UN 38.3 Test Report

Lithium ion Battery Pack

Applicant: TOYOTA MOTOR CORPORATION

Model: BTO-074B

Rated Voltage: 25.2 Vdc

Rated Capacity: 13200 mAh / 336 Wh

Configuration: 7S4P

Cell Mfg. / Type: Panasonic Industrial Devices Sales Taiwan Co., Ltd. / NCR18650GA

Date of issue: 2022-02-24

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Reviewed by Rex Ni Rex Ni

Testing Laboratory 1201

Application and Test information			
Test Standard	Manual of Tests and Criteria ST/SG/AC.10/11/ Rev.7, Section 38.3		
Manufacturer	Mobile Energy Technology Co.,Ltd.		
Manufacturer Address	#13,Kong 9th Road,2nd Industrial Park,LinKou District,New Taipei City,Taiwan,R.O.C.244		
Testing Laboratory	Universal Standard Service, Inc.		
Testing Location/ Address	No. 1196-9, Sec. 1, Zhongyi Road, Guishan District, Taoyuan City, 33372, Taiwan		
Date of Receipt	2021-11-15	Date (s) of Test Period	2021-12-06~2022-01-10
Parts Name	Rechargeable Lithium-Ion Battery Pack	Quantity	16 pieces

1. Test Summary:

Item	Test Item	Test Result	Details
T.1	Altitude simulation test (UN 38.3.4.1)	P	Page 04
T.2	Thermal test (UN 38.3.4.2)	P	Page 05
T.3	Vibration test (UN 38.3.4.3)	P	Page 06
T.4	Shock test (UN 38.3.4.4)	P	Page 07~08
T.5	Short Circuit test (UN 38.3.4.5)	P	Page 09
T.6	Impact / Crush test (UN 38.3.4.6)	N/A	--
T.7	Overcharge test (UN 38.3.4.7)	P	Page 13
T.8	Forced discharge test (UN 38.3.4.8)	N/A	--

Possible test case verdicts:

Test case does not apply to the test object : N/A

Test object does meet the requirement : P (Pass)

Test object does not meet the requirement : F (Fail)

Result summary:

All applicable tests according to the referenced standard have been carried out and pass.

2. Test sample list:

Sample No. for ~~Cell /~~ Batteries	Test Item
001~004	T.1~T.5, first cycle, fully charged state
005~008	T.1~T.5 25th cycle, fully charged state
--	T.6 first cycle, 50% charged state
--	T.6 25th cycle, 50% charged state
009~012	T.7 first cycle, fully charged state
013~016	T.7 25th cycle, fully charged state
--	T.8 first cycle, fully discharged state
--	T.8 25th cycle, fully discharged state
~~Cell or~~ Battery mass (g)	Approx. 2330

Mass loss means a loss of mass that exceeds the values in Table 38.3.1 below.

Table 38.3.1: Mass loss limit

Mass M of cell or battery	Mass loss limit
$M < 1$ g	0.5 %
$1 \text{ g} \leq M \leq 75$ g	0.2 %
$M > 75$ g	0.1 %

NOTE: *In order to quantify the mass loss, the following procedure is provided:*

$$\text{Mass loss (\%)} = \frac{(M_1 - M_2)}{M_1} \times 100$$

Where M_1 is the mass before the test and M_2 is the mass after the test. When mass loss does not exceed the values in Table 38.3.1, it shall be considered as "no mass loss".

3. Test record:

Section 38.3.4.1 Test T.1: Altitude simulation							
Purpose	This test simulates air transport under low-pressure conditions.						
Test procedure	Test cells and batteries shall be stored at a pressure of 11.6 kPa or less for at least six hours at ambient temperature (20 ± 5 °C).						
Sample(s)	4 batteries at first cycle, in fully charged state. (Sample No. 001~004) 4 batteries after 25 cycles ending in fully charged state. (Sample No. 005~008)						
Sample No.	Before Test		After Test		Difference		Results
	Open-circuit voltage (V)	Weight (g)	Open-circuit voltage (V)	Weight (g)	Voltage (%)	Weight (%)	
001	28.48	2336.0	28.47	2336.0	0.04%	0.00%	Pass
002	28.62	2335.0	28.62	2335.0	0.00%	0.00%	Pass
003	28.62	2328.5	28.62	2328.5	0.00%	0.00%	Pass
004	28.64	2341.0	28.64	2341.0	0.00%	0.00%	Pass
005	28.60	2337.5	28.60	2337.5	0.00%	0.00%	Pass
006	28.49	2330.0	28.49	2330.0	0.00%	0.00%	Pass
007	28.57	2332.5	28.57	2332.5	0.00%	0.00%	Pass
008	28.63	2328.0	28.63	2328.0	0.00%	0.00%	Pass
Judge Criteria	No mass loss (< 0.1 %), no leakage, no venting, no disassembly, no rupture and no fire. ~~Cells /~~ Batteries open circuit voltage not less than 90%.						
Test Period	Start: 2021-12-21 10:15 End: 2021-12-21 16:15						
Test Equipment	I00305, I00664, I00686, I00707, I00722, I00723, I00724, I00725, I00749						

