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Test Report

Lithium Ion Battery
UN 38.3 Rev 6

Test Report – No.:	**2229319KAU-001**
Date of issue:	**2017-04-18**

Type:	14s20p
Description:	Li-Ion Battery
Serial number:	KAU1703101000-001 163000303
Manufacturer:	Geiger Engineering GmbH
Applicant:	Geiger Engineering GmbH
Address (Applicant):	Grosse Wiese 4 96114 Hirschaid Germany

Test Result:	The requirements of UN 38.3 Rev.6 (T.1 – T.5 and T.7) are pass. For issue dates of the standards please see standard listing in this report.

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1 Measurements and test specifications

Lithium Ion Battery Requirements according to

☒	UN 38.3 Rev.6	Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria

Tests

☒	UN 38.3 Rev.6 Test T.3	Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Vibration Test
☒	UN 38.3 Rev.6 Test T.4	Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Shock Test
☒	UN 38.3 Rev.6 Test T.5	Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, External short circuit Test
☒	UN 38.3 Rev.6 Test T.7	Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Overcharge Test

2 Size and type of the DUT

Definition of a battery cell module according to UN 38.3 Rev.6:

Battery means two or more cells which are electrically connected together fitted with devices necessary for use, for example, case, terminals, marking and protective devices. A single cell battery is considered a “cell” and shall be tested according to the testing requirements for “cells” for the purposes of the Model Regulations and this Manual (See also the definition for “cell”).

2.1 Size

☐ Small battery without protection
(*Small battery* means a battery with a gross mass of not more than 12 kg)

☐ Large battery without protection
(*Large battery* means a battery with a gross mass of more than 12 kg.)

☐ Small battery with protection (BMS, fuse)
(*Small battery* means a battery with a gross mass of not more than 12 kg)

☒ Large battery with protection (BMS, fuse)
(*Large battery* means a battery with a gross mass of more than 12 kg.)

2.2 Type

☐ Lithium polymer battery

☐ Lithium cobalt dioxide battery ($LiCoO_2$)

☐ Lithium titanate battery

☐ Lithium air battery

☒ Lithium manganese cobalt battery

☐ Lithium iron phosphate battery ($LiFePO_4$)

☐ other type

☐ not given by the manufacturer

3 Test result overview

Lithium Ion Battery UN 38.3	Samples received	pass	fail	applied	Date of test	No
T.3 Vibration Test	2017-03-10	☒	☐	☐	2017-03-17	1
T.4 Shock Test	2017-03-10	☒	☐	☐	2017-03-20	2
T.5 External short circuit	2017-03-10	☒	☐	☐	2017-03-23	3
T.7 Overcharge Test	2017-03-10	☒	☐	☐	2017-03-28- 2017-03-29	4

Table 1 test result overview

The tests have been made in the order of the last column in the “Test results – overview” table.

4 Description of DUT

4.1 Configuration / Operating conditions

This report documents the tests of the battery according to the requirements of the UN 38.3 Rev.6.
Regarding the definition of the UN 38.3 Rev.6 the tested battery is a large battery, because the weight of the battery is more than 12 kg.
To fulfil the UN 38.3 Rev.6 requirements it is necessary to test 1 battery for the tests T.3 – T.5 and T.7.
When testing the battery assembly in which the aggregate lithium content of all anodes, when fully charged, is not more than 500 gr. or in the case of a lithium ion battery, with a Watt-hour rating of not more than 6200 Wh, that is assembled from batteries that have passed all applicable tests, one assembled battery in a fully charged state shall be tested under tests T.3, T.4 and T.5 and, in addition test T.7 in the case of a rechargeable battery.

4.2 Technical data of the battery “14s20p”

Charging current	18	Adc
End of charge voltage	58,8	Vdc
Charging methode	CCCV (Cutoff: 1,8Adc)	
Discharge current	18	Adc
End of discharge voltage	35,7	Vdc
Discharging methode	-/-	
Idle between operation	10 Min	min

Table 2 technical data of the battery “14s20p”

