LITHIUM ION BATTERY SAFETY TESTING REPORT

Applicant:	E-One Moli Energy Corp. Southern Taiwan Science Park,No.10,Dali 2nd Rd.,Shanhua Dist,Tainan 74144,Taiwan Tel: +886-2-25673500 ; E-mail: service@molicel.com Website: http://www.molicel.com
Manufacturer:	E-One Moli Energy Corp. Southern Taiwan Science Park,No.10,Dali 2nd Rd.,Shanhua Dist,Tainan 74144,Taiwan
Product:	Lithium Ion Rechargeable Cell
Model:	INR-21700-P42B
Rating:	3.6 Vdc, 4200 mAh, 15.12 Wh
Test method & Criterion	UNITED NATIONS "Recommendations on the TRANSPORT OF DANGEROUS GOODS" Manual of Tests and Criteria ST/SG/AC.10/11/Rev.6/Amend.1
Appearance	Cylindrical Type
Verification Issuing Office Name	AnTek Certification Inc. 7F., No. 351, Yangguang St., Neihu District, Taipei City, Taiwan Tel: +886-2-8752-3779; Website: www.atclab.com.tw; E-mail: atc@atclab.com.tw
Test Performed Date:	Jun. 01, 2020 – Jun. 23, 2020
Test Items:	See Page 2 for details.
Conclusion:	The sample has passed the test items of UN 38.3
Date of Issued:	Jun. 24, 2020
Comment:	--

Prepared by:

Ann Kuo

Ann Kuo
Test Engineer

Reviewed by:

Nick Wu 2020.6.24

Nick Wu
Project Engineer

TEST ITEMS

No.	Name of Test Items	Conclusion	Remark
T1.	**Altitude Simulation**	Passed	--
T2.	**Thermal Test**	Passed	--
T3.	**Vibration**	Passed	--
T4.	**Shock**	Passed	--
T5.	**External Short Circuit**	Passed	--
T6.	**Impact**	Passed	--
	Crush	N/A	--
T7.	**Overcharge**	N/A	--
T8.	**Forced Discharge**	Passed	--
Test Environment Condition	Ambient Temperature: 23.3 °C ~ 24.8 °C Ambient Humidity: 55% ~ 60%		

SAMPLES FOR TYPE TESTS:

Test Number	Cell / Battery Type	Test Samples
T1 ~ T5	☐ Primary Cells	Ten cells in undischarged states Ten cells in fully discharged states
	☐ Primary Batteries (Small Type)	Four batteries in undischarged states Four batteries in fully discharged states
	☐ Primary Batteries (Large Type)	Four batteries in undischarged states Four batteries in fully discharged states
	☒ Rechargeable Cells	Five cells at first cycle, in fully charged states Five cells after 25 cycles ending in fully charged states
	☐ Single Cell type Battery	Five cells at first cycle, in fully charged states Five cells after 25 cycles ending in fully charged states
	☐ Rechargeable Batteries (Small Type)	Four batteries at first cycle, in fully charged states Four batteries after 25 cycles ending in fully charged states
	☐ Rechargeable Batteries (Large Type)	Two batteries at first cycle, in fully charged states Two batteries after 25 cycles ending in fully charged states
T6	☐ Primary cells	Five cells in undischarged states Five cells in fully discharged states
	☐ Component cells of primary batteries	Five cells in undischarged states Five cells in fully discharged states
	☒ Rechargeable cells	Five cells at first cycle at 50% of the design rated capacity Five cells after 25 cycles ending at 50% of the design rated capacity
	☐ Component cells of rechargeable batteries	Five cells at first cycle at 50% of the design rated capacity Five cells after 25 cycles ending at 50% of the design rated capacity
T7	☐ Rechargeable Batteries (Small Type)	Four batteries at first cycle, in fully charged states Four batteries after 25 cycles ending in fully charged states
	☐ Rechargeable Batteries (Large Type)	Two batteries at first cycle, in fully charged states Two batteries after 25 cycles ending in fully charged states
T8	☐ Primary cells	Ten cells in fully discharged states
	☐ Primary component cells	Ten cells in fully discharged states
	☒ Rechargeable cells	Ten cells, at first cycle in fully discharged states Ten cells after 25 cycles ending in fully discharged states
	☐ Rechargeable component cells	Ten cells, at first cycle in fully discharged states Ten cells after 25 cycles ending in fully discharged states

T1: Altitude Simulation

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).

