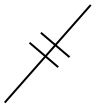
UN Manual of Tests and Criteria Subsection 38.3 (Lithium-Ion / Polymer Battery Pack) Test Report

	Prepared	Checked	Approved
Emerging Power Inc.			

EMERGING POWER, INC.

www.emergingpower.com
200 Holt Street, Hackensack, NJ 07601
TEL:201-441-3590 FAX: 201-441-3592

CONTENTS

Summary

This report analyzes the mechanical and electrical integrity of the lithium-ion battery pack to satisfy the UN Manual of Tests and Criteria section 38.3, Revision 7. The battery pack must go through rigorous tests that include: altitude simulation, storage in extreme temperatures, vibration, and shock to the outer casing, external short circuit, and overcharge. The basic criteria for passing all tests require that the packs must not catch fire, no mass loss, no disassembly, no leakage, no venting, no rupture, and the open circuit voltage of each pack after testing is not less than 90% of its voltage before each test.

1. Scope

1-1. Test Purpose

These tests evaluate the 1600842-13 lithium-ion battery pack to satisfy the UN Manual of Test and Criteria subsection 38.3. Rev. 7

1-2. Cell/Pack Information

Cell	**Manufacturer**	Nanograf	**Charge**	**Voltage**	4.2V
	Model	INR18650-M38A		**Current**	1.9A
	Chemistry	Lithium Ion		**Cut-off**	<0.190 A
	Voltage	3.6V	**Discharge**	**Current**	3.8A
	Capacity	3800 mAh		**Cut-off**	2.65V
Pack	**Manufacturer**	Thales	**Charge**	**Voltage**	12.6V
	PN	1600842-13		**Current**	2.6A
	Configuration	3S2P		**Cut-off**	<0.100 A
	Typical voltage	10.8V	**Discharge**	**Discharge**	3.8A
	Capacity	7600mAh		**Cut-off**	7.5 V
	Watt-hour	82.08 Wh	**Safety**		Over - Current Over - Voltage Over - Discharge

Picture 1: Sample Battery Pack

2. Preparation

2-1. Battery Source

1) Sample sixteen new batteries from the manufacturer. Number samples 1~16.

2) Using the MACCOR 4000 charge samples #1~4 ending in fully charged state. Repeat for samples #9~12.

3) Using the MACCOR 4000, cycle samples #5~8 by charging at 2.6A constant current until the voltage reaches 12.6V followed by a constant voltage of 12.6V with a cutoff at 0.100A. Then discharge the packs at 3.8A constant current to 7.5V. The packs must be cycled for 25 cycles ending in a fully charged state. Repeat for samples #13~16.

3. Test and Result

3-1. Altitude Simulation Test (T1)

This test simulates air transport under low-pressure conditions. It assesses battery assembly integrity and internal electrical connections.

Test Instruments

Electronic Scale (Ohaus Scout Pro SP2001)

Altitude Simulation Machine (Thermotron F-4-CHA-1-1)

Digital Multi-meter (Agilent 34401A)

Test Procedure

1) Record initial voltages and masses of samples 1~8.
2) Store batteries at a pressure of 11.6kPA (87 Torr) for 6 hours at an ambient temperature of 20±5° C and record the voltage and mass of each battery after the test. Note the condition of each battery.

Requirement

The battery meets this requirement if there is no mass loss, no disassembly, no leakage, no venting, no rupture, no fire, and if the open circuit voltage of each test cell after testing is not less than 90% of its voltage before this procedure.

Result (Altitude Simulation Test)

#	Initial Voltage (V)	Post-test Voltage (V)	OCV (%)	Initial Mass (g)	Post-test Mass (g)	Decision
1	12.549	12.451	99	418.6	418.5	**Pass**
2	12.508	12.498	99	421.0	421.0	**Pass**
3	12.522	12.512	99	420.3	420.3	**Pass**
4	12.530	12.519	99	420.1	420.1	**Pass**
5	12.529	12.519	99	418.2	418.2	**Pass**
6	12.530	12.519	99	419.3	419.3	**Pass**
7	12.536	12.525	99	416.3	416.2	**Pass**
8	12.536	12.525	99	420.0	419.9	**Pass**
FINAL RESULT		**PASS**				

3-2. Thermal Shock Test (T2)

This test simulates rapid and extreme temperature changes. It assesses battery assembly integrity and internal electrical connections.