Bedienung und Funktionalität

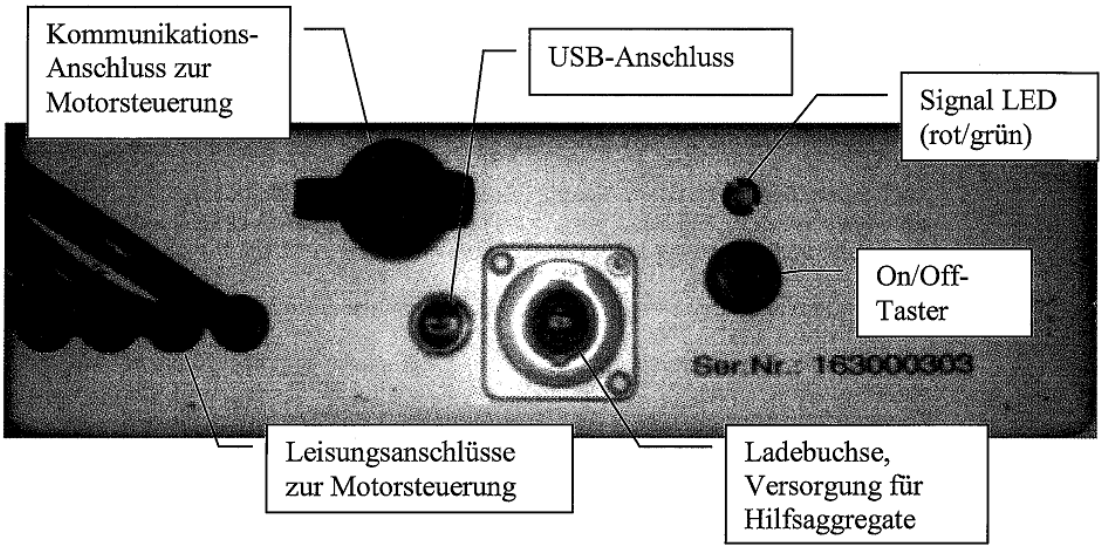
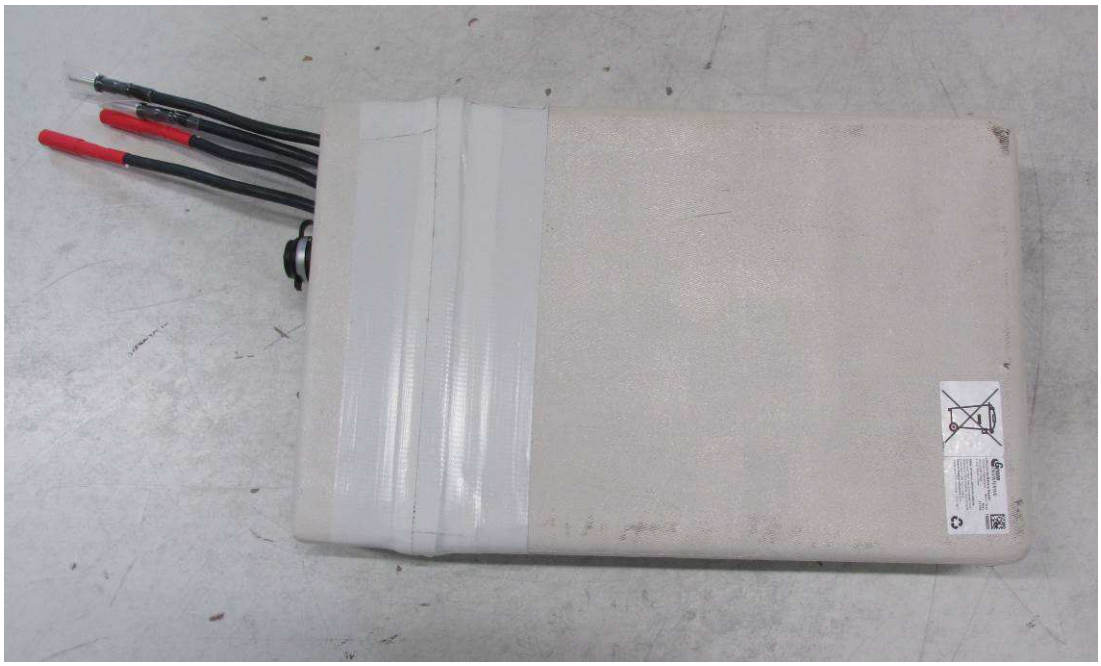


Table 3 technical data of the battery “14s20p”

4.3 General pictures of the battery



Picture 1 top view of “14s20p”

Picture 2 right side view of “14s20p”

Picture 3 front view of “14s20p”

5 Test overview

5.1 Conditioning of the DUT

Cycle means one sequence of fully discharging and fully charging a rechargeable cell or battery.

☒ Batteries were conditioned by the customer according to UN 38.3 Rev.6
Level of the SOC (given by the customer): 50%

☐ Batteries were received not-conditioned, conditioning was done by Intertek Deutschland GmbH according to customer technical specification and UN 38.3 Rev.6

The battery has seen 73 cycles of charging/discharging before delivering to Intertek Germany. Therefore, only charging was done.

5.1.1 Conditioning data

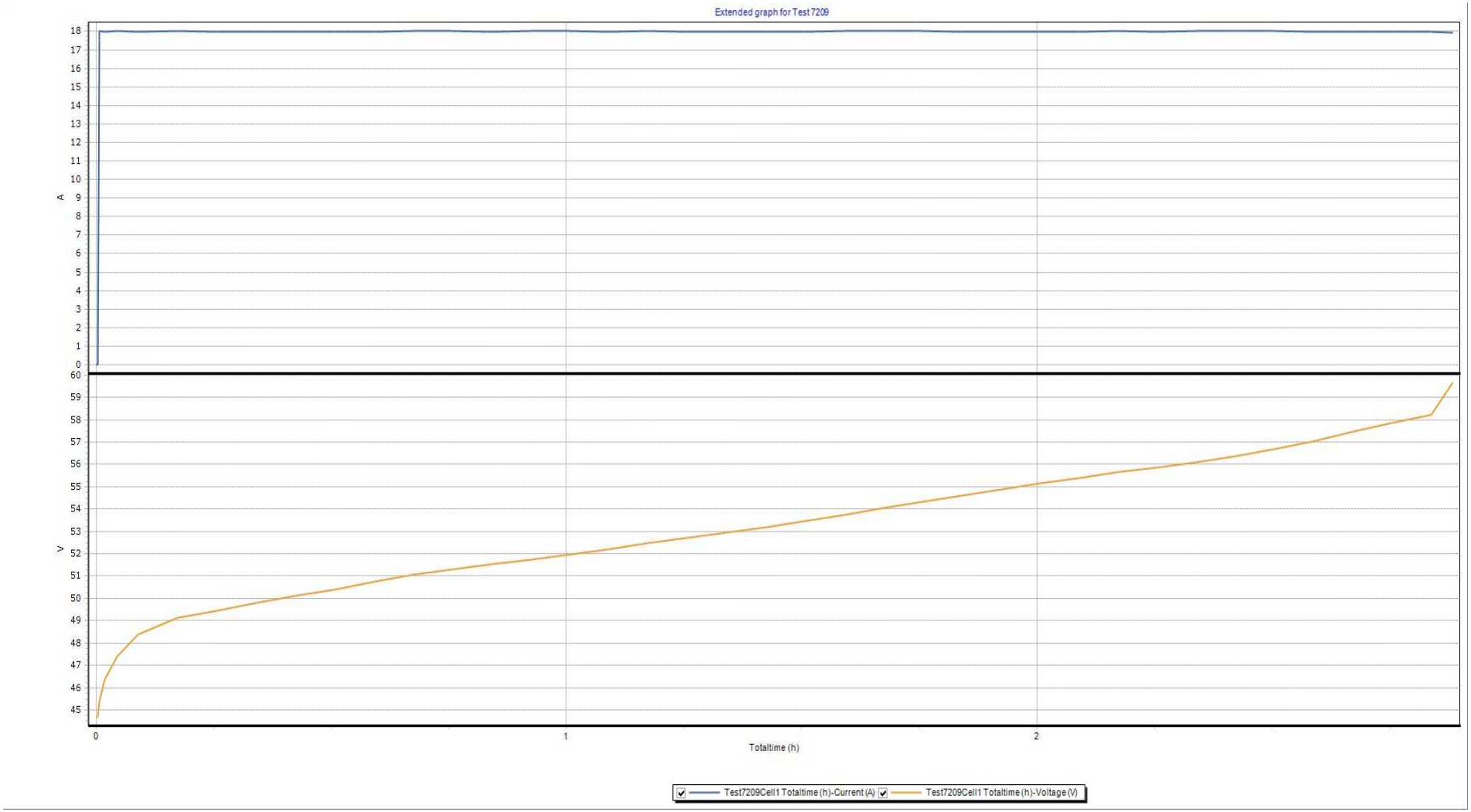
The batteries were received conditioned.
Only charging was done, due to pre-cycling by the customer.

