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Deutsche Akkreditierungsstelle GmbH
as test laboratory

DAkkS Deutsche Akkreditierungsstelle D-PL-20132-01-00

TEST REPORT

Test report no.: BU-2018-09329-2-B1 Date of issue: June 14, 2018

Test laboratory:	Batteryuniversity GmbH Am Sportplatz 30 63791 Karlstein am Main Germany
Customer:	BMZ Batterie-Montage-Zentrum GmbH Am Sportplatz 28 63791 Karlstein am Main Germany
Applied standard(s):	UN ST/SG/AC.10/11/Rev.6, Corr.1 Recommendations on the TRANSPORT OF DANGEROUS GOODS Manual of Tests and Criteria, Part III, section 38.3, Lithium metal and lithium ion batteries
Description of devices under test (DUT):	Lithium-ion batteries 5S1P ICR18650HD2 (18.25 V / 2.0 Ah / 36.5 Wh)
Manufacturer:	Husqvarna AB Drottningsgatan 2 56182 Huskvarna Sweden
DUTs received on:	April 06, 2018
Result:	All performed tests were passed.
Additions:	This test report contains the result of a singular investigation carried out on the DUTs submitted. This report shall not be reproduced, except in full, without the written approval of the Batteryuniversity GmbH. Test reports without signature are not valid.

Test report written by:
Matthias Klement
Test Engineer
Date: June 11, 2018 Signature:

Test report approved by:
Dominik Hennefeld
Laboratory Manager
Date: June 13, 2018 Signature:

Table of Contents

1. Test documentation

Customer:	BMZ Batterie-Montage-Zentrum GmbH Am Sportplatz 28 63791 Karlstein am Main Germany
Applied standard(s):	UN ST/SG/AC.10/11/Rev.6, Corr.1 Recommendations on the TRANSPORT OF DANGEROUS GOODS Manual of Tests and Criteria, Part III, section 38.3, Lithium metal and lithium ion batteries
Performed tests:	Conditioning T.1 Altitude simulation T.2 Thermal test T.3 Vibration T.4 Shock T.5 External short circuit T.7 Overcharge
Executing test laboratory:	Batteryuniversity GmbH Am Sportplatz 30 63791 Karlstein am Main Germany
DUTs received on:	April 06, 2018
Total test duration:	12.04.2018 – 30.05.2018

2. Description of DUTs

2.1 Technical data

Designation of specimens:	Lithium Ion Battery
Manufacturer:	Husqvarna AB Drottningsgatan 2 56182 Huskvarna
Configuration / cell type:	5S1P ICR18650HD2
Nominal capacity:	2.0 Ah
Nominal voltage:	18.25 V
Charge end voltage:	21.0 V
Discharge end voltage:	14.5 V
Dimensions:	Not transmitted
Weight:	366 g
Software status: (if transmitted)	Not transmitted
Hardware status: (if transmitted)	Not transmitted

2.2 Receiving inspection

Figure 1: Receiving inspection – front view

Figure 2: Receiving inspection – back view

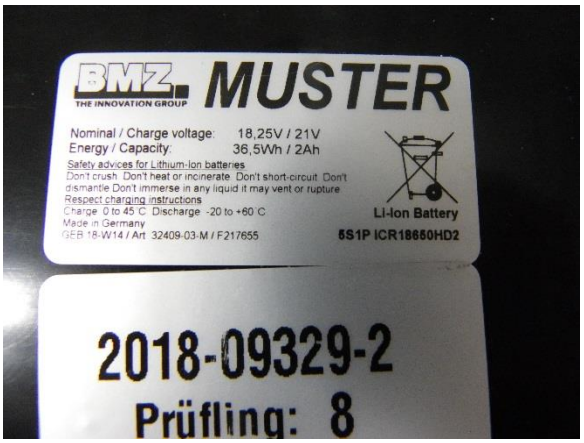


Figure 3: Receiving inspection – label

Figure 4: Receiving inspection – test identification label

Test result:
All DUTs were delivered in good order and condition.
Opinions and interpretations:
Comment(s):

Testing conducted:			
Person in charge:	Hans-Peter Grimm	Date:	April 10, 2018

3. Testing

3.1 Scope

UN Manual of Tests and Criteria, Part III, section 38.3, Lithium metal and lithium ion batteries (ST/SG/AC.10/11/Rev.6, Corr.1)

All cell types shall be subjected to test T.1 to T.6 and T.8.All non-rechargeable battery types, including those composed of previously tested cells shall be subjected to tests T.1 to T.5.All rechargeable battery types, including those composed of previously tested cells shall be subjected to tests T.1 to T.5 and T.7. In addition, rechargeable single cell batteries with overcharge protection shall be subjected to test T.7. A component call that is not transported separately from the battery it is a part of needs only be tested according to tests T.6 and T.8. A component cell that is transported separately from the battery shall be subjected to the tests T.1 to T.6 and T.8.

3.2 Procedure

Tests T.1 to T.5 shall be conducted in sequence on the same battery. Test T.6 and T.8 shall be conducted using not otherwise tasted cells or batteries. T.7 may conducted using undamaged batteries previously used in tests T.1 to T.5 for purposes of testing cycled batteries.

3.3 Test matrix

The following test matrix gives an overview which DUT was part of which partial test and its corresponding evaluation.

Partial test	2018-09329-2							
	1	2	3	4	5	6	7	8
Conditioning	X	X	X	X	X	X	X	X
T.1 Altitude simulation	X	X	X	X	X	X	X	X
T.2 Thermal test	X	X	X	X	X	X	X	X
T.3 Vibration	X	X	X	X	X	X	X	X
T.4 Shock	X	X	X	X	X	X	X	X
T.5 External short circuit	X	X	X	X	X	X	X	X
T.7 Overcharge	X	X	X	X	X	X	X	X

Legend:
X = part of partial test, result passed
X = part of partial test, result failed
O = part of partial test, result has to be evaluated by the customer

3.4 Conditioning

Conditioning according to:				
ST/SG/AC.10/11/Rev.6, Corr.1, UN Manual of Tests and Criteria, Part III, section 38.3.3				
Purpose of conditioning:				
When a cell or battery type is to be tested under this subsection, the cell or battery has to be conditioned as specified in the test procedure.				
Test procedure:				
DUT no.	Number of cycles	State of charge after conditioning	Test equipment used	
2018-09329-2 DUT 1	1	100 %	Ser. No.:	331400384
			Inv. no.:	00266
2018-09329-2 DUT 2	1	100 %	Ser. No.:	331400383
			Inv. no.:	00268
2018-09329-2 DUT 3	1	100 %	Ser. No.:	331400381
			Inv. no.:	00269
2018-09329-2 DUT 4	1	100 %	Ser. No.:	331400372
			Inv. no.:	00270
2018-09329-2 DUT 5	50	100 %	Ser. No.:	331400384
			Inv. no.:	00266
2018-09329-2 DUT 6	50	100 %	Ser. No.:	331400383
			Inv. no.:	00268
2018-09329-2 DUT 7	50	100 %	Ser. No.:	331400381
			Inv. no.:	00269
2018-09329-2 DUT 8	50	100 %	Ser. No.:	331400372
			Inv. no.:	00270
Temperature:	20 ± 5 °C			
Test equipment used:				
Battery test device(s):				
Type:	ATGB1200	Serial no.:	see above	
Manufacturer:	Batteryuniversity GmbH	Inventory no.:	see above	
Last calibration:	May 17, 2017			

Conditioning result:			
Test requirements:	☒ passed	☐ failed	☐ applied

Opinions and interpretations:
Comment(s):

Conditioning conducted:			
Person in charge:	Hans-Peter Grimm	Date:	April 12, 2018

Test protocol:

Test #0: Cycling of batteries

Sample no.	No. of cycles / state	Test Parameter												
		U / V					*m* / g				No venting	No dis-assembly	No rupture	No fire	Result
		Before test	After test	Max. loss [%]	Calc. value [%]	Result	Before test	After test	Max. loss [%]	Result					
1	1st / fully charged	N/A	20,00				377,79	377,81		Passed	Passed	Passed	Passed	Passed	Passed
2	1st / fully charged	N/A	20,13				377,18	377,20		Passed	Passed	Passed	Passed	Passed	Passed
3	1st / fully charged	N/A	20,05				377,71	377,73		Passed	Passed	Passed	Passed	Passed	Passed
4	1st / fully charged	N/A	20,06				377,51	377,52		Passed	Passed	Passed	Passed	Passed	Passed
									0,1						
5	50th/ fully charged	N/A	20,01				377,71	377,73		Passed	Passed	Passed	Passed	Passed	Passed
6	50th/ fully charged	N/A	20,63				378,30	378,32		Passed	Passed	Passed	Passed	Passed	Passed
7	50th/ fully charged	N/A	19,96				378,15	378,17		Passed	Passed	Passed	Passed	Passed	Passed
8	50th/ fully charged	N/A	20,07				377,34	377,34		Passed	Passed	Passed	Passed	Passed	Passed

Measurement equipment:		
Reference	Equipment no.	Last calibration
Scale	00019	February, 2018
Digital multimeter	00092	May, 2017

