

## Quality Department

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# UN Recommendations on the Transport of Lithium Batteries

## Test Report 15Q-681 for: TL-2450, 3.6V Lithium Bell Cell

**Date: Mar 2016**

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The tests are based on the "Recommendations on the Transport of Dangerous Goods, UN Manual of Tests and Criteria, Fifth Revised Edition, Amendment 1, Section 38.3, "Lithium metal and lithium ion batteries".

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## Revisions

1. **Revision 1**- New report
2. **Revision 2 (September 25, 2008)**- minor changes in wording
3. **Revision D** - (Effective date - January, 2013), the Crush test (T6) was performed in accordance with the UN Manual of Tests and Criteria, Part III, Section 38.3, 5<sup>th</sup> revised edition.

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# Cell/Battery Description

Cell Type	TL-2450
Type Designation	Lithium cell, 3.6V, 2450 cell
Number of cells in Series	Single cell
Number of cells in Parallel	N/A
Diodes	None
Resistor	None
Fuse	None
Total Number of cells	1 cell
Lithium Weight per cell	Less than 0.3 gram
Lithium weight per Battery	N/A

## Summary

1. All the TL-2450 cells passed the tests according to the Manual of Tests and Criteria, part III, subsection 38.3.
2. The TL-2450 cell is designed to preclude a violent rupture under conditions normally incident to transport.
3. A drop test for the packaging was performed separately.

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### Test Plan

Test no.	Test description	No. of cells tested		Remarks
		Undischarged	Fully-discharged <sup>(b)</sup>	
1	Altitude Simulation	10	10	
2	Thermal Test	10	10	
3	Vibration	10	10	
4	Shock	10	10	
5	External Short-Circuit	10	10	
6	Impact	5	5	
6*	Crush	5	5	
7	Overcharge	N/A	N/A	(a)
8	Forced Discharge	N/A	10	

\*- *Effective from January, 2013, test report 15Q-934.*

#### Remarks

Remark (a)- Only applicable to rechargeable cells and batteries.

Remark (b)- The discharge was conducted on 330Ω load to end voltage lower than 2V, with capacity delivered over 400mAh.

Test Sequence- *the same cells or batteries are used for tests 1 through 5 in sequence. Test 6 and test 8 are done separately.*

### Requirements

Test 1 through 4- No mass loss ( $\Delta m$ , of less than 0.1%), no leakage (NL), no venting (NV), no disassembly (ND), no rupture (NR), no fire (NF), and practically have no voltage drop for undischarged cells (OCV to be over 90% of their OCV before the test).

Test no. 5- External temperature should not exceed 170°C, no disassembly (ND), no rupture (NR) and no fire (NF) within six hours of the test.

Test no. 6- External temperature should not exceed 170 °C, no disassembly (ND), and no fire (NF) within six hours of the test.

Test no. 8- No disassembly (ND) and no fire (NF) should occur within seven days of the test.

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### Test no. 1- Altitude simulation

According to: UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, T1 in paragraph 38.3.4.1.

Test Sample: 10 undischarged cells (1-10) and 10 fully discharged cells (16-25).

Short description of the test: Cells were stored at a pressure of less than 11.6 kPa for 6 hours at ambient temperature (20±5°C).

Test ID: 05/093

Test Results: No mass loss ( $\Delta m$ , of less than 0.1%), no leakage (NL), no venting (NV), no disassembly (ND), no rupture (NR), no fire (NF), and practically have no voltage drop for undischarged cells (OCV to be over 90% of their OCV before the test).

#### Test no. 1: Test Records

Cell	Cell status	Mass change, $\Delta m$ (%)	OCV after test in % of OCV before test (%)	Other Results
1	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
2	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
3	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
4	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
5	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
6	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
7	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
8	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
9	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
10	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
16	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
17	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
18	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
19	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
20	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
21	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
22	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
23	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
24	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
25	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF

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### Test no. 2- Thermal Test

- According to: UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, T2 in paragraph 38.3.4.2.
- Test Sample: 10 undischarged cells (1-10) and 10 fully discharged cells (16-25).
- Short description of the test: Cells stored 6 Hrs. at  $75^{\circ}\pm 2$  and 6 Hrs. at  $-40\pm 2^{\circ}\text{C}$  with interval time of 0.5 Hrs. The temperature cycle was repeated 10 times. The cells were then stored for 24 Hrs. at  $20\pm 5^{\circ}\text{C}$ .
- Test ID: 300105001
- Test Results: No mass loss ( $\Delta m$ , of less than 0.1%), no leakage (NL), no venting (NV), no disassembly (ND), no rupture (NR), no fire (NF), and practically have no voltage drop for undischarged cells (OCV to be over 90% of their OCV before the test).