Charging current	18 ADC
End of charge voltage	58,8 VDC
Charging methode	CCCV (Cutoff: 1,8Adc)
Discharge current	-/-
End of discharge voltage	35,7 VDC
Discharging methode	-/-
Idle between operation	10 Min
Charging current	18 ADC

Table 4 electrical parameters for conditioning

Client Serial Number	Intertek Serial number	Number of cycles, level SOC % after cycling	Test
163000303	KAU1703101000-001	charging, 100 %	T.3 - T.5 and T.7

Table 5 battery conditioning for T.1 – T.5 testing



Graph 1 battery conditioning, charging – fully charged for T.3 – T.5 and T.7

5.2 UN 38.3 T.3 - Vibration test

5.2.1 Normative references

Methods of measurement according to:	**UN 38.3 Rev.6 T.3**

Samples received	1 Serial numbers: KAU1703101000-001
Date of test	2017-03-17

Description of test samples
One (1) 14s20p

Purpose of test
This test simulates vibration during transport.

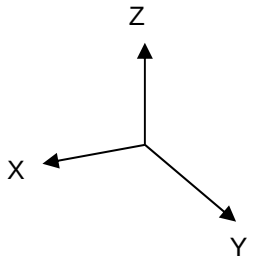
Test procedure
Cells and batteries are firmly secured to the platform of the vibration machine without distorting the cells and in such a manner as to faithfully transmit the vibration. The vibration shall be a sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed 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 up to 12 kg (cells and small batteries), and for batteries 12 kg and greater (large batteries).
For cells and small batteries:
From 7 Hz a peak acceleration of 1 g_n 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 g_n occurs (approximately 50 Hz). A peak acceleration of 8 g_n is then maintained until the frequency is increased to 200 Hz.
For large batteries:
From 7 Hz to a peak acceleration of 1 g_n 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 g_n occurs (approximately 25 Hz). A peak acceleration of 2 g_n is then maintained until the frequency is increased to 200 Hz.
Before and after the test the voltage and mass of the DUT has to be measured.

Acceptance criteria
Cells and batteries meet this requirement if there is no mass loss, no leakage, no venting, no disassembly, no rupture and no fire during the test and after the test. Additional 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 testing. The requirement relating to voltage is not applicable to test cells and batteries at fully discharged states.

Place of test

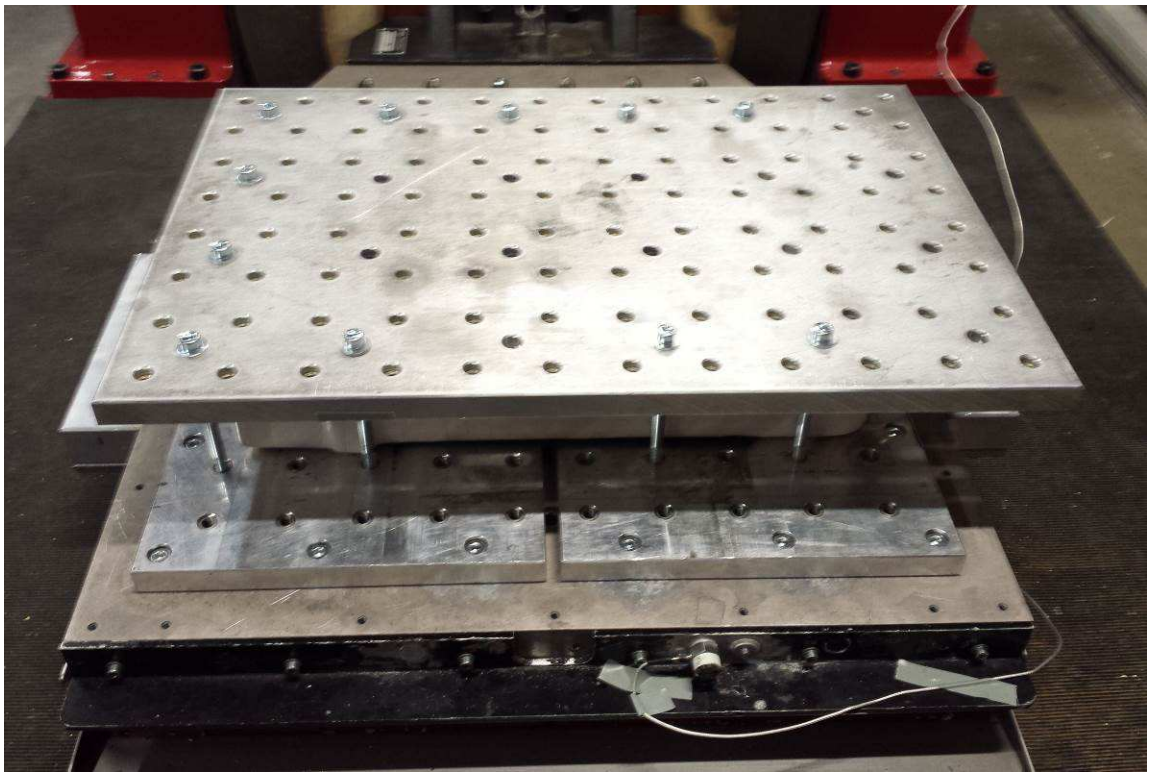
☒ EV Lab Intertek Deutschland GmbH, Kaufbeuren

