery level. The applicant must still demonstrate the battery performance regarding containment of this failure by passing the battery test.
- On top of that, the **'Thermal Runaway Containment Tests'** (DO-227A sections 2.2.3.2.2, 2.4.3.2.2, figure 2-27 and table 2-5), which basically creates, a thermal runaway condition on a given cell but in a different way compared to the cell polarity reversal condition. Eventually, even if the generation of a thermal runaway condition differs from one test to another, the consequences are the same and the applicant must prove that there is no safety issue by passing the associated End Item test evaluation criteria. Only in this case, the End-Item is considered safe for installation on aircraft.

2.5 EASA position

We reject the deviation.

The current DO-227A provides three successive barriers to reduce the effect of cell failures: tests at cell level, at battery level and end-item level. DO-227A also foresees that some cell failures can be mitigated at upper (battery or end-item) level. However, the standard only granted this alleviation to the leak and vent, but not to the fire or rupture (see note 2 to DO-227A table 2-3 for cell polarity reversal test).

The position proposed by the industry removes one of these three barriers with the argument that two barriers are safe enough. Reports of accident and incident involving lithium batteries show that safety events have occurred when at least one of these safety barriers was faulty, e.g. as a result of production issues. This consideration resulted in DO-227A introducing a third barrier (the end-item tests) in comparison to the initial release of DO-227 that contained only two (cell and battery). EASA anyhow acknowledge that in this specific case the three successive barriers approach is not feasible due to a single cell design.

EASA participates to the RTCA Special Committee SC-235 and has noted and acknowledged that the Committee agreed to remove the cell level polarity reversal test. ~~EASA noted that the RTCA Special Committee SC-235 agreed to remove the cell-level polarity reversal test. This position is however not consulted with the public and might not be maintained in the future release of DO-227. Conversely, the standard may incorporate other requirements or tests that might provide further mitigations to the removal of the cell-level polarity reversal test. Furthermore, there is no assurance that the different authorities implementing this standard through an ETSO, TSO or equivalent will not amend the RTCA standard. Consequently, EASA does not consider that the RTCA statement provides an acceptable equivalent level of safety before the future standard is adopted in an ETSO.~~

Anyhow, until DO-227b is published including the removal of the cell level reverse polarity test and requirement and referenced in the updated ETSO upon EASA's Rulemaking processing, the deliberations of the committee SC-235 are not final and therefore cannot (should not) be used as justification to grant a deviation from DO-227a.

For this reasons EASA does not consider that the RTCA statement provides an acceptable equivalent level of safety before the future standard is adopted in an ETSO.

This deviation publishes this deviation to collect comments that would either support or oppose the industry position that could eventually affect EASA position.