#### Test no. 2: Test Records

Cell	Cell status	Mass change, $\Delta m$ (%)	OCV after test in % of OCV before test (%)	Other Results
1	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
2	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
3	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
4	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
5	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
6	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
7	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
8	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
9	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
10	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
16	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
17	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
18	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
19	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
20	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
21	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
22	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
23	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
24	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
25	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF

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### Test no. 3- Vibration

According to: UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, T3 in paragraph 38.3.4.3.

Test Sample: 10 undischarged cells (1-10) and 10 fully discharged cells (16-25).

Short description of the test: Sinusoidal logarithmic sweep between 7-200 Hz and back to 7 Hz in 0.25 Hrs., repeated 12 times for each of the 3 mutually perpendicular cell mounting positions. Peak acceleration of 8g (for 50- 200 Hz).

Test ID: 05/134

Test Results: No mass loss ( $\Delta m$ , of less than 0.1%), no leakage (NL), no venting (NV), no disassembly (ND), no rupture (NR), no fire (NF), and practically have no voltage drop for undischarged cells (OCV to be over 90% of their OCV before the test).

#### Test no. 3: Test Records

Cell	Cell status	Mass change, $\Delta m$ (%)	OCV after test in % of OCV before test (%)	Other Results
1	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
2	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
3	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
4	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
5	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
6	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
7	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
8	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
9	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
10	Undischarged	<0.1%	> 90%	NL, NV, ND, NR, NF
16	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
17	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
18	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
19	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
20	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
21	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
22	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
23	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
24	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF
25	Fully discharged	<0.1%	N/A	NL, NV, ND, NR, NF

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### Test no. 4- Shock

According to: UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, T4 in paragraph 38.3.4.4.

Test Sample: 10 undischarged cells (1-10) and 10 fully discharged cells (16-25).

Short description of the test: Half sine shock of 150 g (peak) for 6 ms. Each cell is subject to 3 shocks in positive and 3 shocks in negative direction of each of the 3 mutually perpendicular positions (total 18 shocks).

Test ID: 05/140

Test Results: No mass loss ( $\Delta m$ , of less than 0.1%), no leakage (NL), no venting (NV), no disassembly (ND), no rupture (NR), no fire (NF), and practically have no voltage drop for undischarged cells (OCV to be over 90% of their OCV before the test).

#### Test no. 4: Test Records

Cell	Cell status	Mass (gr.)			OCV of cells (V)			Other Results
		Before test	After test	$\Delta m$ (%)	Before test	After test	% of OCV before test	
1	Undischarged	9.388	9.389	<0.1%	3.653	3.698	> 90%	NL, NV, ND, NR, NF
2	Undischarged	9.399	9.397	<0.1%	3.655	3.703	> 90%	NL, NV, ND, NR, NF
3	Undischarged	9.278	9.276	<0.1%	3.659	3.703	> 90%	NL, NV, ND, NR, NF
4	Undischarged	9.339	9.338	<0.1%	3.652	3.700	> 90%	NL, NV, ND, NR, NF
5	Undischarged	9.427	9.426	<0.1%	3.655	3.701	> 90%	NL, NV, ND, NR, NF
6	Undischarged	9.319	9.319	<0.1%	3.653	3.699	> 90%	NL, NV, ND, NR, NF
7	Undischarged	9.377	9.377	<0.1%	3.659	3.703	> 90%	NL, NV, ND, NR, NF
8	Undischarged	9.474	9.475	<0.1%	3.655	3.702	> 90%	NL, NV, ND, NR, NF
9	Undischarged	9.352	9.351	<0.1%	3.658	3.703	> 90%	NL, NV, ND, NR, NF
10	Undischarged	9.398	9.397	<0.1%	3.655	3.702	> 90%	NL, NV, ND, NR, NF
16	Fully discharged	9.421	9.420	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
17	Fully discharged	9.313	9.311	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
18	Fully discharged	9.330	9.328	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
19	Fully discharged	9.384	9.384	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
20	Fully discharged	9.388	9.387	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
21	Fully discharged	9.298	9.297	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
22	Fully discharged	9.307	9.307	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
23	Fully discharged	9.373	9.371	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
24	Fully discharged	9.402	9.401	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF
25	Fully discharged	9.343	9.343	<0.1%	N/A	N/A	N/A	NL, NV, ND, NR, NF



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### Test no. 5- Short-Circuit at 55°C

- According to: UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, T5 in paragraph 38.3.4.5.
- Test Sample: 10 undischarged cells (1-10) and 10 fully discharged cells (16-25).
- Short description of the test: Cells stabilized at 55±2 °C. Short circuit done with a total external resistance of less than 100 mΩ. The short is extended for at least one hour after the cell returned to 55±2 °C. The cell is observed for a further 6 hours at 55±2 °C.
- Test ID: 150205001
- Test Results: External temperature should not exceed 170 °C, no disassembly (ND), no rupture (NR) and no fire (NF) within 6 hours of the test.