Partial test result: Passed

*Max. mass loss:
M < 1 g: 0,5%, 1 g <= M <= 75 g: 0,2 %, M > 75 g: 0,1 %

Date: April 18, 2018 Person in charge: Hans-Peter Grimm Signature:

Protocol 1: Conditioning

3.5 T.1 Altitude simulation

Methods of measurement according to:			
ST/SG/AC.10/11/Rev.6, Corr.1, UN Manual of Tests and Criteria, Part III, section 38.3.4.1			
Purpose of conditioning:			
This test simulates air transport under low-pressure conditions.			
Test procedure:			
Absolut atmospheric pressure:	11.6 kPa		
Temperature:	20 ± 5 °C		
Test duration:	6 h		
Devices under test:	2018-09329-2 DUT 1 – DUT 8		
Test equipment used:			
Altitude simulation chamber			
Type:	VO 500	Serial no.:	S507.0017
Manufacturer:	Memmert GmbH + Co. KG	Inventory no.:	00047
Last calibration:	January 31, 2018		
Vacuum pump			
Type:	PM 500	Serial no.:	T507.0006
Manufacturer:	Memmert GmbH + Co. KG	Inventory no.:	00048
Last calibration:	January 29, 2018		
Scale			
Type:	KB2400-2N	Serial no.:	W093485
Manufacturer:	Kern & Sohn GmbH	Inventory no.:	00019
Last calibration:	February 02, 2018		
Digital Multimeter			
Type:	Metrahit Extra	Serial no.:	SJ4106
Manufacturer:	Gossen Metrawatt	Inventory no.:	00092
Last calibration:	May 14, 2018		

Test result:			
Test requirements:	☒ passed	☐ failed	☐ applied
Opinions and interpretations:			
Comment(s):			
Testing conducted:			
Person in charge:	Hans-Peter Grimm	Date:	April 18, 2018

Pictures test setup:

Figure 5: Altitude simulation chamber

Figure 6: DUT inside altitude simulation chamber

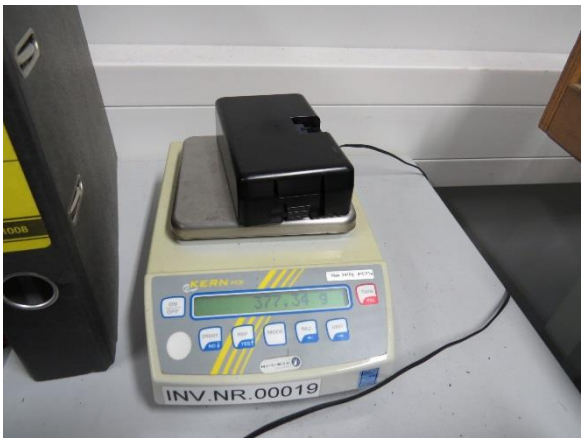


Figure 7: Scale

Figure 8: DMM

Temperature & Pressure diagram:

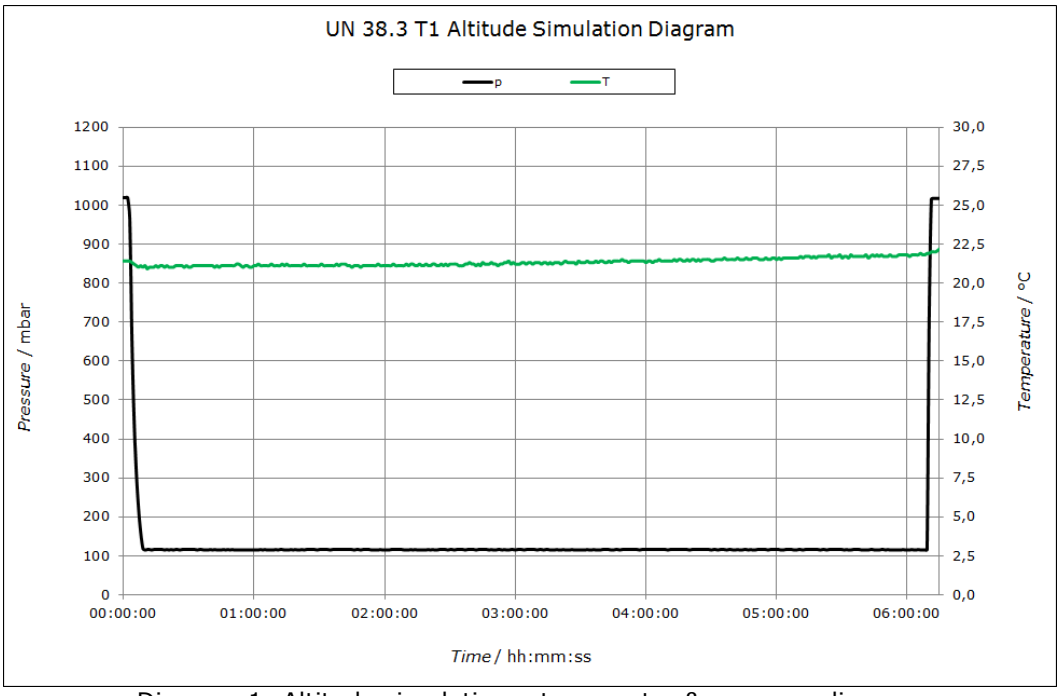


Diagram 1: Altitude simulation – temperatur & pressure diagram

Test protocol:

Test #1: Altitude Simulation (11.6 kPa, 6 h)

Sample no.	No. of cycles / state	Test Parameter													
		U / V					*m* / g				No venting	No dis-assembly	No rupture	No fire	Result
		Before test	After test	Max. loss [%]	Calc. value [%]	Result	Before test	After test	Max. loss [%]	Result					
1	1st / fully charged	20,00	20		0	Passed	377,81	377,77		Passed	Passed	Passed	Passed	Passed	Passed
2	1st / fully charged	20,13	20,13		0	Passed	377,20	377,17		Passed	Passed	Passed	Passed	Passed	Passed
3	1st / fully charged	20,05	20,05		0	Passed	377,73	377,69		Passed	Passed	Passed	Passed	Passed	Passed
4	1st / fully charged	20,06	20,06		0	Passed	377,52	377,49		Passed	Passed	Passed	Passed	Passed	Passed
				10					**0,1**						
5	50th/ fully charged	20,01	20,01		0	Passed	377,73	377,67		Passed	Passed	Passed	Passed	Passed	Passed
6	50th/ fully charged	20,63	20,62		0,0485	Passed	378,32	378,29		Passed	Passed	Passed	Passed	Passed	Passed
7	50th/ fully charged	19,96	19,95		0,0501	Passed	378,17	378,15		Passed	Passed	Passed	Passed	Passed	Passed
8	50th/ fully charged	20,07	20,07		0	Passed	377,34	377,33		Passed	Passed	Passed	Passed	Passed	Passed

Measurement equipment:		
Reference	Equipment no.	Last calibration
Altitude chamber	00047	January, 2018
Scale	00019	February, 2018
Digital multimeter	00092	May, 2017

Partial test result: Passed

*Max. mass loss:

M < 1 g: 0,5%, 1 g <= M <= 75 g: 0,2 %, M > 75 g: 0,1 %

Date: April 18, 2018 Person in charge: Hans-Peter Grimm Signature:

Protocol 2: Altitude simulation

3.6 T.2 Thermal test

Methods of measurement according to:			
ST/SG/AC.10/11/Rev.6, Corr.1, UN Manual of Tests and Criteria, Part III, section 38.3.4.2			
Purpose of test:			
This test assesses cell and battery seal integrity and internal electrical connections. The test is conducted using rapid and extreme temperature changes.			
Test procedure:			
Temperature min:	- 40 ± 2 °C		
Temperature max:	+ 72 ± 2 °C		
Maximum time interval between test temperature extremes:	0.5 h		
Storage time at each temperature:	6 h		
Number of cycles:	10		
Devices under test:	2018-09329-2 DUT 1 – DUT 8		
Test equipment used:			
Climatic test chamber			
Type:	EGNZ-12-7.5CWL	Serial no.:	179289
Manufacturer:	ESPEC	Inventory no.:	00054
Last calibration:	January 24, 2017		
Scale			
Type:	KB2400-2N	Serial no.:	W093485
Manufacturer:	Kern & Sohn GmbH	Inventory no.:	00019
Last calibration:	February 02, 2018		
Digital Multimeter			
Type:	Metrahit Extra	Serial no.:	SJ4106
Manufacturer:	Gossen Metrawatt	Inventory no.:	00092
Last calibration:	May 14, 2018		
Test result:			
Test requirements:	☒ passed	☐ failed	☐ applied

Opinions and interpretations:			
Comment(s):			
Testing conducted:			
Person in charge:	Hans-Peter Grimm	Date:	Month dd, yyyy

Pictures test setup:	
 Figure 9: Climatic test chamber	 Figure 10: DUT inside climatic test chamber

Temperature diagram:

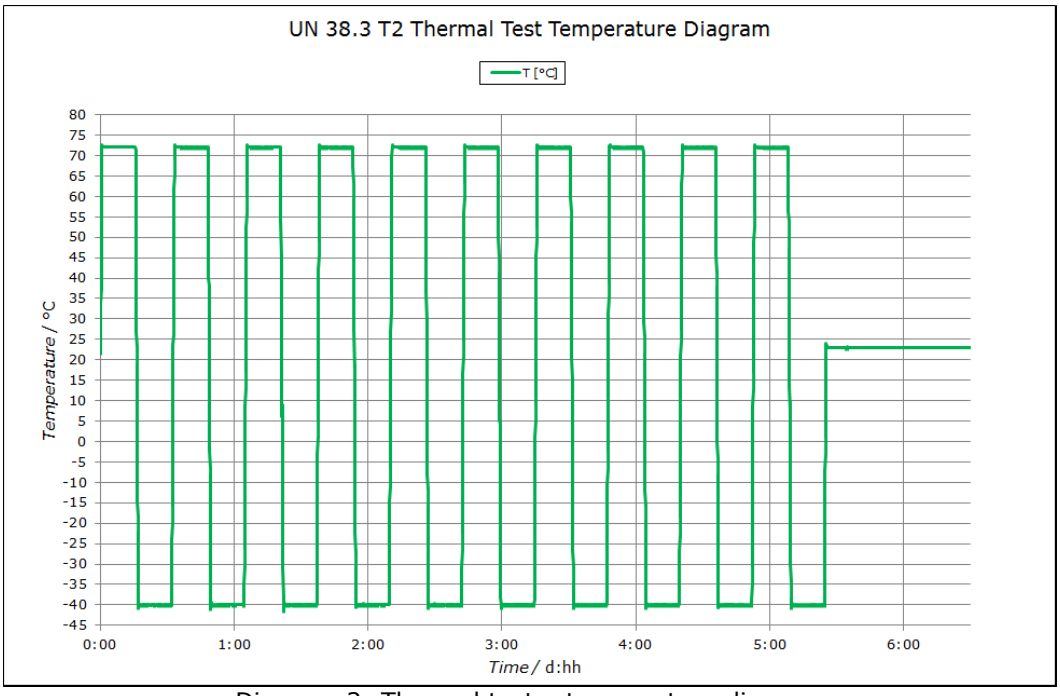


Diagram 2: Thermal test – temperature diagram

Test protocol:

Test #2: Thermal Test (+75 °C / -40 °C, 10 cycles, 6 h at each temperature)

Sample no.	No. of cycles / state	Test Parameter													
		U / V					*m* / g				No venting	No dis-assembly	No rupture	No fire	Result
		Before test	After test	Max. loss [%]	Calc. value [%]	Result	Before test	After test	Max. loss [%]	Result					
1	1st / fully charged	20	19,79		1,05	Passed	377,77	377,77		Passed	Passed	Passed	Passed	Passed	Passed
2	1st / fully charged	20,13	19,9		1,1426	Passed	377,17	377,17		Passed	Passed	Passed	Passed	Passed	Passed
3	1st / fully charged	20,05	19,83		1,0973	Passed	377,69	377,69		Passed	Passed	Passed	Passed	Passed	Passed
4	1st / fully charged	20,06	19,83		1,1466	Passed	377,49	377,48		Passed	Passed	Passed	Passed	Passed	Passed
				10					**0,1**						
5	50th/ fully charged	20,01	19,8		1,0495	Passed	377,67	377,68		Passed	Passed	Passed	Passed	Passed	Passed
6	50th/ fully charged	20,62	20,29		1,6004	Passed	378,29	378,29		Passed	Passed	Passed	Passed	Passed	Passed
7	50th/ fully charged	19,95	19,74		1,0526	Passed	378,15	378,14		Passed	Passed	Passed	Passed	Passed	Passed
8	50th/ fully charged	20,07	19,84		1,146	Passed	377,33	377,31		Passed	Passed	Passed	Passed	Passed	Passed

Measurement equipment:		
Reference	Equipment no.	Last calibration
Climatic test chamber	00054	January, 2018
Scale	00019	February, 2018
Digital multimeter	00092	May, 2017

Partial test result: Passed

*Max. mass loss:

M < 1 g: 0,5%, 1 g <= M <= 75 g: 0,2 %, M > 75 g: 0,1 %

Date: April 25, 2018 Person in charge: Hans-Peter Grimm Signature:

Protocol 3: Thermal test

3.7 T.3 Vibration

Methods of measurement according to:			
ST/SG/AC.10/11/Rev.6, Corr.1, UN Manual of Tests and Criteria, Part III, section 38.3.4.3			
Purpose of test:			
This test simulates vibration during transport.			
Test procedure:			
Wave form:	Sinusoidal		
Logarithmic frequency sweep:	Frequency:	Peak acceleration / amplitude:	
	7 Hz – 18 Hz	1 g_n	
	18 Hz – 50 Hz	0.8 mm	
	50 Hz – 200 Hz	8 g_n	
Number of sweeps per axis: (7 Hz – 200 Hz – 7 Hz)	12		
Number of axis to be tested:	3 mutually perpendicular mounting positions of the cell (one must be perpendicular to the terminal face).		
Temperature:	20 ± 5 °C (RT)		
Test time each axis:	3 h		
Total test duration:	9 h		
Devices under test:	2018-09329-2 DUT 1 – DUT 8		
Test equipment used:			
Electrodynamic test system			
Type:	SW2-2320	Serial no.:	15489
Manufacturer:	RMS	Inventory no.:	00021
Last calibration:	January 16, 2018		
Acceleration sensor – mounted on slip table			
Type:	353B34	Serial no.:	132461
Manufacturer:	PCB Piezotronics	Inventory no.:	00025
Last calibration:	November 29, 2017		
Acceleration sensor – mounted on DUT/fixture			
Type:	356B21	Serial no.:	91237
Manufacturer:	PCB Piezotronics	Inventory no.:	00024
Last calibration:	November 29, 2017		

Scale			
Type:	KB2400-2N	Serial no.:	W093485
Manufacturer:	Kern & Sohn GmbH	Inventory no.:	00019
Last calibration:	February 02, 2018		
Digital Multimeter			
Type:	Metrahit Extra	Serial no.:	SJ4106
Manufacturer:	Gossen Metrawatt	Inventory no.:	00092
Last calibration:	May 14, 2018		
Test result:			
Test requirements:	☒ passed	☐ failed	☐ applied
Opinions and interpretations:			
Comment(s):			
Testing conducted:			
Person in charge:	Hans-Peter Grimm	Date:	April 30, 2018 – May 03, 2018

Pictures test setup:

Figure 11: Electrodynamic test system

Figure 12: DUT – fitted towards X-direction

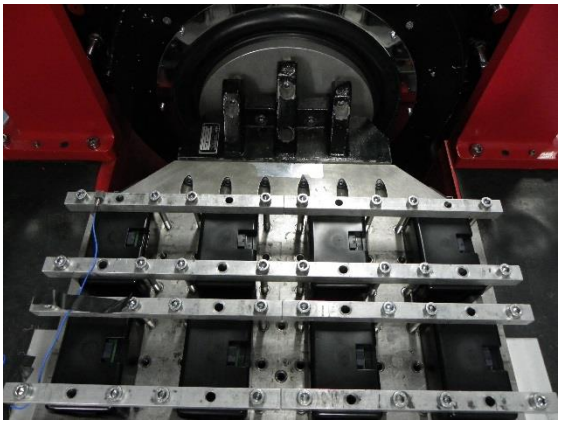


Figure 13:DUT – fitted towards Y-direction

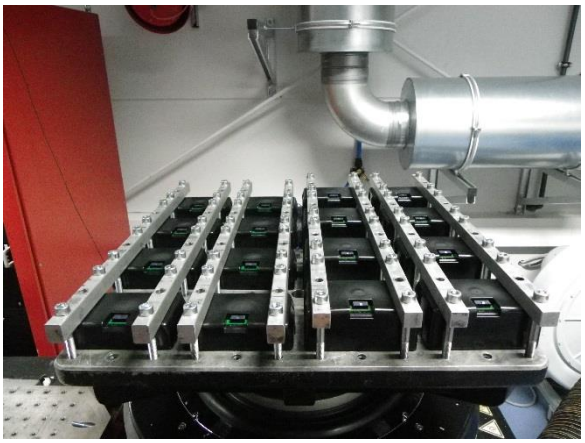


Figure 14: DUT – fitted towards Z-direction

Vibration diagram X-direction:

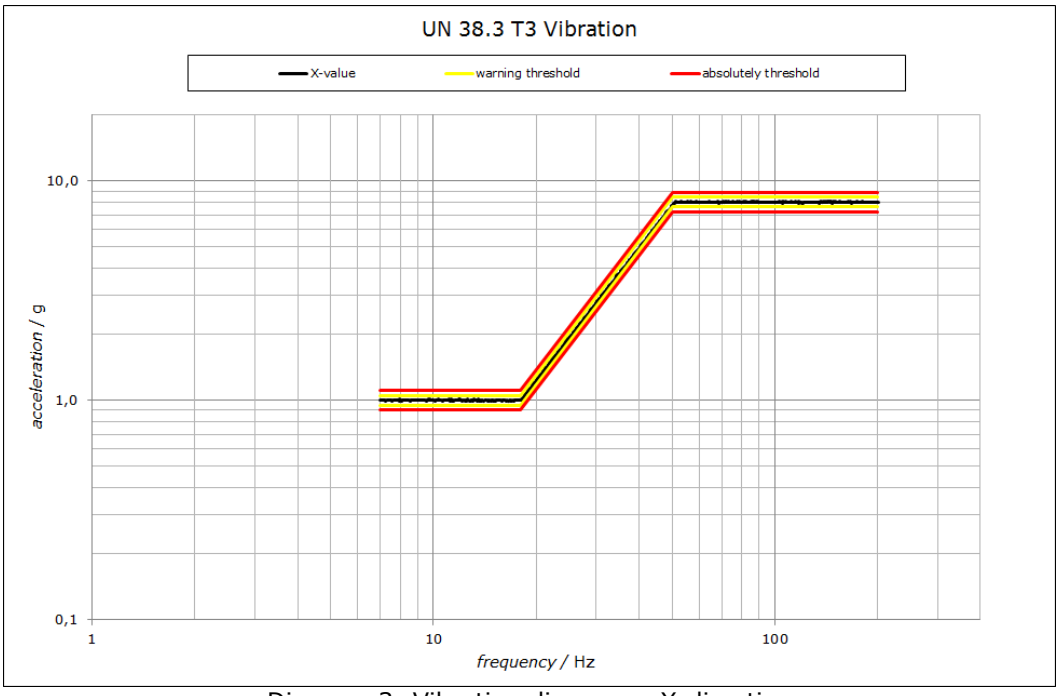


Diagram 3: Vibration diagram – X-direction

Vibration diagram Y-direction:

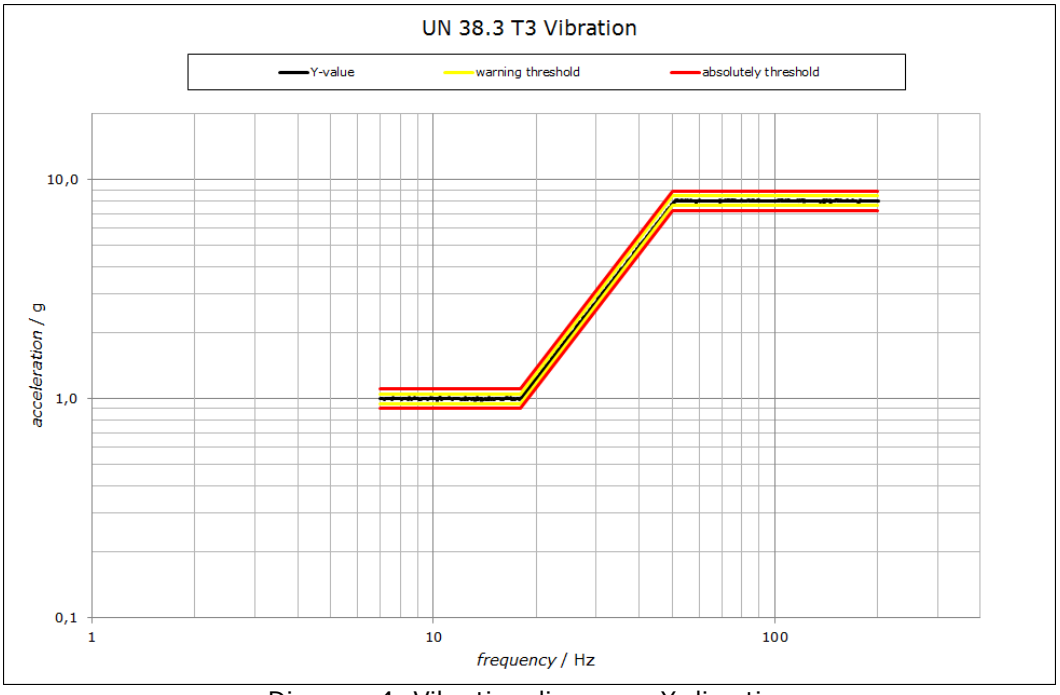


Diagram 4: Vibration diagram – Y-direction

Vibration diagram Z-direction:

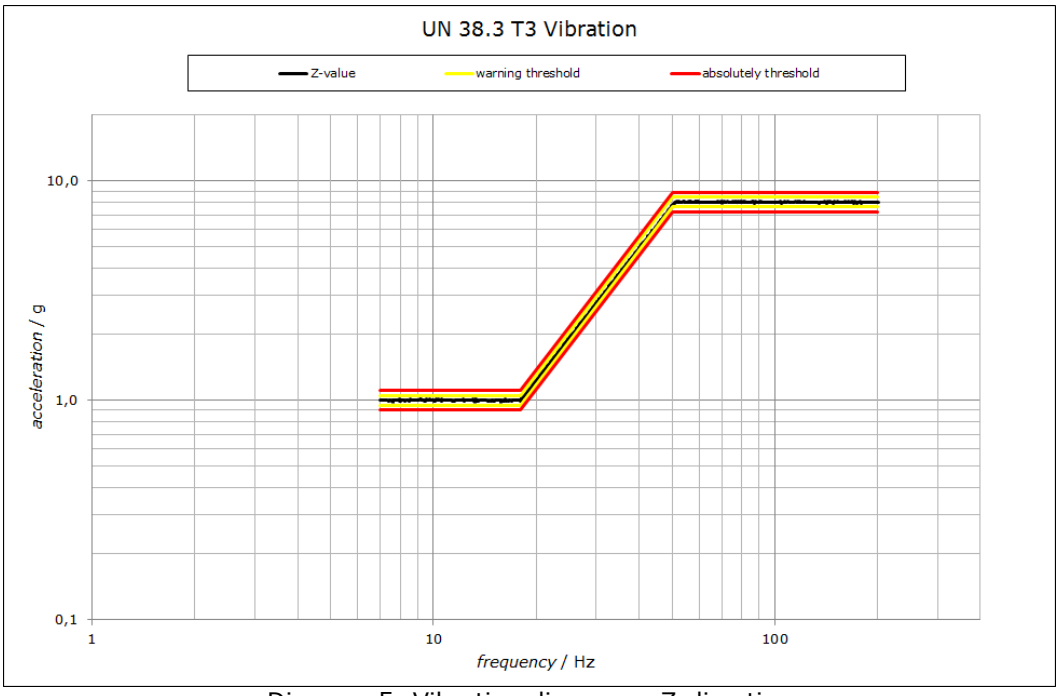


Diagram 5: Vibration diagram – Z-direction

Test protocol:

Test #3: Vibration (sinusoidal sweep, 7 - 200 Hz, 8 g, 9 h total)

Sample no.	No. of cycles / state	Test Parameter													
		U / V					*m* / g				No venting	No dis-assembly	No rupture	No fire	Result
		Before test	After test	Max. loss [%]	Calc. value [%]	Result	Before test	After test	Max. loss [%]	Result					
1	1st / fully charged	19,79	19,77		0,1011	Passed	377,77	377,77		Passed	Passed	Passed	Passed	Passed	Passed
2	1st / fully charged	19,9	19,88		0,1005	Passed	377,17	377,17		Passed	Passed	Passed	Passed	Passed	Passed
3	1st / fully charged	19,83	19,81		0,1009	Passed	377,69	377,68		Passed	Passed	Passed	Passed	Passed	Passed
4	1st / fully charged	19,83	19,81		0,1009	Passed	377,48	377,49		Passed	Passed	Passed	Passed	Passed	Passed
				10					**0,1**						
5	50th/ fully charged	19,8	19,78		0,101	Passed	377,68	377,68		Passed	Passed	Passed	Passed	Passed	Passed
6	50th/ fully charged	20,29	20,26		0,1479	Passed	378,29	378,28		Passed	Passed	Passed	Passed	Passed	Passed
7	50th/ fully charged	19,74	19,72		0,1013	Passed	378,14	378,13		Passed	Passed	Passed	Passed	Passed	Passed
8	50th/ fully charged	19,84	19,82		0,1008	Passed	377,31	377,31		Passed	Passed	Passed	Passed	Passed	Passed

Measurement equipment:		
Reference	Equipment no.	Last calibration
Dynamic test system	00021	January, 2018
Sensor slip table	00025	November, 2017
Sensor head expander	00024	November, 2017
Sensor on DUT	00024	November, 2017
Scale	00019	February 2018
Digital multimeter	00092	May, 2017

Partial test result: Passed

*Max. mass loss:

M < 1 g: 0,5%, 1 g <= M <= 75 g: 0,2 %, M > 75 g: 0,1 %

Date: May 3, 2018 Person in charge: Hans-Peter Grimm Signature:

Protocol 4: Vibration simulation

3.8 T.4 Shock

Methods of measurement according to:			
ST/SG/AC.10/11/Rev.6, Corr.1, UN Manual of Tests and Criteria, Part III, section 38.3.4.4			
Purpose of test:			
This test assesses the robustness of cells and batteries against cumulative shocks.			
Test procedure:			
Wave form:	Half-sine		
Peak acceleration:	150 g_n or result of formula: $Accel.(g_n) = \sqrt{\left(\frac{100850}{mass\,[kg]}\right)}$ whichever is smaller	150 g_n	
Pulse duration:	6 ms		
Number of shocks per half-axis:	3		
Number of axis to be tested:	6 half-axis (3 in the positive direction and 3 in the negative direction)		
Total number of shocks:	18		
Temperature:	23 ± 3 °C (RT)		
Devices under test:	2018-09329-2 DUT 1 – DUT 8		
Test equipment used:			
Shock test system			
Type:	886	Serial no.:	938.70
Manufacturer:	MTS	Inventory no.:	00022
Last calibration:	January 16, 2018		
Acceleration sensor – mounted on shock table			
Type:	353C03	Serial no.:	86584
Manufacturer:	PCB Piezotronics	Inventory no.:	00039
Last calibration:	November 29, 2017		
Scale			
Type:	KB2400-2N	Serial no.:	W093485
Manufacturer:	Kern & Sohn GmbH	Inventory no.:	00019
Last calibration:	February 02, 2018		

Digital Multimeter			
Type:	Metrahit Extra	Serial no.:	SJ4106
Manufacturer:	Gossen Metrawatt	Inventory no.:	00092
Last calibration:	May 14, 2018		
Test result:			
Test requirements:	☒ passed	☐ failed	☐ applied
Opinions and interpretations:			
Comment(s):			
Testing conducted:			
Person in charge:	Hans-Peter Grimm	Date:	May 09, 2018 – May 11, 2018

Pictures test setup:

Figure 15: Shock test system

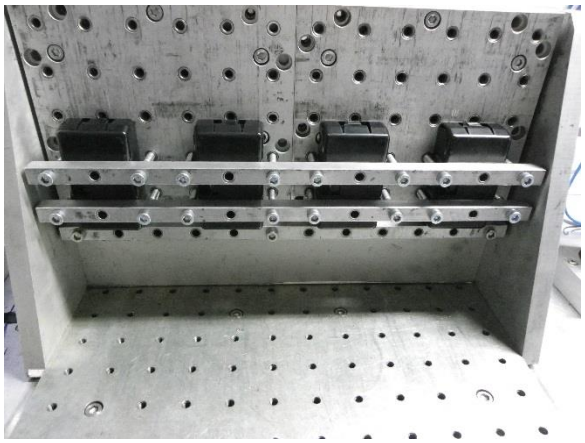


Figure 16: DUT – fitted towards +X-direction

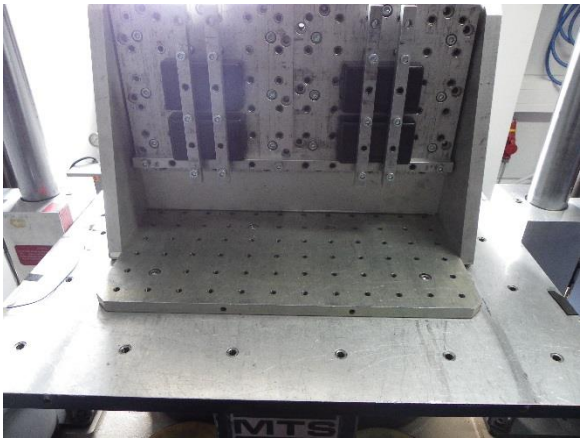


Figure 17: DUT – fitted towards +Y-direction

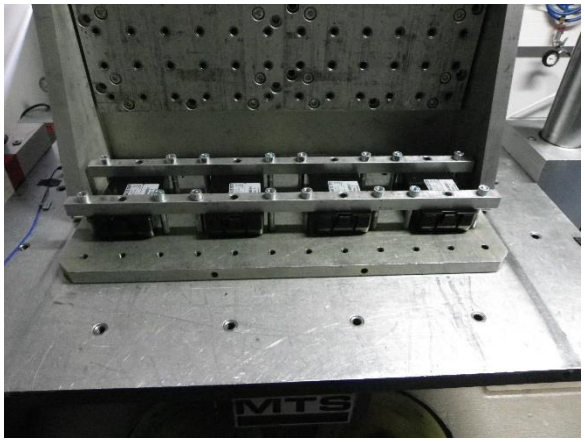


Figure 18: DUT – fitted towards +Z-direction

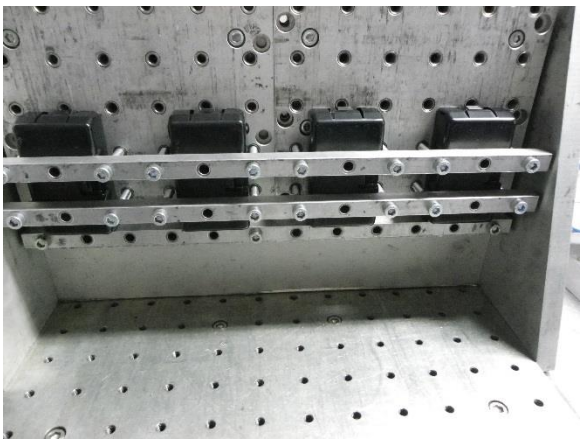


Figure 19: DUT – fitted towards -X-direction

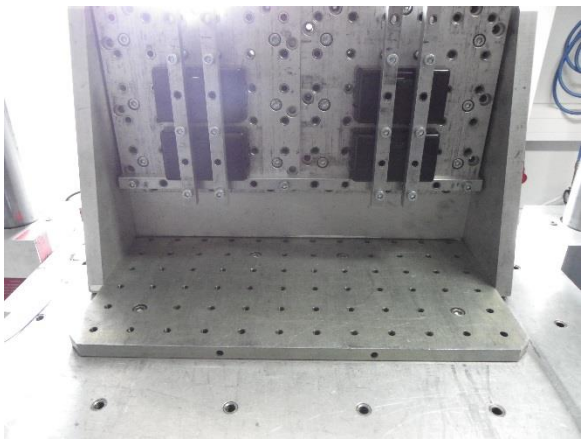
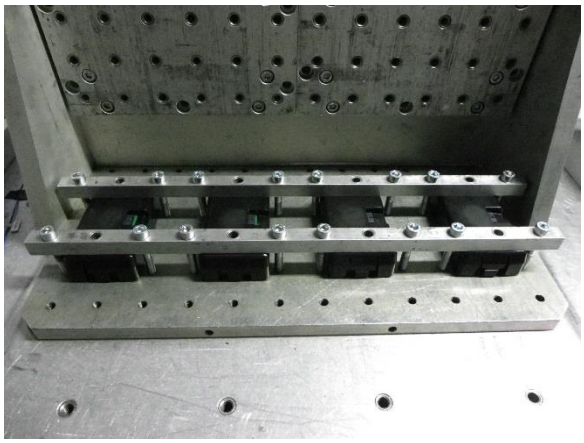
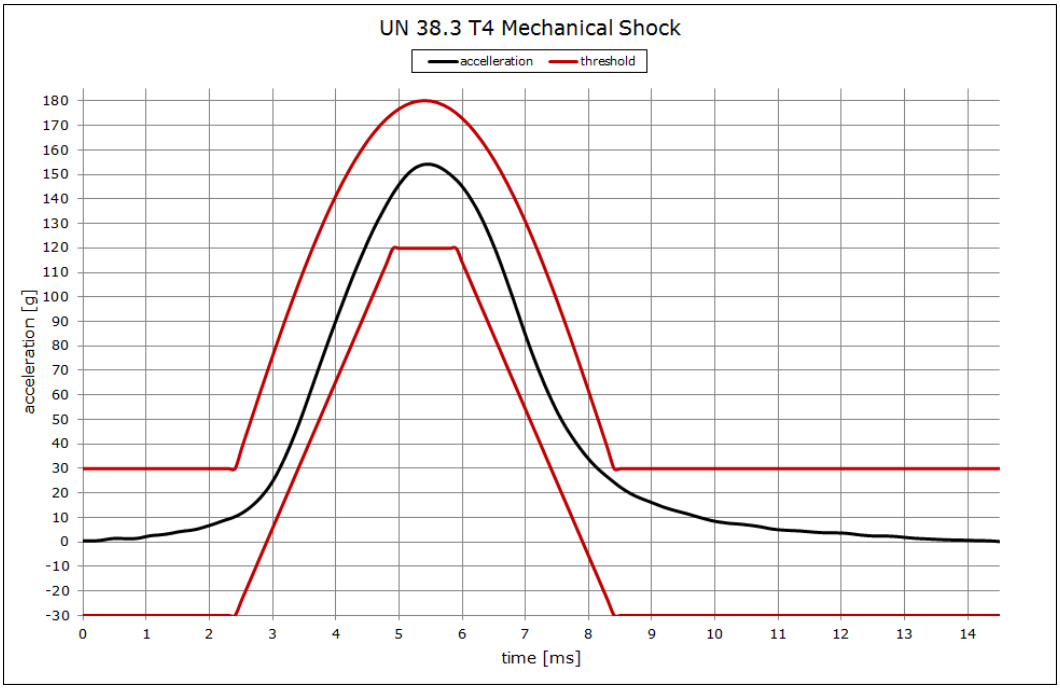