Section 38.3.4.2 Test T.2: Thermal test	
Purpose	This test assesses cell and battery seal integrity and internal electrical connections. The test is conducted using rapid and extreme temperature changes.
Test procedure	Test cells and batteries are to be stored for at least six hours at a test temperature equal to 72 ± 2 °C, followed by storage for at least six hours at a test temperature equal to - 40 ± 2 °C. The maximum time interval between test temperature extremes is 30 minutes. This procedure is to be repeated until 10 total cycles are complete, after which all test cells and batteries are to be stored for 24 hours at ambient temperature (20 ± 5 °C). For large cells and batteries the duration of exposure to the test temperature extremes should be at least 12 hours.
Sample(s)	4 batteries at first cycle, in fully charged state. (Sample No. 001~004) 4 batteries after 25 cycles ending in fully charged state. (Sample No. 005~008)

Sample No.	Before Test		After Test		Difference		Results
	Open-circuit voltage (V)	Weight (g)	Open-circuit voltage (V)	Weight (g)	Voltage (%)	Weight (%)	
001	28.47	2336.0	28.20	2335.0	0.95%	0.04%	Pass
002	28.62	2335.0	28.45	2333.5	0.59%	0.06%	Pass
003	28.62	2328.5	28.45	2327.5	0.59%	0.04%	Pass
004	28.64	2341.0	28.45	2340.0	0.66%	0.04%	Pass
005	28.60	2337.5	28.43	2335.5	0.59%	0.09%	Pass
006	28.49	2330.0	28.26	2329.0	0.81%	0.04%	Pass
007	28.57	2332.5	28.38	2331.5	0.67%	0.04%	Pass
008	28.63	2328.0	28.47	2327.0	0.56%	0.04%	Pass

Judge Criteria	No mass loss (<_0.1_%), no leakage, no venting, no disassembly, no rupture and no fire. ~~Cells /~~ Batteries open circuit voltage not less than 90%.
Test Period	Start: 2021-12-21 16:30 End: 2021-12-28 16:30
Test Equipment	I00305, I00664, I00686, I00705, I00749

Section 38.3.4.3 Test T.3: Vibration	
Purpose	This test simulates vibration during transport.
Test procedure	Cells and batteries are firmly secured to the platform of the vibration machine without distorting the cells in such a manner as to faithfully transmit the vibration. The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the cell. One of the directions of vibration must be perpendicular to the terminal face. For cells and small batteries: from 7 Hz a peak acceleration of 1 gn is maintained until 18 Hz is reached. The amplitude is then maintained at 0.8 mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 8 gn occurs (approximately 50 Hz). A peak acceleration of 8 gn is then maintained until the frequency is increased to 200 Hz.
Sample(s)	4 batteries at first cycle, in fully charged state. (Sample No. 001~004) 4 batteries after 25 cycles ending in fully charged state. (Sample No. 005~008)

Sample No.	Before Test		After Test		Difference		Results
	Open-circuit voltage (V)	Weight (g)	Open-circuit voltage (V)	Weight (g)	Voltage (%)	Weight (%)	
001	28.20	2335.0	26.53	2335.0	5.92%	0.00%	Pass
002	28.45	2333.5	28.41	2334.0	0.14%	0.02%	Pass
003	28.45	2327.5	28.42	2328.0	0.11%	0.02%	Pass
004	28.45	2340.0	28.42	2340.0	0.11%	0.00%	Pass
005	28.43	2335.5	28.40	2336.0	0.11%	0.02%	Pass
006	28.26	2329.0	28.23	2329.0	0.11%	0.00%	Pass
007	28.38	2331.5	28.34	2331.5	0.14%	0.00%	Pass
008	28.47	2327.0	28.45	2327.0	0.07%	0.00%	Pass

Judge Criteria	No mass loss (< 0.1 %), no leakage, no venting, no disassembly, no rupture and no fire. ~~Cells /~~ Batteries open circuit voltage not less than 90%.
Test Period	Start: 2021-12-29 End: 2022-01-04
Test Equipment	I00305, I00664, I00686, I00708, I00749