Requirement:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

Results:

Sample No	Sample State	Before Test		After Test		Mass Loss (%)	Residual Voltage (%)	Phenomenon
		Mass (g)	Open-Circuit Voltage (V)	Mass (g)	Open-Circuit Voltage (V)			
01	A	66.860	4.228	66.860	4.225	0.00	99.93	O
02	A	66.656	4.220	66.656	4.218	0.00	99.95	O
03	A	66.834	4.229	66.834	4.227	0.00	99.95	O
04	A	66.709	4.245	66.709	4.243	0.00	99.95	O
05	A	66.851	4.227	66.851	4.224	0.00	99.93	O
06	B	66.735	4.231	66.735	4.230	0.00	99.98	O
07	B	66.774	4.241	66.774	4.239	0.00	99.95	O
08	B	66.728	4.232	66.728	4.228	0.00	99.91	O
09	B	66.733	4.234	66.733	4.231	0.00	99.93	O
10	B	66.678	4.220	66.678	4.217	0.00	99.93	O

Sample state:
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
Phenomenon:
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

T2: Thermal Test

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.

Requirement:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

Results:

Sample No	Sample State	Before Test		After Test		Mass Loss (%)	Residual Voltage (%)	Phenomenon
		Mass (g)	Open-Circuit Voltage (V)	Mass (g)	Open-Circuit Voltage (V)			
01	A	66.860	4.225	66.860	4.109	0.00	97.25	O
02	A	66.656	4.218	66.656	4.107	0.00	97.37	O
03	A	66.834	4.227	66.834	4.110	0.00	97.23	O
04	A	66.709	4.243	66.708	4.114	0.00	96.96	O
05	A	66.851	4.224	66.851	4.111	0.00	97.32	O
06	B	66.735	4.230	66.734	4.112	0.00	97.21	O
07	B	66.774	4.239	66.774	4.114	0.00	97.05	O
08	B	66.728	4.228	66.728	4.111	0.00	97.23	O
09	B	66.733	4.231	66.733	4.111	0.00	97.16	O
10	B	66.678	4.217	66.676	4.106	0.00	97.37	O

Sample state:
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
Phenomenon:
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

T3: Vibration

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.

The logarithmic frequency sweep shall differ for cells and batteries with a gross mass of not more than 12 kg (cells and small batteries), and for batteries with a gross mass of more than 12 kg (large batteries).

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.

For large batteries: from 7 Hz to 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 2 gn occurs (approximately 25 Hz). A peak acceleration of 2 gn is then maintained until the frequency is increased to 200 Hz.

Requirement:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire during the test and after the test and if the open circuit voltage of each test cell or battery directly after testing in its third perpendicular mounting position is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

Results:

Sample No	Sample State	Before Test		After Test		Mass Loss (%)	Residual Voltage (%)	Phenomenon
		Mass (g)	Open-Circuit Voltage (V)	Mass (g)	Open-Circuit Voltage (V)			
01	A	66.860	4.109	66.858	4.108	0.00	99.98	O
02	A	66.656	4.107	66.652	4.107	0.01	100.00	O
03	A	66.834	4.110	66.834	4.110	0.00	100.00	O
04	A	66.708	4.114	66.708	4.113	0.00	99.98	O

Sample No	Sample State	Before Test		After Test		Mass Loss (%)	Residual Voltage (%)	Phenomenon
		Mass (g)	Open-Circuit Voltage (V)	Mass (g)	Open-Circuit Voltage (V)			
05	A	66.851	4.111	66.836	4.111	0.02	100.00	O
06	B	66.734	4.112	66.733	4.111	0.00	99.98	O
07	B	66.774	4.114	66.768	4.113	0.01	99.98	O
08	B	66.728	4.111	66.725	4.111	0.00	100.00	O
09	B	66.733	4.111	66.729	4.111	0.01	100.00	O
10	B	66.676	4.106	66.674	4.105	0.00	99.98	O

Sample state:
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
Phenomenon:
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

T4: Shock

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.

