

Test Report

For

ANSI/CAN/UL9540A

Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems [Module Level]

Report Number: CQES230600023001

Date of issue: 2023-07-05

Total number of pages: 25 pages

Test object / Model: ESM-57280AS1

Applicant's name: Huawei Technologies Co., Ltd.

**Address: Administration Building, Headquarters of Huawei
Technologies Co., Ltd., Bantian, Longgang District,
Shenzhen, 518129 Guangdong, China**



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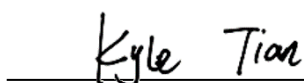
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Report Number: CQES230600023001
Manufacturer: Huawei Technologies Co., Ltd.
Address: Administration Building, Headquarters of Huawei Technologies Co., Ltd., Bantian, Longgang District, Shenzhen, 518129 Guangdong, China
Factory: Huizhou Sunwoda Energy Technology Co., Ltd.
Address: "Ji Duwei"(a local area), Zhenxing Avenue, Lixi Economic Union, Yuanzhou Town, Boluo County, Huizhou, Guangdong, China
Test object / Model: ESM-57280AS1
Test specifications: ANSI/CAN/UL9540A:2019 Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems Fourth Edition, Dated November 12, 2019
Date of receipt: 2023-06-15
Sample No.: M1
Test Period: 2023-06-15 to 2023-06-17
Issuing Laboratory: SGS-CEC New Energy Technology (Chongqing) Co., Ltd.
Address: Affiliate No. 6, No. 2 Fuyun Road, Shuangfu Street, Jiangjin District, Chongqing, China (No.1 Laboratory Building, Chongqing Energy College)
Testing location: SGS-CEC New Energy Technology (Chongqing) Co., Ltd.
 Affiliate No. 6, No. 2 Fuyun Road, Shuangfu Street, Jiangjin District, Chongqing, China (No.1 Laboratory Building, Chongqing Energy College)
Test Result: Refer to summary of test results page for details.
Remark: Test results reported relate only to the items being tested.
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Confidential level: ☐ Private and Confidential
☐ Public

Tested by / Witness by

Reviewed by



Kyle Tian
Project Engineer



Ryan Hu
Project Manager



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[Summary of Test results]

Cell Level Test
Cell model: LF280K
Report No:
4789795626

Cell Design:	LF280K
Thermal Runaway Methodology:	External heating
Cell Surface Temperature at Gas venting:	146.9 °C
Cell Surface Temperature at Thermal Runaway:	147.7 °C
Gas Composition:	Mainly Hydrocarbon, CO, CO ₂ , H ₂
Lower Flammability Limit:	7.15 Vol% at the ambient temperature 6.45 Vol% at 146.9 °C
Burning Velocity:	79 cm/s
Pmax:	102 psig
Thermal Runaway was Induced in the Cell or not:	Induced
Cell Vent Gas is Flammable or not in Air:	Flammable

Remark: Information was cited from UL test report 4789795626

Module Level Test
Module model: ESM-57280AS1
Report No:
CQES230600023001

Module Design:	ESM-57280AS1
Thermal Runaway Methodology:	External heating using film heater
External Flaming:	No external flaming observed
Locations of Flame Venting:	No flame extension observed
Flying Debris:	No flying debris observed
Peak smoke release rate :	19.112 m ² /s
Gas Generation and Composition:	Hydrocarbon, CO, CO ₂ , H ₂
Thermal Runaway are Contained by the Module Design or not:	Contained by the Module Design
Cell Vent Gas is Flammable or not:	Flammable
Other Description:	N/A
Test Video file:	Archived by Applicant

Remark: This report only evaluated module level test which is listed inside the dotted box.