Test Instruments

Electronic Scale (Ohaus Scout Pro SP2001)

Environmental Chamber (Thermotron SE-300-4-4)

Digital Multimeter, 6.5 digit (Agilent 34401A)

Test Procedure

1) Test the initial voltages and masses of samples 1~8 and record.

2) Store batteries for 6 hours at a test temperature equal to 72±2°C followed by 6 hours at a test temperature of - 40±2°C with a maximum change interval of 30 minutes.

Repeat step 2, a total of ten times after which all batteries are stored for 24 hours at an ambient temperature of 20±5° C. At the conclusion, record the mass and voltage. Note the condition of each battery.

Requirement

The battery meets this requirement if there is no mass loss, no disassembly, no leakage, no venting, no rupture, no fire, and if the open circuit voltage of each test cell after testing is not less than 90% of its voltage before this procedure.

Result (Thermal Shock Test)

#	Initial Voltage (V)	Post-test Voltage (V)	OCV (%)	Initial Mass (g)	Post-test Mass (g)	Decision
1	12.451	12.262	98	418.5	418.4	**Pass**
2	12.498	12.272	98	421.0	420.9	**Pass**
3	12.512	12.278	98	420.3	420.2	**Pass**
4	12.519	12.290	98	420.1	420.1	**Pass**
5	12.519	12.286	98	418.2	418.2	**Pass**
6	12.519	12.276	98	419.3	419.2	**Pass**
7	12.525	12.278	98	416.2	416.3	**Pass**
8	12.525	12.277	98	419.9	419.9	**Pass**
FINAL RESULT		**PASS**				

3-3. Vibration Test (T3)

This test simulates vibration during transportation.

Test Instruments

Electronic Scale (Ohaus Scout Pro SP2001)

Vibration Machine (LDS V726)

Digital Multimeter, 6.5 digit (Agilent 34401A)

Test Procedure

1) Record the initial voltages and masses of samples 1~8.
2) Firmly secure the batteries to the platform of the vibration machine in such a manner as to faithfully transmit the vibration. Perform the test beginning with a sinusoidal waveform with a logarithmic sweep between 7Hz and 200Hz and back to 7Hz traversed in 15 minutes. Repeat this cycle 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the battery. One direction of vibration shall be perpendicular to the terminal face. At the conclusion record the mass and voltage. Note the condition of each battery.

Requirement

The battery meets this requirement if there is no mass loss, no disassembly, no leakage, no venting, no rupture, and no fire and if the open circuit voltage of each test cell after testing is not less than 90% of its voltage before this procedure.

Result (Vibration Test)

#	Post-test Voltage (V)	Initial Voltage (V)	OCV (%)	Initial Mass (g)	Post-test Mass (g)	Decision
1	12.263	12.262	99	418.4	418.4	**Pass**
2	12.273	12.272	99	420.9	420.9	**Pass**
3	12.279	12.278	99	420.2	420.2	**Pass**
4	12.291	12.290	99	420.1	420.1	**Pass**
5	12.286	12.286	100	418.2	418.2	**Pass**
6	12.277	12.276	99	419.2	419.2	**Pass**
7	12.279	12.278	99	416.3	416.2	**Pass**
8	12.278	12.277	99	419.9	419.9	**Pass**
FINAL RESULT			PASS			

NOTE:

3-4. Shock Test (T4)

This test simulates possible impacts during transportation.

Test Instruments

Electronic Scale (Ohaus Scout Pro SP2001)

Shock Tower (MPM Technologies)

Digital Multi-meter (Agilent 34401A)

Test Procedure

1) Record the initial voltages and masses of samples 1~8.
2) Secure the battery to the shock tower. Subject the battery to a half-sine shock of peak acceleration of 150_g and pulse duration of 6 milliseconds in the positive direction followed by three shocks in the negative direction of three mutually perpendicular mounting positions of the battery for a total of 18 shocks. At the conclusion record the mass and voltage. Note the condition of each battery.

Requirement

The battery meets this requirement if there is no mass loss, no disassembly, no leakage, no venting, no rupture, no fire, and if the open circuit voltage of each test cell after testing is not less than 90% of its voltage before this procedure.

