

Deviation Request ETSO-C142b#5 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 Non-rechargeable lithium cells and batteries

2.1 Summary of Deviation

Deviates from RTCA DO-227A by permitting an Open Circuit Voltage (OCV) increase of 6% during one test of the environmental test sequence instead of a 2% change allowed in section 2.4.4 *Test samples and test sequences* for LiMnO₂ cells and batteries.

2.2 Original Requirement

RTCA DO-227A **Table 2-3: Cell Test Evaluation Criteria** and **Table 2-4: Battery Test Evaluation Criteria**

“1. The change in open circuit voltage during the test shall be less than 2%.”

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.

Table 2-4: Battery Test Evaluation Criteria

Code: F = Fail, A = Allowable

Test	Rqmnt Paragraph	Test Paragraph	Leak	Vent	Distort	Fire	Rupture	OCV
Pre-Test Battery Capacity	2.2.2.1.1	2.4.2.1.1	F	F	F	F	F	-
Vibration	2.2.2.1.2	2.4.2.1.2	F	F	F	F	F	F ¹
Shock	2.2.2.1.3	2.4.2.1.3	F	F	F	F	F	F ¹
Temperature Cycling	2.2.2.1.4	2.4.2.1.4	F	F	F	F	F	F ¹
Altitude Tolerance	2.2.2.1.5	2.4.2.1.5	F	F	F	F	F	F ¹
Decompression	2.2.2.1.6	2.4.2.1.6	F	F	F	F	F	F ¹
Humidity	2.2.2.1.7	2.4.2.1.7	F	F	F	F	F	F ¹
Battery Discharge	2.2.2.1.8	2.4.2.1.8	F	F	F	F	F	-
Post-Test Battery Capacity	2.2.2.1.9	2.4.2.1.9	F	F	F	F	F	-
Battery Cell Polarity Reversal ³	2.2.2.2.1	2.4.2.2.1	F ²	F ²	A	F	F	-
Battery Drop	2.2.2.2.2	2.4.2.2.2	F	F	F	F	F	-
Battery Impact	2.2.2.2.3	2.4.2.2.3	A	F	A	F	F	F
External Short Circuit	2.2.2.2.4	2.4.2.2.4	A	A	A	F	F	A
Battery Single Cell Short Circuit ³	2.2.2.2.5	2.4.2.2.5	F ²	F ²	A	F	F	-
Battery Short Circuit w/o Protection	2.2.2.2.6	2.4.2.2.6	F ²	F ²	A	F	F	-
Handle Strength	2.2.2.2.7	2.4.2.2.7	-	-	F	-	-	-

1. The change in open circuit voltage during the test shall be less than 2%.
2. This is a failure at the battery level. If used at the End Item level, this failure may be mitigated at the end item level. The condition is reportable. If the battery is used as the End Item, no mitigation is possible and leak and/or vent is considered a failure.
3. Test not applicable to single cell batteries.

2.3 Industry

RTCA DO-227A requires that cells and batteries OCV increase does not exceed 2% between the value before and after each of tests of the environmental test sequence composed of the following tests:

- At cell level:
 - o Vibration (§2.4.1.1.2),
 - o Shock (§2.4.1.1.3),
 - o Temperature Cycling (§2.4.1.1.4),
 - o Altitude Tolerance (§2.4.1.1.5),
 - o Humidity (§2.4.1.1.6).
- At battery level:
 - o Vibration (§2.4.2.1.2),
 - o Shock (§2.4.2.1.3),
 - o Temperature Cycling (§2.4.2.1.4),
 - o Altitude Tolerance (§2.4.2.1.5),
 - o Decompression (§2.4.2.1.6),
 - o Humidity (§2.4.2.1.7).

LiMnO₂ cells are known to exhibit a dynamic behaviour under large change of temperature due to a reversible and moderate passivation phenomenon that could occur on the anode during the storage of a cell. Due to this phenomena **increases** of OCV **exceeding 2%** have been measured during test sequences on cells and batteries.

This reaction can appear after temperature variations and its magnitude depends on the cell initial state. Once this new state is achieved the chemistry remains stable, no major OCV increase will be observed. This reaction is similar in occurrence and proportion on cells and battery packs.

According to these previous points it is proposed that, for the cells and batteries subject to this deviation:

An increase of OCV of not larger than 6% will be acceptable for one test of the test sequence.
Other tests will remain with an OCV change limit at 2%.

2.3.1 Acceptance criteria

2.3.1.1 deviation criteria:

Additional acceptance criteria:

As this Average increase will affect mainly lower OCV items, we shall see a **reduction of the OCV average deviation** on item population during the specific test.

The average deviation is calculated with the following formula:

$$\frac{1}{n} \sum |x - \bar{x}|$$

This verification ensures OCV values convergence through a test where samples have OCV increasing of more than 2%:

- If average deviation reduces during the test this signifies convergence of OCV values showing more uniformity.
- At the opposite, if average deviation is more important after the test this signifies divergence of values and less uniformity.

Finally, the purpose of this verification is to avoid the remoteness of one item OCV from tested population after an increase of more than 2%.

2.3.1.2 Global OCV increase criteria:

DO-227A does not limit the cumulated change of OCV for the complete sequence but only a variation per test (variation of OCV measured prior and after individual test in the test sequence) with a maximum of 2% change increase allowed.

As the environmental sequence is composed of 5 tests for cells and 6 tests for batteries, the worst case allowed by the standard can be an overall test sequence increase of OCV of about 10% (2% per test) for a cell and about 12% (2% per test) for a battery.

Additional acceptance criteria:

An **increase** of OCV between the start and the end of **the full environmental sequence shall be limited to 6%** (instead of 10% for cells and 12% for batteries).

2.3.1.3 Long term stability:

Additional acceptance criteria:

Long term OCV stability shall be measured **at least 30 days** after the test sequence completion, on at least **4 samples** per qualification sequence:

- **OCV shall not have increased.**
- A decrease can be observed, it shall be limited to the item initial OCV value (before the test sequence).

2.3.2 Deviation:

If an item (cell or battery) has an OCV increase between 2% and 6% during one test of the environmental sequence, the test result is accepted if:

- ✓ Single test OCV increase may exceed the 2% limit for one test of the environmental sequence and
- ✓ OCV average deviation reduces through this specific test as described in §2.3.1.1. and
- ✓ Item OCV change through the entire environmental sequence is less than 6% as described in §2.3.1.2. and
- ✓ Long term stability shall be verified as described in §2.3.1.3.

2.4 Equivalent Level of Safety

The deviation provides for an equivalent level of safety to the relaxed OCV criteria (6% increase instead of 2%) because:

- Cell manufacturers state that increase of OCV is the expected behavior of LiMnO₂ cells and has no impact on product safety and operating life.
- A diminution of the OCV average deviation shows a more uniform behavior of items within the qualification batch, increasing the level of safety.
- The change of OCV on the complete test sequence is required to be maintained within the same 6% limit, showing the absence of degradation, whereas the DO-227A is only limiting the OCV increase to 2% for each individual test.
- The OCV remains stable (no increase) after a long period of time as substantiated according to §2.3.1.3 method.

2.5 EASA position

We accept the deviation.