Section 38.3.4.4 Test T.4: Shock	
Purpose	This test assesses the robustness of cells and batteries against cumulative shocks.
Test procedure	Test cells and batteries shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test battery. Each cell shall be subjected to a half-sine shock of peak acceleration of 150 gn and pulse duration of 6 milliseconds. Alternatively, large cells may be subjected to a half-sine shock of peak acceleration of 50 gn and pulse duration of 11 milliseconds. Each battery shall be subjected to a half-sine shock of peak acceleration depending on the mass of the battery. The pulse duration shall be 6 milliseconds for small batteries and 11 milliseconds for large batteries. The formulas below are provided to calculate the appropriate minimum peak accelerations. Each cell or battery shall be subjected to three shocks in the positive direction and to three shocks in the negative direction in each of three mutually perpendicular mounting positions of the cell or battery for a total of 18 shocks.
Sample(s)	4 batteries at first cycle, in fully charged state. (Sample No. 001~004) 4 batteries after 25 cycles ending in fully charged state. (Sample No. 005~008)

Sample No.	Before Test		After Test		Difference		Results
	Open-circuit voltage (V)	Weight (g)	Open-circuit voltage (V)	Weight (g)	Voltage (%)	Weight (%)	
001	26.53	2335.0	26.35	2335.0	0.68%	0.00%	Pass
002	28.41	2334.0	28.42	2334.0	0.04%	0.00%	Pass
003	28.42	2328.0	28.42	2328.0	0.00%	0.00%	Pass
004	28.42	2340.0	28.42	2340.0	0.00%	0.00%	Pass
005	28.40	2336.0	28.40	2336.0	0.00%	0.00%	Pass
006	28.23	2329.0	28.23	2329.0	0.00%	0.00%	Pass
007	28.34	2331.5	28.34	2332.0	0.00%	0.02%	Pass
008	28.45	2327.0	28.45	2327.5	0.00%	0.02%	Pass

Judge Criteria	No mass loss (< 0.1 %), no leakage, no venting, no disassembly, no rupture and no fire. ~~Cells /~~ Batteries open circuit voltage not less than 90%.
Test Period	Start: 2022-01-04 End: 2022-01-04
Test Equipment	I00664, I00686, I00706, I00749

Minimum Peak Acceleration	Small batteries (150 gn or result of formula whichever is smaller): Mass: 2.33 (kg), Acceleration (g_n)= $\sqrt{}$(100850/mass) = 208.05

Section 38.3.4.5 Test T.5: External short circuit			
Purpose	This test simulates an external short circuit.		
Test procedure	The cell or battery to be tested shall be heated for a period of time necessary to reach a homogeneous stabilized temperature of 57 ± 4 °C, measured on the external case. This period of time depends on the size and design of the cell or battery and should be assessed and documented. If this assessment is not feasible, the exposure time shall be at least 6 hours for small cells and small batteries, and 12 hours for large cells and large batteries. Then the cell or battery at 57 ± 4 °C shall be subjected to one short circuit condition with a total external resistance of less than 0.1 ohm. This short circuit condition is continued for at least one hour after the cell or battery external case temperature has returned to 57 ± 4 °C, or in the case of the large batteries, has decreased by half of the maximum temperature increase observed during the test and remains below that value. The short circuit and cooling down phases shall be conducted at least at ambient temperature.		
Sample No.	Open-circuit voltage (V)	~~Cells /~~ Batteries case max. temperature (°C)	Results
001	26.35	56.8	Pass
002	28.42	57.0	Pass
003	28.42	56.3	Pass
004	28.42	56.6	Pass
005	28.40	56.2	Pass
006	28.23	56.5	Pass
007	28.34	56.5	Pass
008	28.45	55.6	Pass
Judge Criteria	~~Cells /~~ Batteries exterior peak temperature <170^{o}C. No disassembly, No rupture and No fire.		
Test Period	Start: 2022-01-06 End: 2022-01-10		
Observed Time	Start: 2022-01-10 10:00 End: 2022-01-10 16:00		
Test Equipment	I00064, I00263, I00305, I00480, I00607, I00749		

Section 38.3.4.6 Test T.6: Impact / Crush	
Purpose	These tests simulate mechanical abuse from an impact or crush that may result in an internal short circuit.
Test procedure	Test procedure – Impact (applicable to cylindrical cells not less than 18.0 mm in diameter) **NOTE**: Diameter here refers to the design parameter (for example the diameter of 18 650 cells is 18.0 mm). The test sample cell or component cell is to be placed on a flat smooth surface. A 15.8 mm ± 0.1 mm diameter, at least 6 cm long, or the longest dimension of the cell, whichever is greater, Type 316 stainless steel bar is to be placed across the centre of the sample. A 9.1 kg ± 0.1kg mass is to be dropped from a height of 61 ± 2.5 cm at the intersection of the bar and sample in a controlled manner using a near frictionless, vertical sliding track or channel with minimal drag on the falling mass. The vertical track or channel used to guide the falling mass shall be oriented 90 degrees from the horizontal supporting surface. The test sample is to be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the 15.8 mm ± 0.1 mm diameter curved surface lying across the centre of the test sample. Each sample is to be subjected to only a single impact.
	Test Procedure – Crush (applicable to prismatic, pouch, coin/button cells and cylindrical cells less than 18.0 mm in diameter) **NOTE**: Diameter here refers to the design parameter (for example the diameter of 18650 cells is 18.0 mm). A cell or component cell is to be crushed between two flat surfaces. The crushing is to be gradual with a speed of approximately 1.5 cm/s at the first point of contact. The crushing is to be continued until the first of the three options below is reached. (a) The applied force reaches 13 kN ± 0.78 kN; Example: The force shall be applied by a hydraulic ram with a 32 mm diameter piston until a pressure of 17 MPa is reached on the hydraulic ram. (b) The voltage of the cell drops by at least 100 mV; or (c) The cell is deformed by 50% or more of its original thickness. Once the maximum pressure has been obtained, the voltage drops by 100 mV or more, or the cell is deformed by at least 50% of its original thickness, the pressure shall be released.