5.2.2 Axis definition of the DUT



Picture 4 axis definition of the DUT

5.2.3 Picture of the test setup



Picture 5 test setup for T.3 - vibration test y-axis

5.2.4 Test results

Test requirements ☒ **pass** ☐ **fail** ☐ **applied**

Comment
According to the specified profile a peak acceleration of $2g_n$ was applied to the batteries. The test samples meet the requirements; there was no loss of mass, no leakage, no venting, no disassembly, no rupture and no fire. Additional the open circuit voltage of each test sample after testing was not less than 90% of its voltage immediately prior to T.3 testing. See following tables for pre-and post-test voltage and mass measurements.

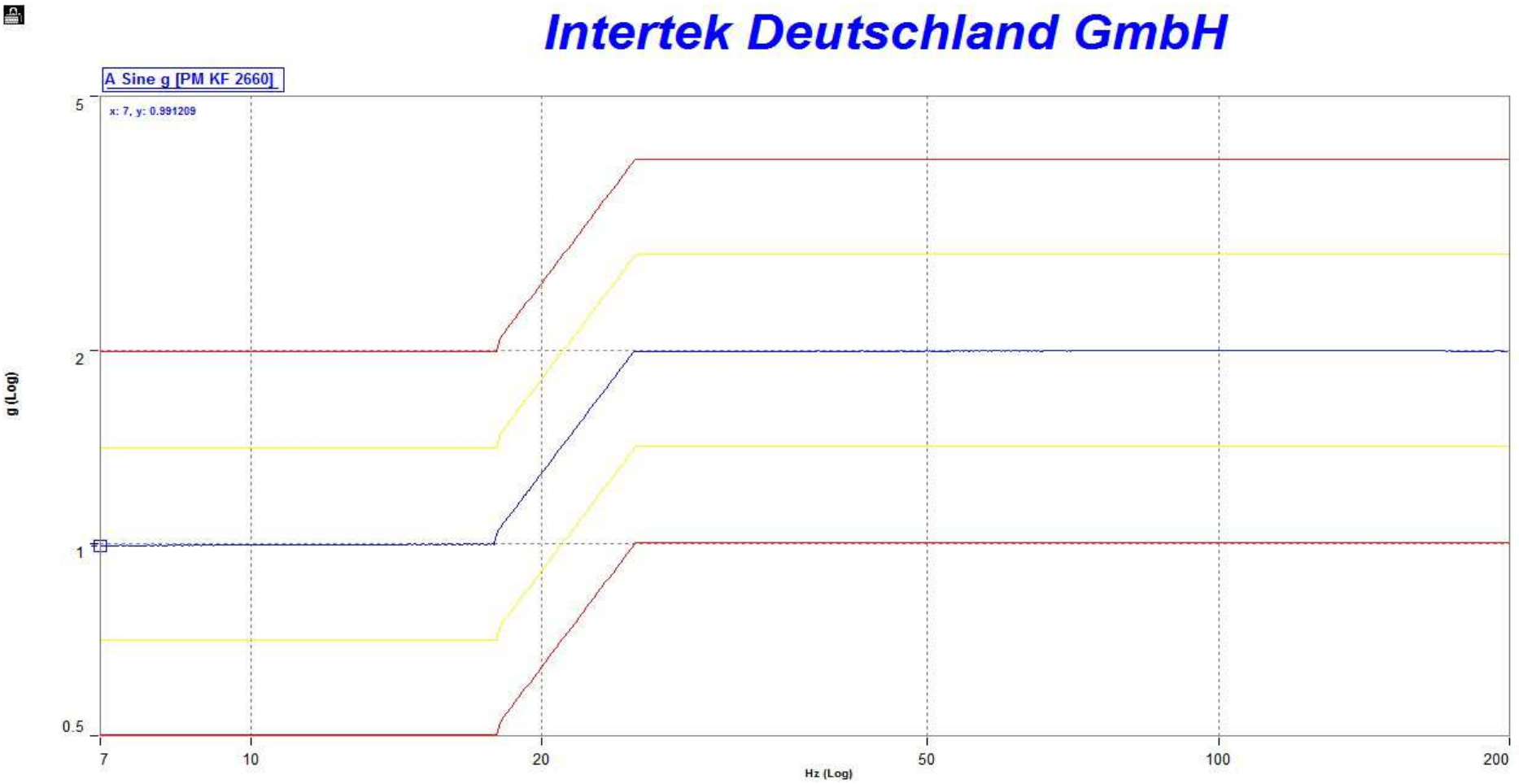
Disposition of test sample:
After the completion of testing, all samples continued to T.4 – shock testing

Test T.3 - Vibration Test					
Sample No.	**Voltage Pre Conditioning [VDC]**	**Voltage Pre Test [VDC]**	**Voltage after Test [VDC]**	**% Change (Not Greater Than 10%)**	**Meets requirement**
KAU-001	56,750	56,750	56,750	0,00	Pass

Table 6 test results T.3 - vibration test, voltage

Test T.3 - Vibration Test					
Sample No.	**Weight Pre Test [kg]**	**Weight after Test [kg]**	**% Change (Not Greater Than 0.1%)**	**Meets requirement**	**Pre Conditioning**
KAU-001	16,155	16,155	0,000	Pass	1 cycle, 100 % SOC