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[Test object Description]

Table 1: Description of component cell

Model:	LF280K	
Manufacturer:	EVE POWER Co., Ltd	
Nominal capacity:	280 Ah	
Nominal voltage:	3.2 Vdc	
Chemistry:	Lithium iron phosphate	
Maximum charge current:	280 A	
Maximum discharge current:	280 A	
Maximum charge voltage:	3.65 Vdc	
Cut-off Voltage:	2.5 Vdc	
Charge temperature range:	0 °C to 55 °C	
Discharge temperature range:	-20 °C to 55 °C	
External dimensions:	(72±0.5) mm *(173.7±0.5) mm* (207.5±0.5) mm	
Weight:	(5.42±0.3) kg	
UL 1973 compliant:	<input type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: N/A
UL 9540A report provide:	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: UL test report: 4789795626



Figure 1. View of component cell



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Table 2: Description of battery module

Model:	ESM-57280AS1	
Manufacturer:	Huawei Technologies Co., Ltd.	
Nominal capacity:	280 Ah	
Nominal voltage:	57.6 Vd.c.	
Maximum charge current:	140 A	
Maximum discharge current:	145 A	
Maximum charge voltage:	65.25 V	
Cut-off Voltage:	48.6V or any cell reaches 2.5V	
Charge temperature range:	0 °C to 55 °C	
Discharge temperature range:	-20 °C to 55 °C	
Module configuration:	18S	
External dimensions:	(442+1.5/-0.5) mm*(660+1.5/-1.0) mm*(307+1.5/-0.5) mm	
Enclosure material:	Fe、PC	
Weight:	(130±3) kg	
UL 1973 compliant:	<input type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: N/A



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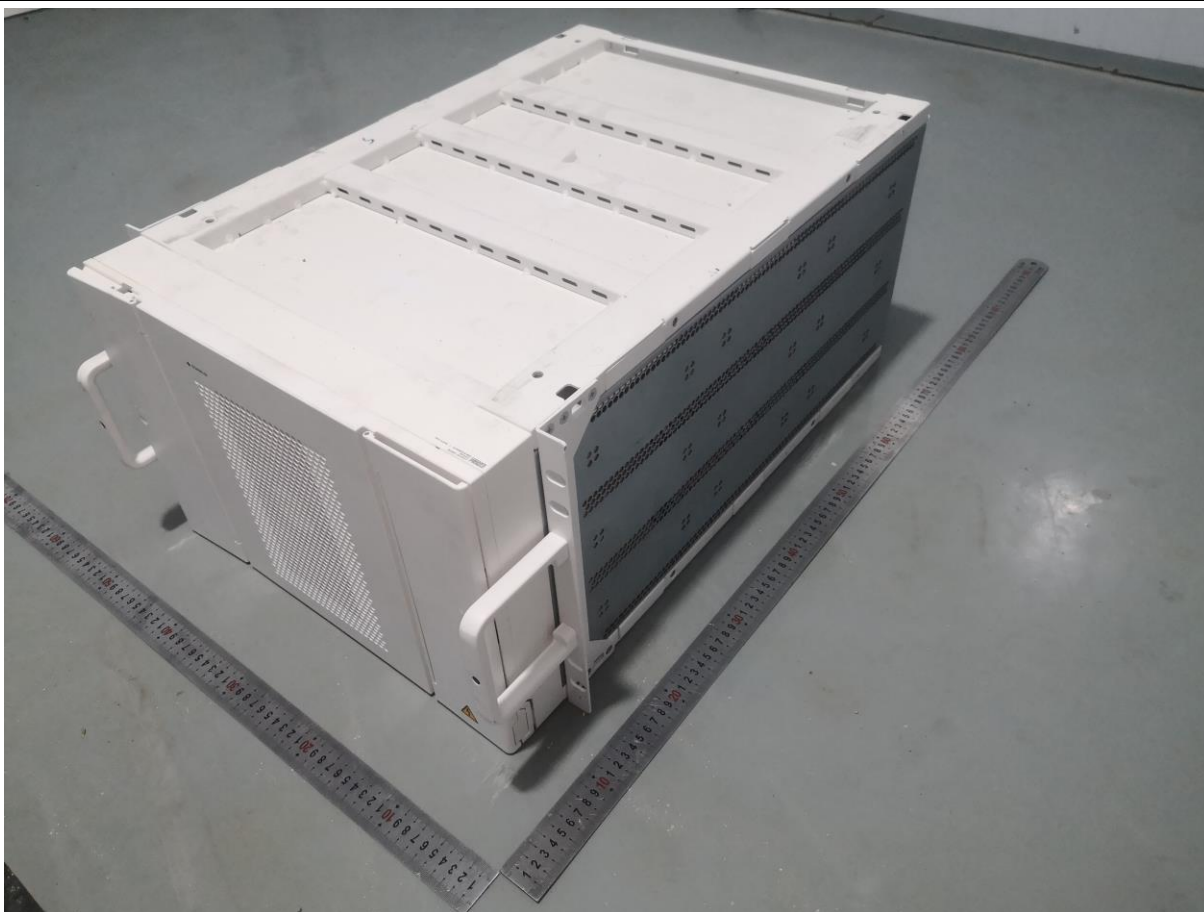