Battery	Minimum peak acceleration	Pulse duration
Small batteries	150 g_n or result of formula $Acceleration(g_n) = \sqrt{\left(\frac{100850}{mass^a}\right)}$ whichever is smaller	6 ms
Large batteries	50 g_n or result of formula $Acceleration(g_n) = \sqrt{\left(\frac{30000}{mass^a}\right)}$ whichever is smaller	11 ms

[a] Mass is expressed in kilograms.

The relationship between minimum peak acceleration and mass is illustrated in Figure 38.3.4.1 for small batteries and Figure 38.3.4.2 for large batteries.

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.

Requirement:

Cells and batteries meet this requirement if there is no leakage, no venting, no disassembly, no rupture and no fire and if the open circuit voltage of each test cell or battery after testing is not less than 90% of its voltage immediately prior to this procedure. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

Results:

Sample No	Sample State	Before Test		After Test		Mass Loss (%)	Residual Voltage (%)	Phenomenon
		Mass (g)	Open-Circuit Voltage (V)	Mass (g)	Open-Circuit Voltage (V)			
01	A	66.858	4.108	66.858	4.108	0.00	100.00	O
02	A	66.652	4.107	66.652	4.107	0.00	100.00	O
03	A	66.834	4.110	66.834	4.110	0.00	100.00	O
04	A	66.708	4.113	66.708	4.113	0.00	100.00	O
05	A	66.836	4.111	66.836	4.110	0.00	99.98	O
06	B	66.733	4.111	66.733	4.111	0.00	100.00	O
07	B	66.768	4.113	66.768	4.113	0.00	100.00	O
08	B	66.725	4.111	66.725	4.110	0.00	99.98	O
09	B	66.729	4.111	66.729	4.111	0.00	100.00	O
10	B	66.674	4.105	66.674	4.105	0.00	100.00	O

Sample state:
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.
Phenomenon:
L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire.
O - No leakage, no venting, no disassembly, no rupture and no fire.

T5: 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.

Requirement:

Cells and batteries meet this requirement if their external temperature does not exceed 170 °C and there is no disassembly, no rupture and no fire during the test and within six hours after the test.

Results:

Sample No	Sample State	External Highest Temperature (°C)	Initial Voltage(V)	External resistance(mΩ)	Phenomenon
01	A	107.2	4.108	82.34	O
02	A	102.8	4.107	80.19	O
03	A	101.6	4.110	92.47	O
04	A	105.1	4.113	75.86	O
05	A	104.3	4.110	89.11	O
06	B	105.7	4.111	73.98	O
07	B	107.4	4.113	80.26	O
08	B	103.5	4.110	87.43	O
09	B	101.8	4.111	85.48	O
10	B	96.0	4.105	92.56	O

Sample state:
A – Battery at first cycle, in fully charged states.
B – Battery after 25 cycles ending in fully charged states.

Sample No	Sample State	External Highest Temperature (°C)	Initial Voltage(V)	External resistance(mΩ)	Phenomenon
Phenomenon: L – Leakage; V – Venting; D – Disassembly; R – Rupture; F – Fire. O - No leakage, no venting, no disassembly, no rupture and no fire.					

T6: Impact/Crush

☒ Test procedure - Impact (applicable to cylindrical cells not less than 18.0 mm in diameter):

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):

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.

Note: Diameter here refers to the design parameter (for example the diameter of 18650 cells is 18.0 mm).

Requirement:

Cells and component cells meet this requirement if their external temperature does not exceed 170 °C and there is no disassembly and no fire during the test and within six hours after this test.