Table 7 test results T.3 - vibration test, weight



Graph 2 vibration test T.3 - vibration plot

5.3 T.4 Mechanical Shock test

5.3.1 Normative references

Methods of measurement according to:	**UN 38.3 Rev.6 T.4**

Samples received	1 Serial numbers: KAU1703101000-001
Date of test	2017-03-20

Description of test samples
One (1) 14s20p

Purpose of test
This test assesses the robustness of cells and batteries against cumulative shocks

Test procedure
The DUT shall be secured to the testing machine by means of a rigid mount which
will support all mounting surfaces of each tested DUT.
Each cell shall be subjected to a half- sine shock of peak acceleration of 150 g_n
and pulse duration of 6 milliseconds. Alternatively, large cells may be subjected to
a half-sine shock of peak acceleration of 50 g_n and pulse duration of 11 milliseconds.
Each battery shall be subjected to a half-sine shock of peak acceleration depending
on the mass of battery, calculation of shocks has to be done according to Table 8.
The pulse duration shall be 6 milliseconds for small batteries and 11 milliseconds
for large batteries. The formulas provided in Table 7 are to calculate the minimum
peak accelerations.
Each cell or battery shall be subjected to three shocks in the positive direction
followed by three shocks in the negative direction of all three mutually
perpendicular mounting positions of the cell or battery for a total of 18 shocks.

Acceptance criteria
Cells and batteries meet this requirement if there is no mass loss, no leakage, no
venting, no disassembly, no rupture and no fire during the test and after the test.
Additional 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 T.4 testing. The requirement relating to voltage is not
applicable to test cells and batteries at fully discharged states.

Place of test

☒ EV lab Intertek Deutschland GmbH, Kaufbeuren

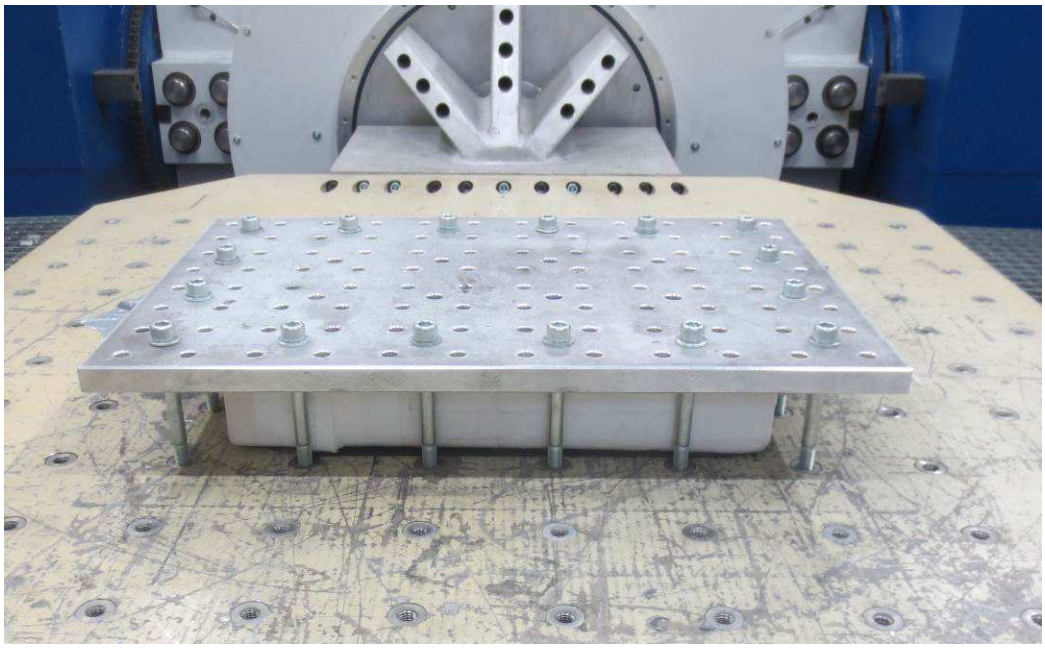
5.3.2 Test setup

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

* Mass is expressed in kilograms.

Table 8 calculation of minimum peak acceleration

Picture 6 test setup for T.4 – mechanical shock test, z-axis



Picture 7 test setup for T.4 – mechanical shock test, y-axis

5.3.3 Test results

Test requirements ☒ **pass** ☐ **fail** ☐ **applied**

Comment
A shock with a minimum of 43g – 6 ms was applied at all axis to all batteries.
The test samples meet the requirements; there was no loss of mass, no leakage, no venting, no disassembly, no rupture and no fire.
Additional the open circuit voltage of each test sample after testing was not less than 90% of its voltage immediately prior to T.4 testing.
See following tables for pre-and post-test voltage and weight measurements.