Results (Shock Test)

#	Initial Voltage (V)	Post-test Voltage (V)	OCV (%)	Initial Mass (g)	Post-test Mass (g)	Decision
1	12.263	12.257	99	418.4	418.4	**Pass**
2	12.273	12.267	99	420.9	420.9	**Pass**
3	12.279	12.272	99	420.2	420.2	**Pass**
4	12.291	12.283	99	420.1	420.1	**Pass**
5	12.286	12.279	99	418.2	418.2	**Pass**
6	12.277	12.270	99	419.2	419.2	**Pass**
7	12.279	12.272	99	416.3	416.2	**Pass**
8	12.278	12.271	99	419.9	419.9	**Pass**
FINAL RESULT		**PASS**				

3-5. External Short Circuit Test (T5)

This test simulates an external short-circuit.

Test Instruments

Electronic Scale (Ohaus Scout Pro SP2001)

Environmental Chamber (Thermotron S-8-3800)

Data Acquisition System, Thermocouple, DVM (Agilent 34970A)

Short Circuit Apparatus (self-made, 2kW 0.1Ohm)

Test Procedure

1) Record the initial voltages and masses of samples 1~8. Stabilize the environmental chamber temperature to 57±4°C. The surface of the battery pack must measure 57±4°C before the short circuit is started.
2) Then subject each battery to an external short circuit condition with a total external resistance of less than 0.1Ω at 57±4°C for 1 hour.
3) After short circuit, continue observation for at least 6 more hours. Note the battery's condition.

Requirement

The batteries meet this requirement if their external temperatures do not exceed 170°C and there is no disassembly, no fire, and no rupture within six hours of the test.

Results (External Short Circuit Test)

#	Initial Voltage (V)	Initial Mass (g)	Temperature Maximum (°C)	Fire	Disassembly	Decision
1	12.257	418.5	58	no	no	**Pass**
2	12.267	421.0	58	no	no	**Pass**
3	12.272	420.2	58	no	no	**Pass**
4	12.283	420.0	58	no	no	**Pass**
5	12.279	418.2	58	no	no	**Pass**
6	12.270	419.2	58	no	no	**Pass**
7	12.272	416.2	58	no	no	**Pass**
8	12.271	419.9	58	no	no	**Pass**
FINAL RESULT		**Pass**				

3-6. Impact (T6)

According to the UN Manual of Tests and Criteria subsection 38.3, Li-Ion / polymer packs are only required to go through tests T1~T5 and T7. **Test T6 (Impact) and test T8 (Forced Discharge) are NOT required testing for Li-Ion / Polymer packs**. T6 and T8 are **only required for Li-Ion / Polymer cells**. To get information on the UN Manual of Tests and Criteria subsection 38.3 test report for the cells, please contact the cell manufacturer.

3-7. Overcharge Test (T7)

This test simulates an overcharge condition.

Test Instruments

Electronic Scale (Ohaus Scout Pro SP2001)

Analog Power Supply (Agilent E3634A)

Test Procedure

Using the power supply charge the batteries at twice the manufacturer's recommended charging current. The minimum voltage shall be:

a) When the manufacturer's recommended charge voltage is not more than 18V, the minimum voltage shall be the lesser of two times the maximum charge voltage of battery or 22V.

b) When the manufacturer's recommended charge voltage is more than 18V, the minimum voltage of the test shall be 1.2 times the maximum charge voltage.

Conduct test at ambient temperatures and a duration of 24 hours.

Observe for seven more days after the overcharge condition.

Requirement

Batteries meet this requirement if there is no disassembly and no fire within seven days of the test.

Results (Overcharge)

#	Initial Voltage (V)	Mass (g)	Disassembly / Fire	Decision
9	12.415	419.4	No	Pass
10	12.429	420.2	No	Pass
11	12.461	420.1	No	Pass
12	12.469	420.3	No	Pass
13	12.450	419.2	No	Pass
14	12.455	419.1	No	Pass
15	12.447	416.5	No	Pass
16	12.461	419.3	No	Pass

Note: Charging voltage: 22V
Charging current: 3.8A
- PCM shuts off charging.