Results:

Sample No	Sample State	External Highest Temperature (°C)	Phenomenon
11	A	24.9	O
12	A	25.5	O
13	A	25.2	O
14	A	25.4	O
15	A	25.8	O
16	B	25.6	O
17	B	24.8	O
18	B	25.6	O
19	B	25.7	O
20	B	25.0	O

Sample state:
A – Cell at first cycle at 50% of the design rated capacity.
B – Cell after 25 cycles ending at 50% of the design rated capacity.
Phenomenon:
D – Disassembly; F – Fire; O - No disassembly and no fire;

T8: Forced Discharge

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).

Requirement

Primary or rechargeable cells meet this requirement if there is no disassembly and no fire during the test and within seven days after the test.

Results:

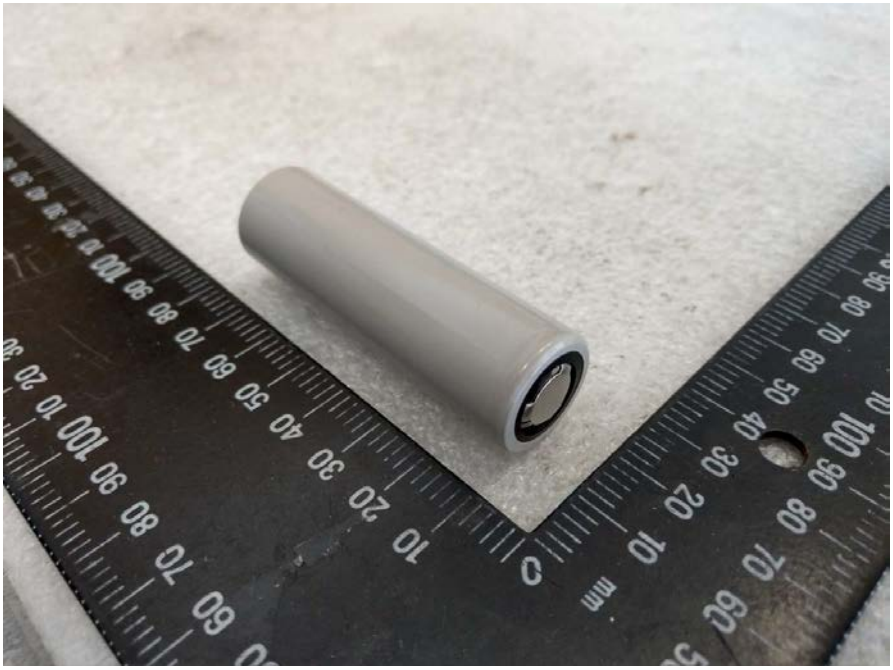
Sample No	Sample State	Discharge Current	Discharge Duration	Phenomenon
21	A	45 A	0.09 h	O
22	A	45 A	0.09 h	O
23	A	45 A	0.09 h	O
24	A	45 A	0.09 h	O
25	A	45 A	0.09 h	O
26	A	45 A	0.09 h	O
27	A	45 A	0.09 h	O
28	A	45 A	0.09 h	O
29	A	45 A	0.09 h	O
30	A	45 A	0.09 h	O
31	B	45 A	0.09 h	O
32	B	45 A	0.09 h	O
33	B	45 A	0.09 h	O
34	B	45 A	0.09 h	O
35	B	45 A	0.09 h	O
36	B	45 A	0.09 h	O
37	B	45 A	0.09 h	O
38	B	45 A	0.09 h	O
39	B	45 A	0.09 h	O
40	B	45 A	0.09 h	O

Sample state:
A – Cell at first cycle in fully discharged states.
B – Cell after 25 cycles ending in fully discharged states.

Sample No	Sample State	Discharge Current	Discharge Duration	Phenomenon
Phenomenon: D – Disassembly; F – Fire; O - No disassembly and no fire.				

Photographs

<Fig. #1>



<Fig. #2>