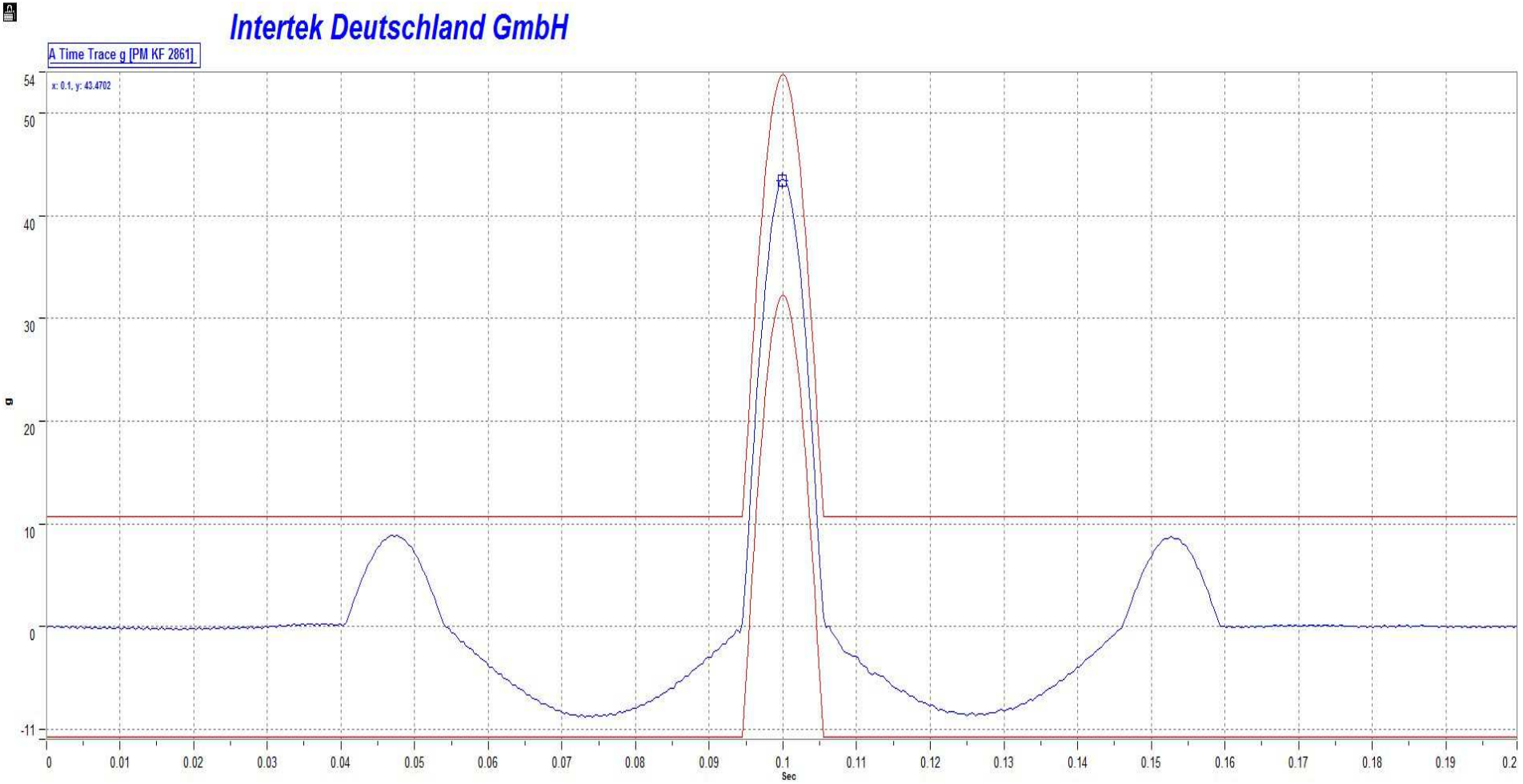
Disposition of test samples:
After the completion of testing, all samples continued to T.5 – short circuit testing.

Test T.4 - Shock					
Sample No.	**Voltage Pre Conditioning [VDC]**	**Voltage Pre Test [VDC]**	**Voltage after Test [VDC]**	**% Change (Not Greater Than 10%)**	**Meets requirement**
KAU-001	56,750	56,750	56,660	-0,16	Pass

Table 9 test results T.4 - mechanical shock test, voltage

Test T.4 - Shock					
Sample No.	**Weight Pre Test [kg]**	**Weight after Test [kg]**	**% Change (Not Greater Than 0.1%)**	**Meets requirement**	**Pre Conditioning**
KAU-001	16,155	16,149	-0,04	Pass	1 cycle, 100 % SOC

Table 10 test results T.4 - mechanical shock test, weight



Graph 3 plot from T.4 - shock test, positive shock

Graph 4 plot from T.4 - shock test, negative shock

5.4 T.5 External short circuit test

5.4.1 Normative references

Methods of measurement according to:	**UN 38.3 Rev.6 T.5**

Samples received	1 Serial numbers: KAU1703101000-001
Date of test	2017-03-23

Description of test Samples
One (1) 14s20p

Purpose of test
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 depends on the size and design of the cells 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 batteries, and 12 hours for large
cells and 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.

Acceptance criteria
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.