3-8. Forced Discharge Test (T8)

According to the UN Manual of Tests and Criteria subsection 38.3, Li-Ion / polymer packs are only required to go through tests T1~T5 and T7. **Test T6 (Impact) and test T8 (Forced Discharge) are NOT required testing for Li-Ion / Polymer packs**. T6 and T8 are **only required for Li-Ion / Polymer cells**. To get information on the UN Manual of Tests and Criteria subsection 38.3 test report for the cells, please contact the cell manufacturer.

Appendix A

A-1. T2: Thermal Shock Profile

The following shows the program settings of the ThermotronSE-300-4-4. In this profile, the chamber starts at 20°C. It then ramps up to 72°C in 30 minutes where it is maintained for 6 hours. Once this is complete, the chamber has 30 minutes to ramp down to -40°C where once again it is maintained for 6 hours. The temperature of the chamber then goes back to 72°C. The total number of iterations is 10 times. Notice that the temperature is allowed to deviate 2°C.

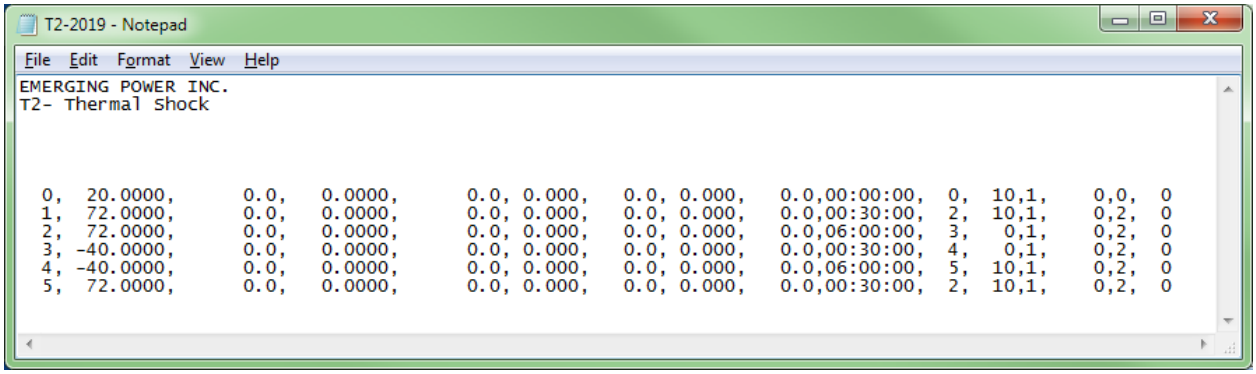


Figure A-1: Thermal Chamber Profile

A-2. T3: Vibration Test Simulation Data

The following shows the output of the LDS V726 Vibration Machine. For this test, the samples were subjected to a sinusoidal waveform with a logarithmic sweep between 7Hz and 200Hz and back to 7Hz traversed in 15 minutes. This cycle was repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the battery with one direction of vibration perpendicular to the terminal face.