Figure 20: DUT – fitted towards –Y-direction

Pictures test setup:	
 Figure 21: DUT – fitted towards –Z-direction	

Shock diagram +X-direction:
 Diagram 6: Shock diagram – +X-direction

Shock diagram +Y-direction:

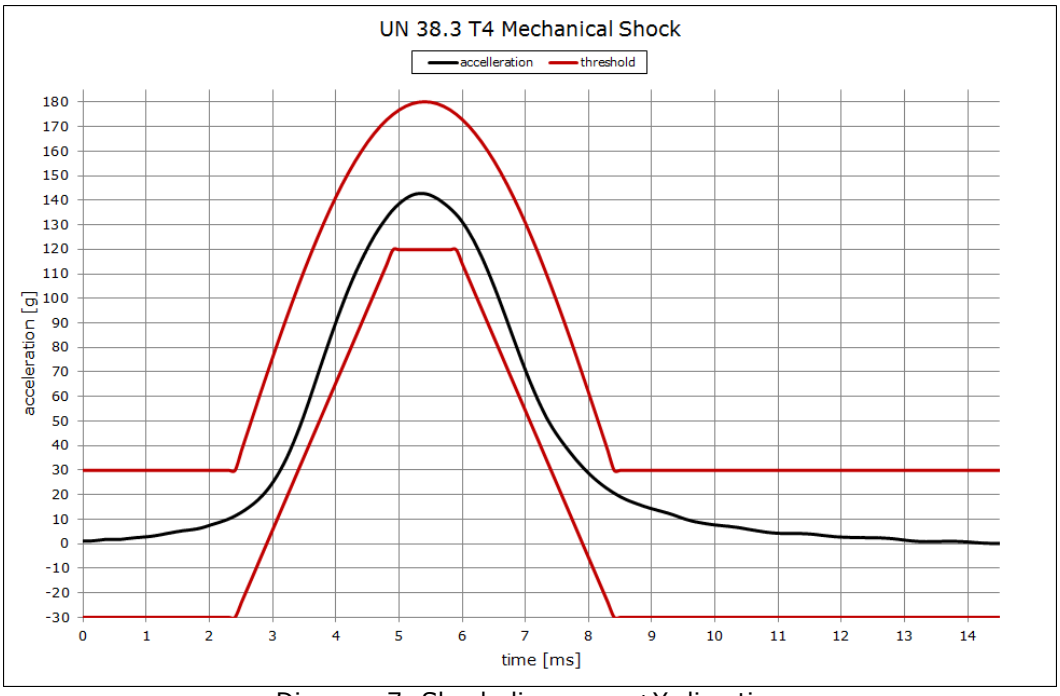


Diagram 7: Shock diagram – +Y-direction

Shock diagram +Z-direction:

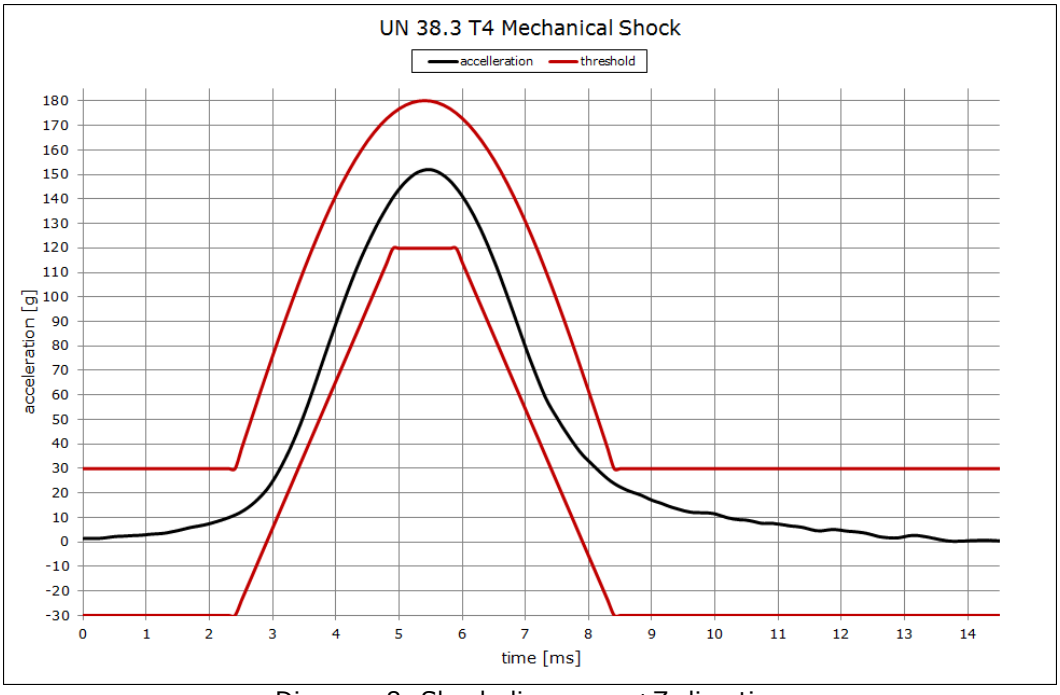


Diagram 8: Shock diagram – +Z-direction

Shock diagram -X-direction:

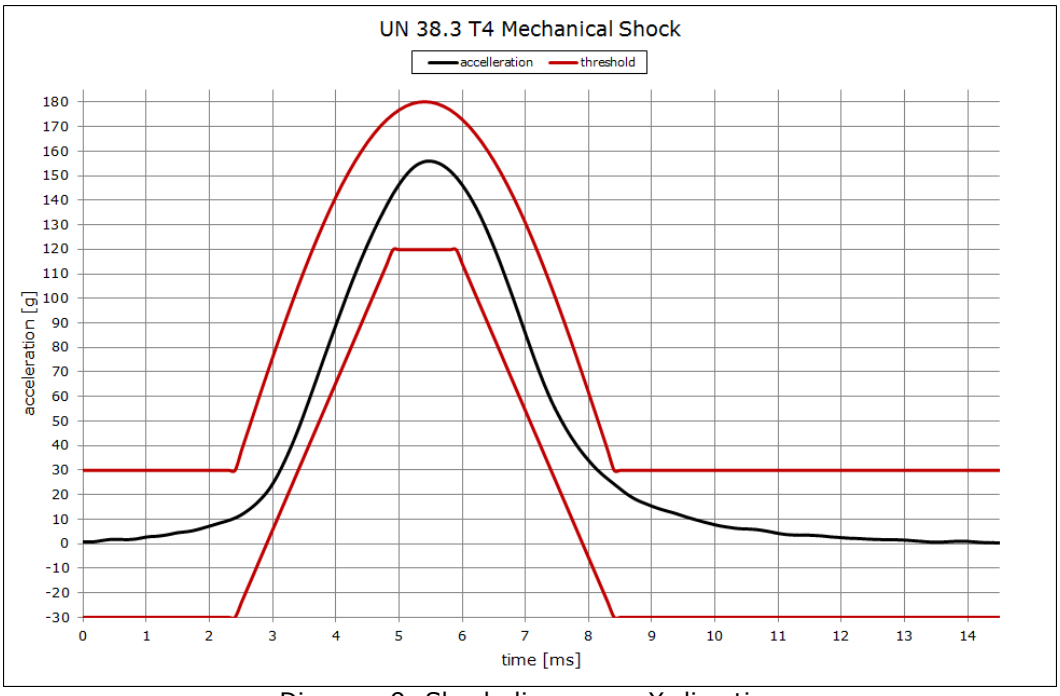


Diagram 9: Shock diagram – -X-direction

Shock diagram -Y-direction:

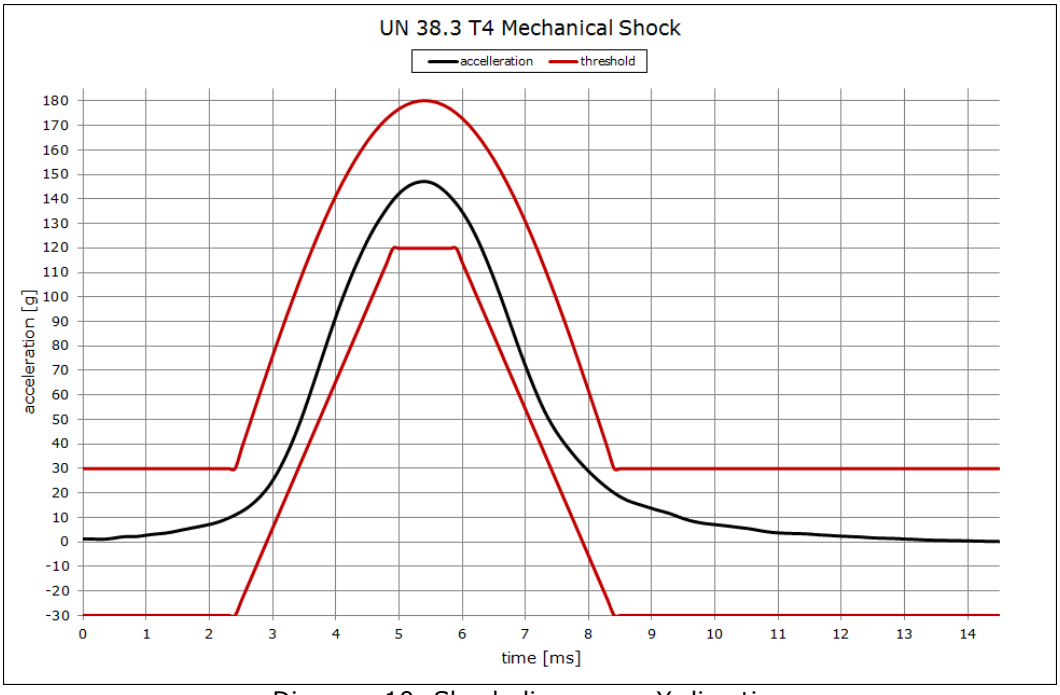


Diagram 10: Shock diagram – -Y-direction

Shock diagram -Z-direction:

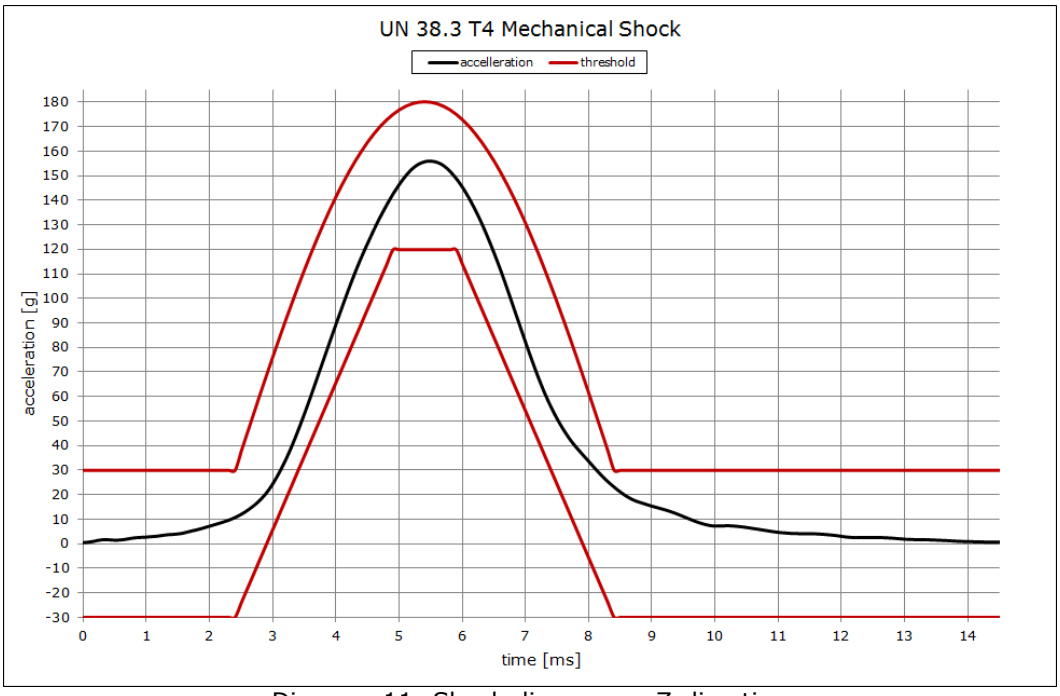


Diagram 11: Shock diagram – -Z-direction

Test protocol:

Test #4: Shock (half-sine, 6 ms, 18 shocks total)

Sample no.	No. of cycles / state	Test Parameter													
		U / V					*m* / g				No venting	No dis-assembly	No rupture	No fire	Result
		Before test	After test	Max. loss [%]	Calc. value [%]	Result	Before test	After test	Max. loss [%]	Result					
1	1st / fully charged	19,77	19,75		0,1012	Passed	377,77	377,78		Passed	Passed	Passed	Passed	Passed	Passed
2	1st / fully charged	19,88	19,86		0,1006	Passed	377,17	377,18		Passed	Passed	Passed	Passed	Passed	Passed
3	1st / fully charged	19,81	19,79		0,101	Passed	377,68	377,7		Passed	Passed	Passed	Passed	Passed	Passed
4	1st / fully charged	19,81	19,78		0,1514	Passed	377,49	377,5		Passed	Passed	Passed	Passed	Passed	Passed
				10					**0,1**						
5	50th/ fully charged	19,78	19,76		0,1011	Passed	377,68	377,7		Passed	Passed	Passed	Passed	Passed	Passed
6	50th/ fully charged	20,26	20,24		0,0987	Passed	378,28	378,3		Passed	Passed	Passed	Passed	Passed	Passed
7	50th/ fully charged	19,72	19,7		0,1014	Passed	378,13	378,16		Passed	Passed	Passed	Passed	Passed	Passed
8	50th/ fully charged	19,82	19,79		0,1514	Passed	377,31	377,33		Passed	Passed	Passed	Passed	Passed	Passed

Measurement equipment:		
Reference	Equipment no.	Last calibration
Shock test system	00022	January, 2018
Acceleration sensor	00039	November, 2017
Scale	00019	February, 2018
Digital multimeter	00092	May, 2017

$$Acceleration[g] \equiv \sqrt{\frac{100850}{mass[kg]}}$$

Partial test result: Passed

Acceleration: 150 g

*Max. mass loss:

M < 1 g: 0,5%, 1 g <= M <= 75 g: 0,2 %, M > 75 g: 0,1 %

Date: May 11, 2018 Person in charge: Hans-Peter Grimm Signature:

Protocol 5: Mechanical shock

3.9 T.5 External short circuit

Methods of measurement according to:			
ST/SG/AC.10/11/Rev.6, Corr.1, UN Manual of Tests and Criteria, Part III, section 38.3.4.5			
Purpose of test:			
This test simulates an external short circuit.			
Test procedure:			
Temperature:	+57 ± 4 °C		
Exposure time for stabilization:	At least 6 h		
Total external resistance:	Less than 0.1 Ω		
Test duration:	1 h, after external case temperature has returned to +57 ± 4 °C		
Observation time::	6 h after the test		
Devices under test:	2018-09329-2 DUT 1 – DUT 8		
Test equipment used:			
Short circuit test chamber:			
Type:	Kurzschluss 1	Serial no.:	00387
Manufacturer:	Batteryuniversity GmbH	Inventory no.:	00387
Last calibration:	April 24, 2018		
Temperature test chamber			
Type:	UN 160	Serial no.:	B517.0238
Manufacturer:	Memmert GmbH + Co. KG	Inventory no.:	00344
Last calibration:	April 24, 2018		
Test result:			
Test requirements:	☒ passed	☐ failed	☐ applied
Opinions and interpretations:			
Comment(s):			
Testing conducted:			
Person in charge:	Hans-Peter Grimm	Date:	May 15, 2018 - May 17, 2018

Pictures test setup:

Figure 22: Temperature test chamber

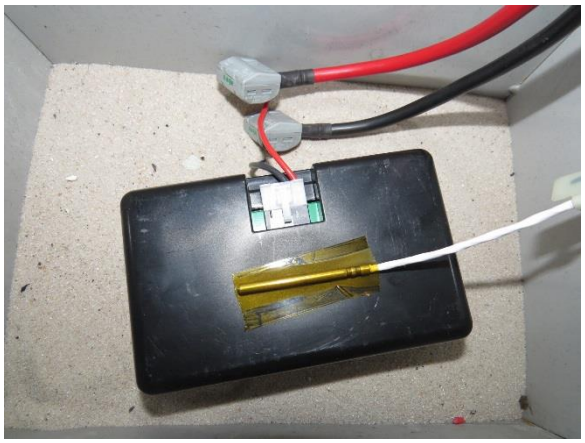


Figure 23: DUT inside temperature test chamber

Short circuit diagram:

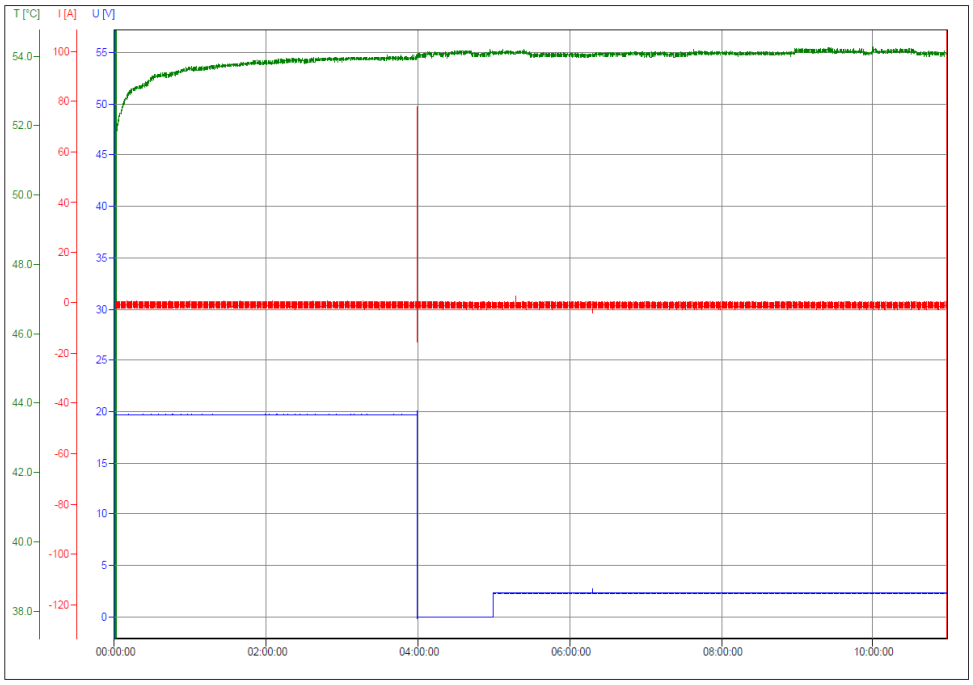


Diagram 12: Short circuit – temperature-, voltage-, current-time diagram

The DUTs were stored at an ambient temperature of 57±4°C and as soon as the case temperature reached the necessary value the contactors were closed. A current peak of about 80 A was detected and the voltage fell down to 0 V. One hour later the contactors were opened again and the voltage rose up to about 2 V. Then the observation time of 6 hours has started.

Test protocol:

Test #5: External Short Circuit (+55 °C, 1 h)

Sample no.	No. of cycles / state	Test Parameter									Temp. < +170 °C	No dis-assembly	No rupture	No fire	Result
1	1st / fully charged										Passed	Passed	Passed	Passed	Passed
2	1st / fully charged										Passed	Passed	Passed	Passed	Passed
3	1st / fully charged										Passed	Passed	Passed	Passed	Passed
4	1st / fully charged										Passed	Passed	Passed	Passed	Passed
5	50th/ fully charged										Passed	Passed	Passed	Passed	Passed
6	50th/ fully charged										Passed	Passed	Passed	Passed	Passed
7	50th/ fully charged										Passed	Passed	Passed	Passed	Passed
8	50th/ fully charged										Passed	Passed	Passed	Passed	Passed

Measurement equipment:		
Reference	Equipment no.	Last calibration
Climatic test chamber	00344	April, 2018
Short circuit test bench	00387	April, 2018

Partial test result: Passed

Date: May 17, 2018 Person in charge: Hans-Peter Grimm Signature:

Protocol 6: External short circuit

3.10T.7 Overcharge

Methods of measurement according to:			
ST/SG/AC.10/11/Rev.6, Corr.1, UN Manual of Tests and Criteria, Part III, section 38.3.4.7			
Purpose of test:			
This test evaluates the ability of a rechargeable battery to withstand an overcharge condition.			
Test procedure:			
Charge current:	Twice the manufacturer`s recommended maximum continuous charge current		24.0 A
Charge voltage:	Recommended charge voltage > 18 V: The minimum voltage shall be 1.2 times the maximum charge voltage.		25.2 V
Temperature:	23 ± 3 °C (RT)		
Test duration:	24 h		
Observation time::	7 d		
Devices under test:	2018-09329-2 DUT 1 – DUT 8		
Test equipment used:			
Overcharge test chamber:			
Type:	Überladen 2	Serial no.:	00386
Manufacturer:	Batteryuniversity GmbH	Inventory no.	00386
Last calibration:	April 24, 2018		
Power supply 1 – 4			
Type:	PS 8080-602U	Serial no.:	1049920001 1049920002 1051670001 1051670002
Manufacturer:	EA	Inventory no.	00017 00018 00035 00036
Test result:			
Test requirements:	☒ passed	☐ failed	☐ applied
Opinions and interpretations:			
Comment(s):			
Testing conducted:			
Person in charge:	Hans-Peter Grimm	Date:	May 22, 2018 – May 30, 2018

Pictures test setup:

Figure 24: Overcharge test setup

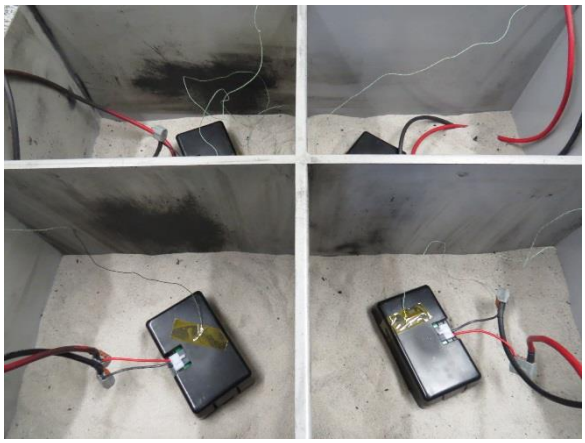


Figure 25: DUT inside overcharge test chamber

Overcharge diagram:

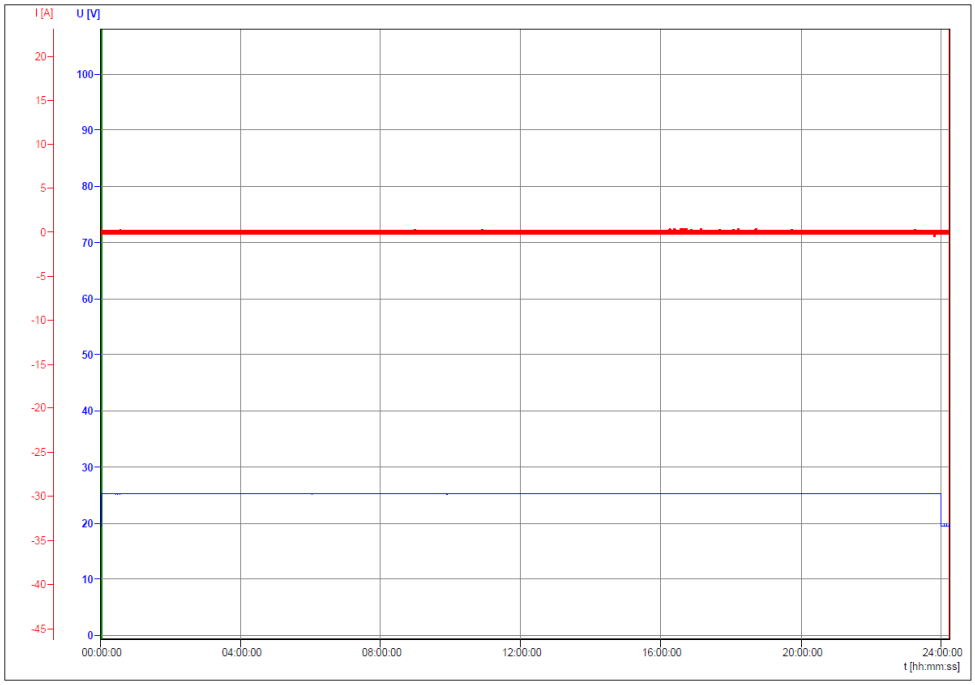


Diagram 13: Overcharge – voltage-, current-time diagram

The overcharging process was interrupted immediately and the voltage rose up to the pre-set overcharge voltage. 24 h later the test has ended and the voltage fell down to the previous level of about 20 V. Then the observation time of 7 days has started.

Test protocol:

Test #7: Overcharge (+20 °C, 24 h)

Sample no.	No. of cycles / state	Test Parameter										No dis-assembly		No fire	Result
1	1st / fully charged											Passed		Passed	Passed
2	1st / fully charged											Passed		Passed	Passed
3	1st / fully charged											Passed		Passed	Passed
4	1st / fully charged											Passed		Passed	Passed
5	50th/ fully charged											Passed		Passed	Passed
6	50th/ fully charged											Passed		Passed	Passed
7	50th/ fully charged											Passed		Passed	Passed
8	50th/ fully charged											Passed		Passed	Passed

Measurement equipment:		
Reference	Equipment no.	Last calibration
Overcharge test bench	00386	April, 2018

Partial test result: Passed

Charging voltage: 25.2 V

Charging current: 24.0 A

Date: May 30, 2018 Person in charge: Hans-Peter Grimm Signature:

Protocol 7: Overcharge

4. Summary

All performed tests were successfully passed.

Tests and Criteria	Requirement	Test Passed?
T.1: Altitude Simulation	Cells and batteries meet this requirement if there is no mass loss, 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.	Yes
T.2: Thermal Test		Yes
T.3: Vibration		Yes
T.4: Shock		Yes
T.5: External Short Circuit	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.	Yes
T.7: Overcharge	Rechargeable batteries meet this requirement if there is no disassembly and no fire during the test and within seven days after the test.	Yes

5. Appendix

5.1 List of protocols

5.2 List of diagrams

5.3 List of figures