Place of test

☒ EV lab Intertek Deutschland GmbH, Kaufbeuren

5.4.2 Pictures of the Test set-up

Picture 8 test setup T.5 - short circuit

5.4.3 Test results

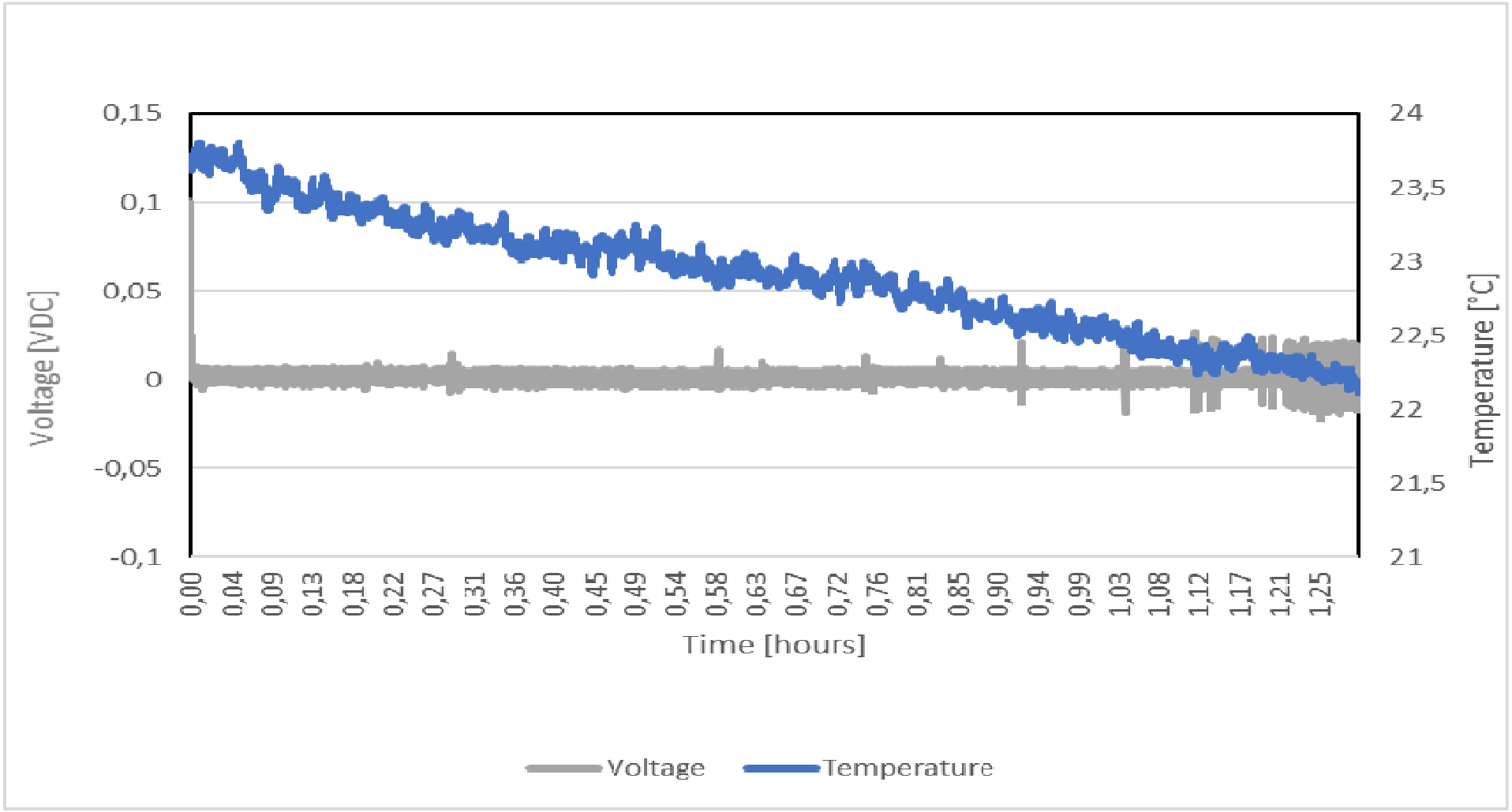
Test requirements ☒ **pass** ☐ **fail** ☐ **applied**

Comment
The batteries have been heated for more than 12 hours at 57 °C in a climate chamber prior to the external short circuit test. The batteries did discharge without temperature increase. During and after the test no abnormal behaviour could be detected at all tested batteries. There was no disassembly, no rupture and no fire during the test and within 6 hours after the test.

Resistance of the short circuit test setup	1,25 mΩ

Table 11 measured resistance of test setup for T.5 – short circuit

Disposition of test samples:
After the completion of testing, all samples continued to T.7 – overcharge testing.



Graph 9 voltage and temperature during T.5 - short circuit test

5.5 UN 38.3 T.7 – Overcharge test

5.5.1 Normative references

Methods of measurement according to:	**UN 38.3 Rev.5 Amend.2 T.7**

Samples received	1 Serial numbers: KAU1703101000-001
Date of test	2017-03-28 – 2017-03-29

Description of test samples
One (1) 14s20p

Purpose of test
This test evaluates the ability of a 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 18VDC, the minimum voltage of the test shall be the lesser of two times the maximum charge voltage of the battery or 22VDC.
(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.
Tests are to be conducted at ambient temperature. The duration of the test shall be 24 hours.

Acceptance criteria
Rechargeable batteries meet this requirement if there is no disassembly and no fire during the test and within seven days after the test.