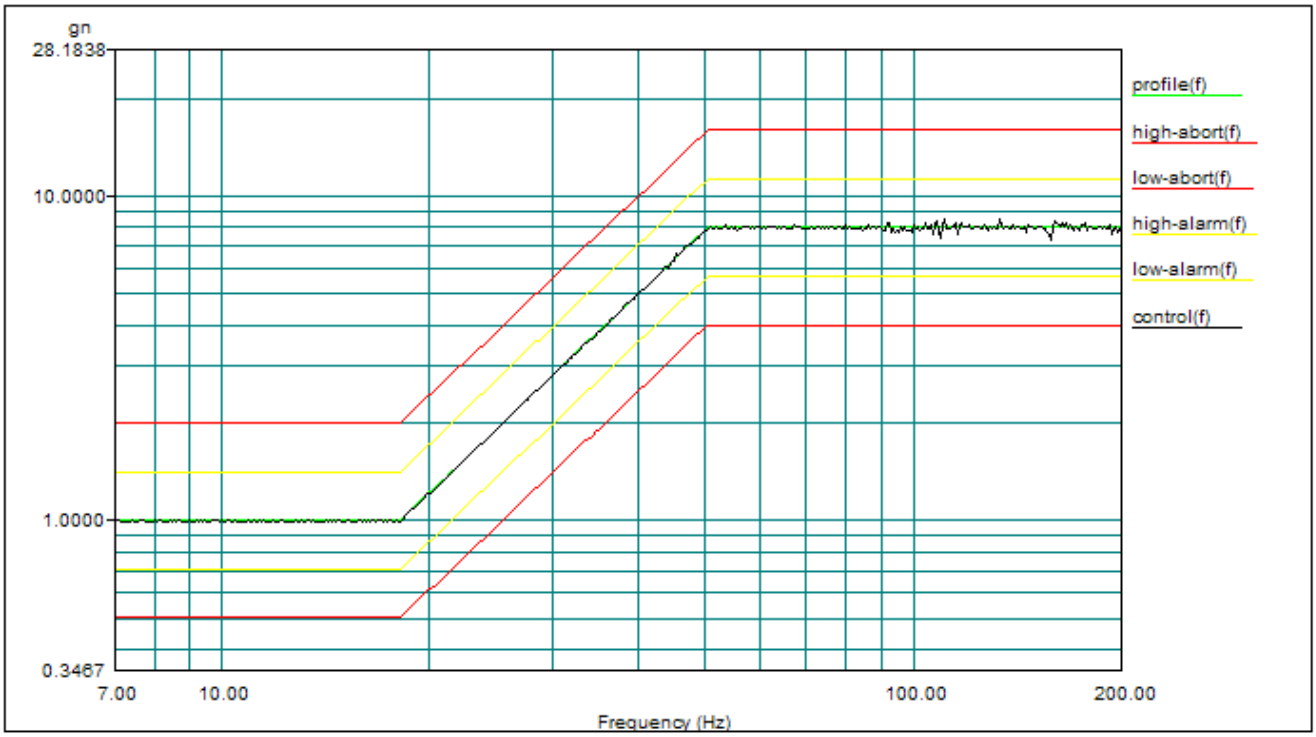


Figure A-2: Vibration Machine Output

A-3. T4: Shock Test Simulation Data

The following shows data taken from the MPM Shock Tower. In this example, the sample was subjected to a half-sine shock with a peak acceleration of 150.6$_g$ with a pulse duration of 5.19ms. This was done three times in the positive direction and 3 times in the negative direction for three mutually perpendicular mounting positions.

Impact V5.0

Summary Report

Sample ID

MBITR (nanograf cells) TURNKEY

Material Description

Thales MBITR (nanograf cells) TURNKEY

Test Parameter	Value
Operator	Michael Faine
Date	01/18/2024 14:24
Temperature	20.00 °C
Oscilloscope	MPM 1250-0604 Oscilloscope
Orientation	N/A
Damping Material	Hard Rubber
Damping Material Thickness	27.00 mm
Energy Adjustment	1.0000
Filter Type	Butterworth LP
Cut Off Frequency	1000.00

Results

Measured Parameter	Result
Peak Acceleration (g)	150.6
Pulse Duration (s)	5.19E-3
Absorbed Energy (N m)	NaN
Absorbed Energy Ratio	NaN