#### Test no. 5: Test Records

Cell	Cell status	Maximum temperature (°C)	Other test results
1	Undischarged	70	ND, NR, NF
2	Undischarged	74	ND, NR, NF
3	Undischarged	70	ND, NR, NF
4	Undischarged	74	ND, NR, NF
5	Undischarged	73	ND, NR, NF
6	Undischarged	76	ND, NR, NF
7	Undischarged	74	ND, NR, NF
8	Undischarged	72	ND, NR, NF
9	Undischarged	74	ND, NR, NF
10	Undischarged	73	ND, NR, NF
16	Fully discharged	60	ND, NR, NF
17	Fully discharged	59	ND, NR, NF
18	Fully discharged	61	ND, NR, NF
19	Fully discharged	62	ND, NR, NF
20	Fully discharged	60	ND, NR, NF
21	Fully discharged	61	ND, NR, NF
22	Fully discharged	62	ND, NR, NF
23	Fully discharged	62	ND, NR, NF
24	Fully discharged	63	ND, NR, NF
25	Fully discharged	62	ND, NR, NF

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### Test no. 6- Impact

- According to: UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, T6 in paragraph 38.3.4.6.
- Test Sample: 5 undischarged cells (11-15) and 5 fully discharged cells (26-30).
- Short description of the test: Cell is placed on a flat surface. A 15.8 mm diameter bar was placed perpendicular to the center of its longitudinal axis, which is parallel to the flat surface. A 9.1 kg mass was dropped from a height of  $61 \pm 2.5$  cm on the sample.
- Test ID: 030305001
- Test Results: External temperature should not exceed 170 °C, no disassembly (ND), and no fire (NF) within six hours of the test.

#### Test no. 6: Test Records

Cell	Cell status	Maximum Temperature (°C)	Other test results
11	Undischarged	40	ND, NF
12	Undischarged	41	ND, NF
13	Undischarged	36	ND, NF
14	Undischarged	37	ND, NF
15	Undischarged	35	ND, NF
26	Fully discharged	37	ND, NF
27	Fully discharged	29	ND, NF
28	Fully discharged	30	ND, NF
29	Fully discharged	30	ND, NF
30	Fully discharged	30	ND, NF

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# Test No. 6- Crush (Test report 15Q-934)

- According to: UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, paragraph 38.3.4.6.
- Test Sample: 5 undischarged cells (41-45) and 5 fully discharged cells (46-50).
- Test procedure: The cell was crushed between two flat surfaces. The crushing was gradual with a speed of approximately 1.5 cm/s at the first point of contact. The crushing was continued until the first of the three options below was reached.
1. The applied force reaches  $13 \text{ kN} \pm 0.78 \text{ kN}$ ;
  2. The voltage of the cell drops by at least 100 mV; or
  3. The cell is deformed by 50% or more of its original thickness.
- Test ID: Digital recorders files folder: QC-934
- Test Results: External temperature should not exceed 170 °C, no disassembly (ND), and no fire (NF) within six hours of the test.

## Test No. 6: Test Records

Cell No.	Cell Status	Maximum Temperature (°C)	Other Test Results
41	Undischarged	35.6	ND, NF
42	Undischarged	33.5	ND, NF
43	Undischarged	38.3	ND, NF
44	Undischarged	34.9	ND, NF
45	Undischarged	35.1	ND, NF
46	Fully discharged	32.7	ND, NF
47	Fully discharged	38.8	ND, NF
48	Fully discharged	30.4	ND, NF
49	Fully discharged	30.5	ND, NF
50	Fully discharged	31.7	ND, NF

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### Test no. 8- Forced discharge

According to: UN Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, T8 in paragraph 38.3.4.8.

Test Sample: 10 fully discharged cells (31-40).

Short description of the test: Cell was connected in series with 12 V DC power supply at initial current of 50mA. The cell was overdischarged for capacity of 1.20Ah.

Test ID: 160205001

Test Results: No disassembly (ND) and no fire (NF) within seven days of the test.

#### Test no. 8: Test Records

Cell	Cell status	Test results
31	Fully discharged	ND, NF
32	Fully discharged	ND, NF
33	Fully discharged	ND, NF
34	Fully discharged	ND, NF
35	Fully discharged	ND, NF
36	Fully discharged	ND, NF
37	Fully discharged	ND, NF
38	Fully discharged	ND, NF
39	Fully discharged	ND, NF
40	Fully discharged	ND, NF