	A prismatic or pouch cell shall be crushed by applying the force to the widest side. A button/coin cell shall be crushed by applying the force on its flat surfaces. For cylindrical cells, the crush force shall be applied perpendicular to the longitudinal axis. Each test cell or component cell is to be subjected to one crush only. The test sample shall be observed for a further 6 h. The test shall be conducted using test cells or component cells that have not previously been subjected to other tests.

Impact Test (applicable to cylindrical cells not less than 18 mm in diameter)			
Sample No.	Open-circuit voltage at before test (V)	Cell case max. temperature (^{o}C)	Results
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Judge Criteria	External temperature of cell does not exceed 170^{o}C and there is no disassembly and no fire within 6 hours of the test.
Test Period	Start: -- End: --
Observed Time	Start: -- End: --
Test Equipment	--

Crush Test (applicable to prismatic, pouch, coin/button cells and cylindrical cells less than 18 mm in diameter)							
Sample No.	Open-circuit voltage at start of test (V)	Open-circuit voltage at removal of test (V)	Measured width / diameter of cells before crush (mm)	Measured width / diameter of cells after crush (mm)	Measured maximum force of test (kN)	Cell case max. temperature (^{o}C)	Results
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Judge Criteria	External temperature of cell does not exceed 170^{o}C and there is no disassembly and no fire within 6 hours of the test.
Test Period	Start: -- End: --
Observed Time	Start: -- End: --
Test Equipment	--

Section 38.3.4.7 Test T.7: Overcharge	
Purpose	This test evaluates the ability of a rechargeable battery or a single cell rechargeable battery to withstand an overcharge condition.
Test procedure	The charge current shall be twice the manufacturer's recommended maximum continuous charge current. The minimum voltage of the test shall be as follows: (a) When the manufacturer's recommended charge voltage is not more than 18 V, the minimum voltage of the test shall be the lesser of two times the maximum charge voltage of the battery or 22 V. (b) When the manufacturer's recommended charge voltage is more than 18 V, the minimum voltage of the test shall be 1.2 times the maximum charge voltage. Tests are to be conducted at ambient temperature. The duration of the test shall be 24 hours.

Sample No.	Charge voltage (V)	Charge current (A)	Battery pack enclosure max. temperature (^{o}C)	Results
009	34.44	10	23.1	Pass
010	34.44	10	23.0	Pass
011	34.44	10	22.9	Pass
012	34.44	10	23.0	Pass
013	34.44	10	24.2	Pass
014	34.44	10	21.2	Pass
015	34.44	10	21.0	Pass
016	34.44	10	21.0	Pass

Judge Criteria	Rechargeable batteries meet this requirement if there is no disassembly and no fire during the test and within seven days after the test.
Test Period	Start: 2021-12-23 11:12 End: 2021-12-24 11:12 Start: 2021-12-27 13:08 End: 2021-12-28 13:08
Observed Time	Start: 2021-12-24 11:15 End: 2021-12-31 11:15 Start: 2021-12-28 13:11 End: 2021-01-04 13:11
Test Equipment	I00263, I00267, I00305, I00480, I00607, I00676, I00749

Section 38.3.4.8 Test T.8: Forced discharge				
Purpose	This test evaluates the ability of a primary or a rechargeable cell to withstand a forced discharge condition.			
Test procedure	Each cell shall be forced discharged at ambient temperature by connecting it in series with a 12V D.C. power supply at an initial current equal to the maximum discharge current specified by the manufacturer. The specified discharge current is to be obtained by connecting a resistive load of the appropriate size and rating in series with the test cell. Each cell shall be forced discharged for a time interval (in hours) equal to its rated capacity divided by the initial test current (in ampere).			
Sample No.	Open-circuit voltage (V)	Reverse charge current (A)	Test time (Hour)	Results
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Judge Criteria	No disassembly, no fire within seven days of the test.			
Test Period	Start: --	End: --		
Test Equipment	Start: --	End: --		
Test Equipment	--			