Place of test

☒ EV lab Intertek Deutschland GmbH, Kaufbeuren

5.5.2 Picture of the test setup

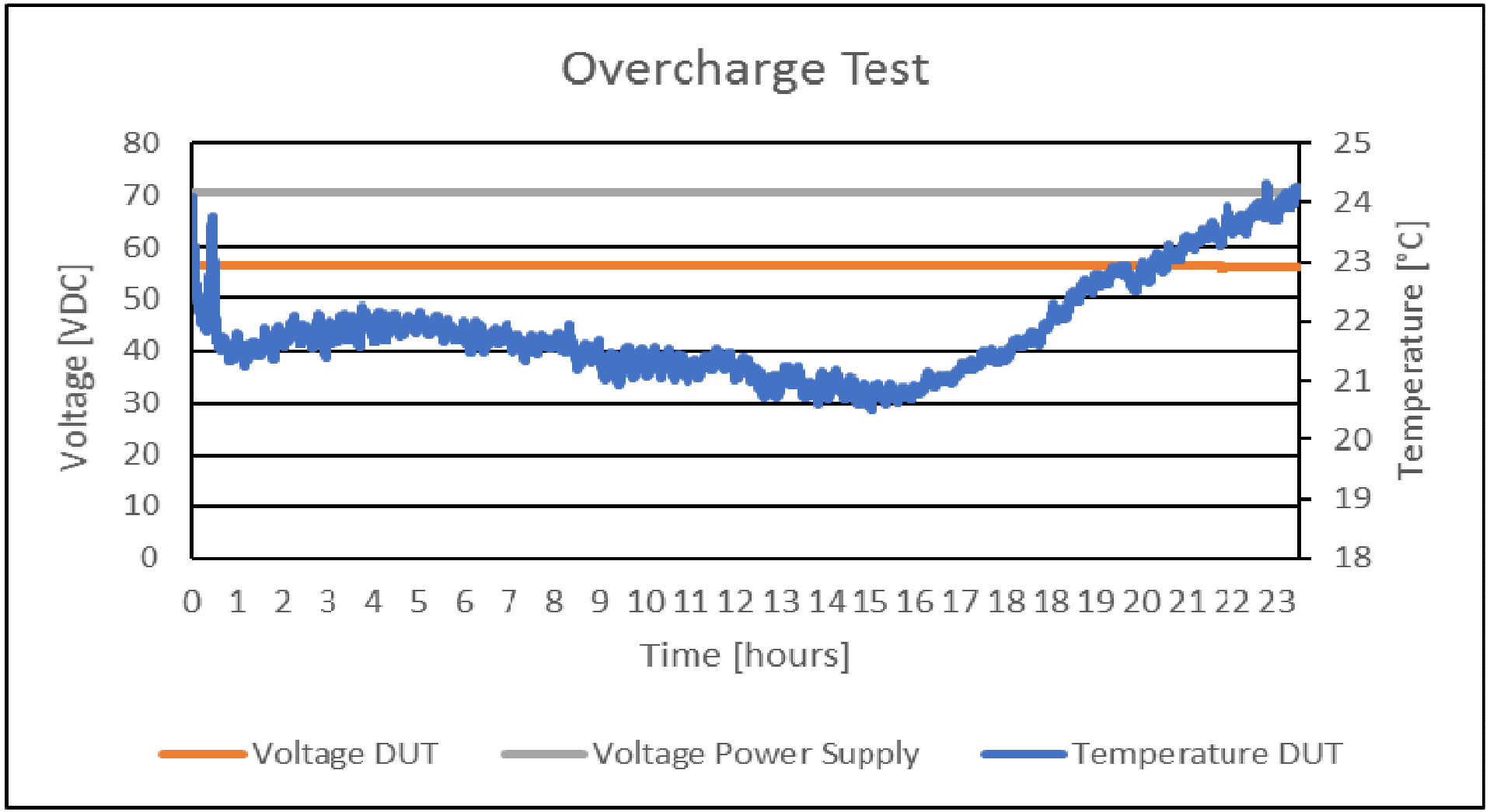
Picture 10 test setup for T.7 - overcharge test

5.5.3 Test results

Test requirements ☒ **pass** ☐ **fail** ☐ **applied**

Comment
After the test, no abnormal behaviour could be detected at the tested battery.
After applying the high voltage (approx. 70,56 VDC) and 2 times the current (36 ADC) the cell electronics switched off the Charging input, charging was not possible. See evaluation below

Disposition of test samples:
The sample was stored under controlled ambient conditions until return to the customer or disposal.



Graph 5 voltage vs. temperature during overcharge test T.7

6 Attachment

6.1 Test devices

6.1.1 T.3 – Vibration test

Equipment	Type	Manufacturer	Ser. No.	Inventory-No.
☒ Vibration table	SW2-4370	RMS	14852	PM KF 1431
☒ Steering Software	PUMA 2421	-/-	2283	PM KF 1450
☒ Acceleration sensor	KS77C.100-M59	Metra	14031	PM KF 2660
☒ Multimeter	FLUKE	177	22990494	PM KF 2288
☒ Scale	DS 150K1	Kern&Sohn	W1603386	PM KF 3034
☒ Data logger Almemo	MA2590-2	Ahlborn	H09040400	PM KF 1485
☒ Temperature/humidity sensor	FHA646-6	Ahlborn	09060077	PM KF 1486
☒ Air pressure sensor	FDA612-SA	Ahlborn	09040360	PM KF 1487

6.1.2 T.4 - Mechanical shock test

Equipment	Type	Manufacturer	Ser. No.	Inventory-No.
☒ Shock table	TV59420	Tira GmbH	021/12	PM KF 2262
☒ Steering Software	PUMA 2421	Spectral Dynamics	2445	PM KF 2263
☒ Multimeter	FLUKE	177	22990494	PM KF 2288
☒ Scale	DS 150K1	Kern&Sohn	W1603386	PM KF 3034
☒ Data logger Almemo	MA85909	Ahlborn	T13030051	PM KF 2342
☒ Temperature/humidity sensor	FHAD46-2L00	Ahlborn	14040047	PM KF 2348
☒ Air pressure sensor	FDA612-SA	Ahlborn	10070364	PM WI 0793
☒ Acceleration sensor	KS77C.10-M77	Metra	14014	PM KF 2861

6.1.3 T.5 - Short circuit test

Equipment	Type	Manufacturer	Ser. No.	Inventory-No.
☒ Data Acquisition Unit	34972A	Agilent	MY49017533	PM KF 2730
☒ Data logger Almemo	MA25904S	Ahlborn	H13020177	PM KF 2338
☒ Temp./Humidity sensor	FHAD46-2L00	Ahlborn	13020002	PM KF 2340
☒ Slot card	34901A	Agilent	US37246071	PM KF 2283-4
☒ Shunt	2500 A	Knoch	-/-	PM KF 2554
☒ Thermocouple Type J	Typ J	Ahlborn	-/-	PM KF 3045
☒ Battery Tester	BT3563-01	HIOKI	140746854	PM KF 2736
☒ Climate chamber	3836/17	Feutron	21/2014	PM KF 2603
☒ Air pressure sensor	FDA612-SA	Ahlborn	10070364	PM WI 0793

6.1.4 T.7 – Overcharge Test

Equipment	Type	Manufacturer	Ser. No.	Inventory-No.
☒ Data Acquisition Unit	34972A	Agilent	MY49017451	PM KF 2691
☒ Data logger Almemo	MA25904S	Ahlborn	H13020177	PM KF 2338
☒ Temp./Humidity sensor	FHAD46-2L00	Ahlborn	13020002	PM KF 2340
☒ Slot card	34901A	Agilent	MY41183498	PM KF 2713
☒ Thermocouple Type J	Typ J	Ahlborn	-/-	PM KF 3045
☒ Air pressure sensor	FDA612-SA	Ahlborn	10070364	PM WI 0793

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