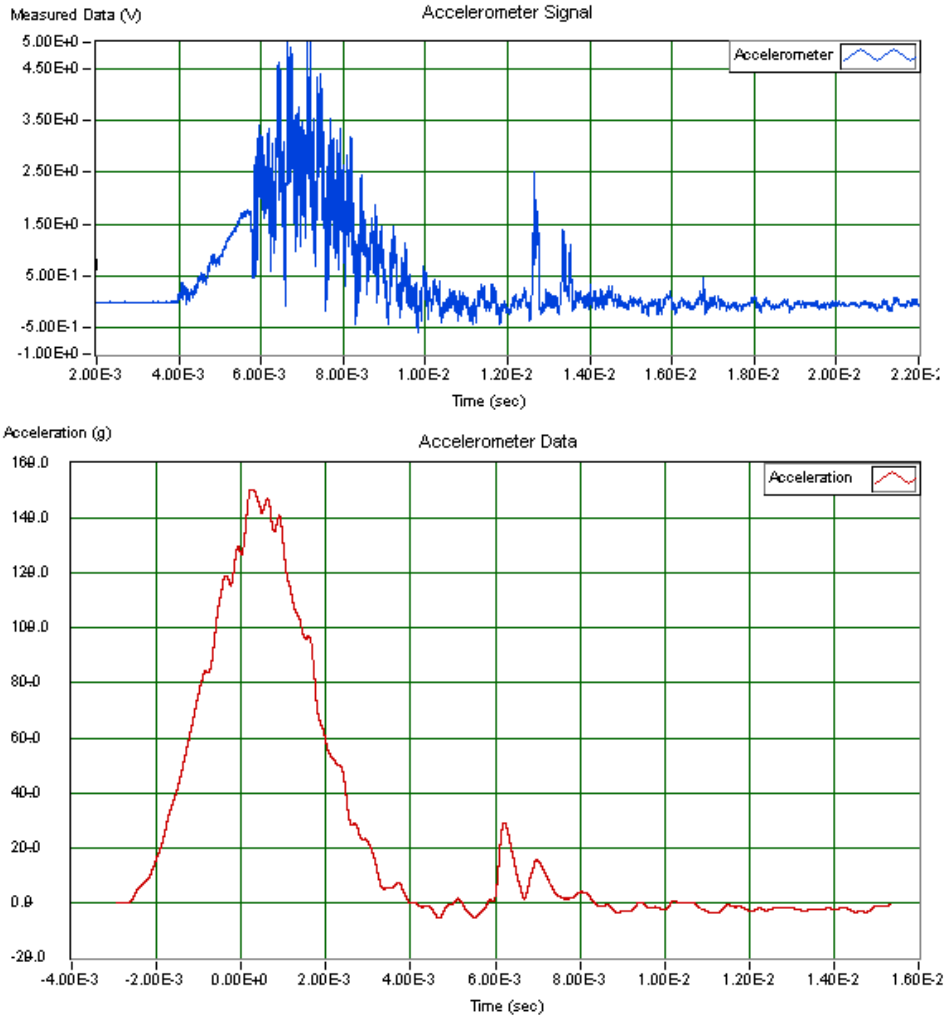
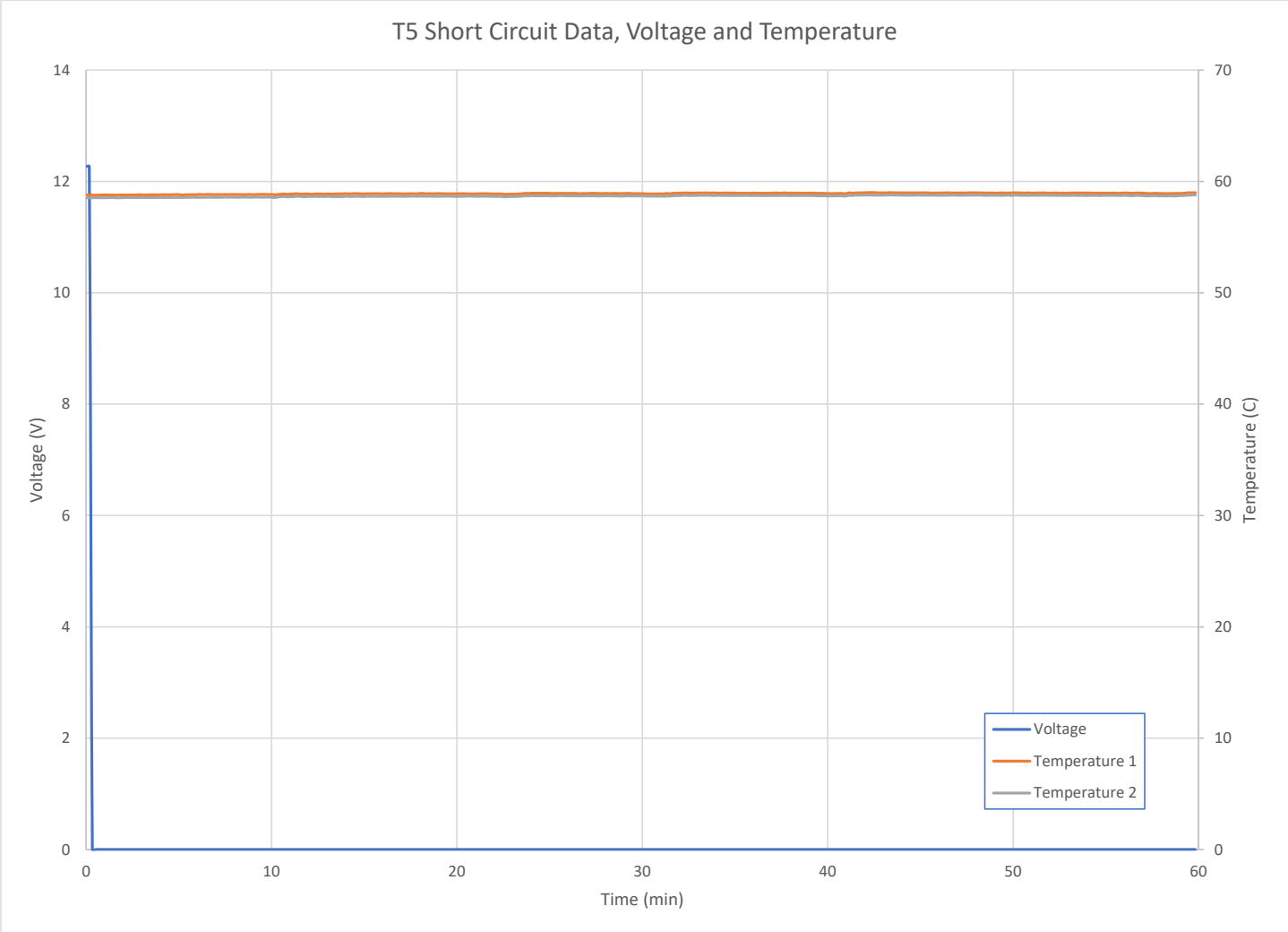


Figure A-3: Accelerometer Results of a Shock Test

A-4. T5: External Short-Circuit Data

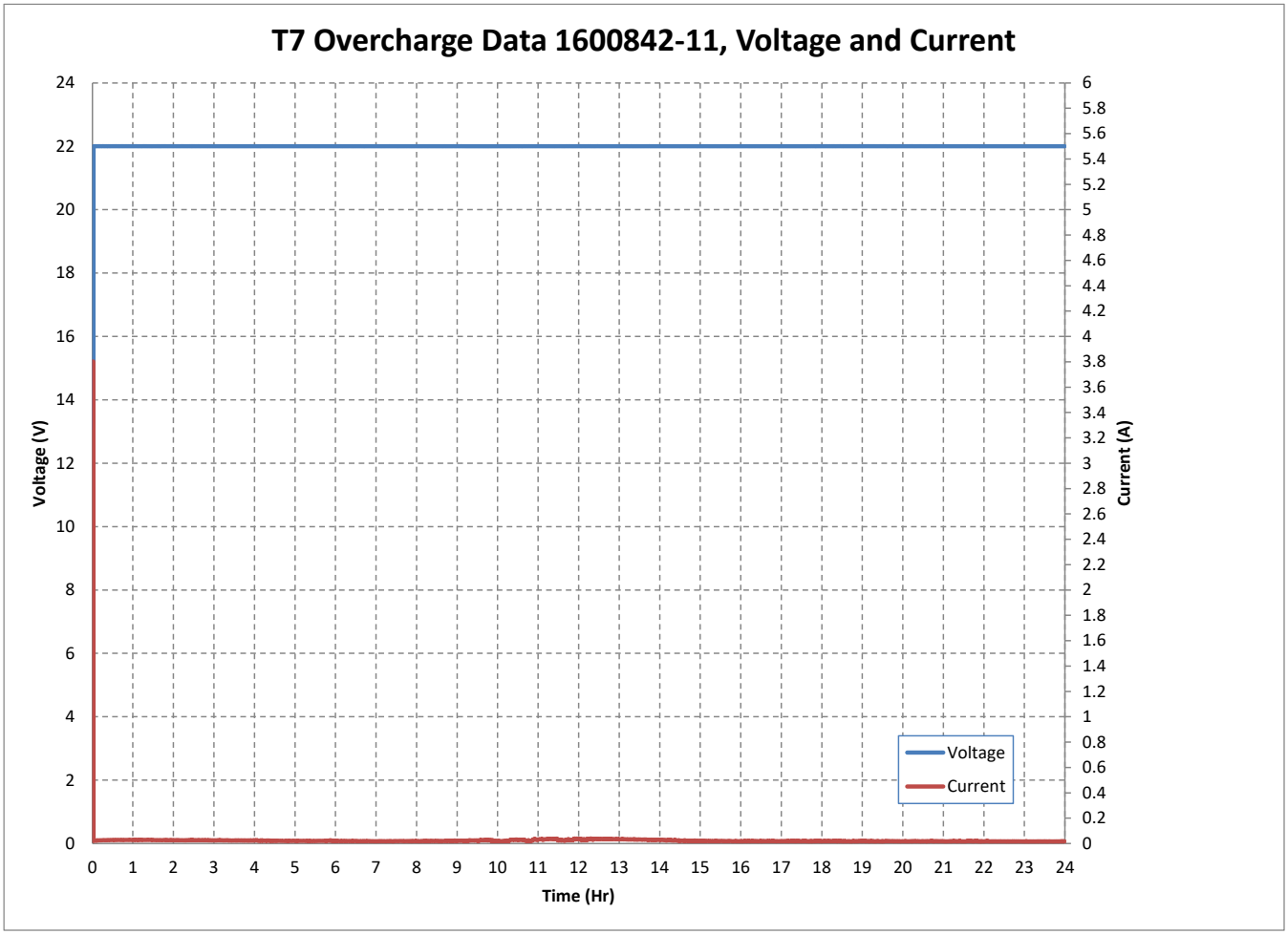
For this test, the outside temperature of the pack is stabilized at 57±4°C. It is then short-circuited at its terminals using a resistance of less than 100mΩ for 1 hour. This example shows the pack immediately prevented itself from being shorted (as the voltage dropped to zero).

All of the packs that were tested did not reach an external case temperature of 58°C.



A-5. T7: Overcharge Data

For this test, data were collected using a DC power supply with a serial port connection. The output was set at 22V and 3.8 amps. Scanning was done every 15 seconds for 24 hrs.



APPENDIX B
Test Photographs

Figure B-1: Samples in the Altitude Chamber (T1)

Figure B-2: Samples in the Environmental Chamber (T2)

Figure B-3: Samples on the Vibration Table (T3)

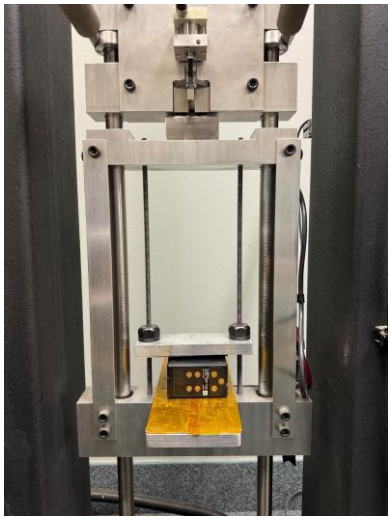


Figure B-4: Sample on the Shock Tower (T4)

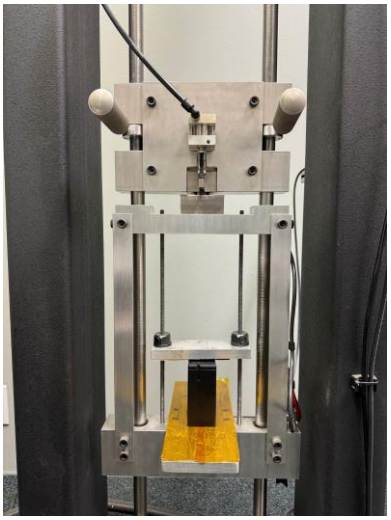


Figure B-5: Sample on the Shock Tower (T4)

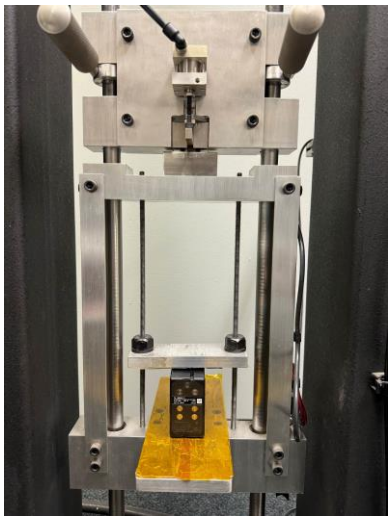


Figure B-6: Sample on the Shock Tower (T4)

Figure B-7: Sample during Short Circuit Test (T5)

Figure B-8: Sample during Overcharge (T7)