Figure 2. View of battery module

[Description of thermal runaway methodology]

Pre-condition of test sample

Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a minimum of 2 cycles, using a manufacturer specified methodology to verify that the module is functional. Each cycle shall be defined as a charge to 100% SOC and allowed to rest a maximum of 8 h and then discharged to an end of discharge voltage (EODV) specified by the module manufacturer.

The module to be tested shall be charged to 100% SOC and allowed to rest a maximum of 8 h before the start of the test. The module voltage shall be determined by measuring at the module terminals after charging up to the fully charged condition and before beginning testing. The sample module shall stabilize for a minimum of one hour prior to testing.

Table 3: Charge and discharge parameters (provided by manufacturer)

Charge		Discharge	
Charge current (A)	140	Discharge current (A)	145
Max. charge voltage (V)	65.25	Cut-off voltage (V)	48.6V or any cell reaches 2.5V
Cut-off charge current (A)	14		



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Remark: The charging cut-off condition is the maximum voltage of the cell reaches 3.65 V. The discharge cut-off condition is that the minimum voltage of the cell reaches 2.5 V.

Module level Test method description

Ambient indoor laboratory conditions shall be 25 ±5°C (77 ±9°F) and 50 ±25% RH at the initiation of the test.

The test shall be conducted under a smoke collection hood that is sized appropriately to collect the gasses generated from the module.

The methodology used for initiating thermal runaway pursuant to cell level test shall be used to initiate thermal runaway within the module.

Thermal runaway methodology for module level test:

The propensity of the module to exhibit thermal runaway was demonstrated by heating the cell with externally applied heater. With a surface heating rate of 4°C (7.2°F) to 7°C (12.6°F) per minute until cell thermal runaway occurs within the test module.

The number of cells within the module that are forced into thermal runaway can be one or multiple cells, and is dependent upon the energy contained within the individual cells. A sufficient number of cells shall be forced into thermal runaway to create a condition of cell to cell propagation within the module. For example, it may be necessary to force nine, 3-Ah cells into thermal runaway as opposed to one, 30-Ah cell in order to get cell to cell propagation. The location of the cell (s) forced into thermal runaway shall be selected to present the greatest thermal exposure to adjacent cells that are not forced into thermal runaway. Factors to be taken into consideration shall include selecting locations within the module where heat transfer is maximized to other cells, cooling by ventilation is restricted or limited, and thermal sensors, detection and suppression discharge points are remote.

The module shall be placed on top of a noncombustible horizontal surface with the module orientation representative of its intended final installation.

The chemical heat release rate of the module in thermal runaway shall be measured with oxygen consumption calorimetry.

The chemical heat release rate shall be measured for the duration of the test.

Occurrence of thermal runaway shall be verified by sustained temperature above the cell surface temperature at the onset of thermal runaway, as determined in cell level test.

The chemical heat release rate shall be measured by a measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple. The instrumentation shall be located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influence of bends or exhaust devices.

Calculate the chemical heat release rate at each of the flows as follows:

$$HRR_1 = \left[E \times \varphi - (E_{co} - E) \times \frac{1 - \varphi}{2} \times \frac{X_{co}}{X_{O_2}} \right] \times \frac{\dot{m}_e}{1 + \varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X_{H_2O}^o) \times X_{O_2}^o$$

Vent gas composition shall be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm⁻¹ and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer, and velocity and temperature measurements respectively shall be obtained in the exhaust duct of the heat release rate calorimeter using equipment.



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The hydrocarbon content of the vent gas shall be measure using flame ionization detection.
Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.

The light transmission in the exhaust duct of the heat release rate calorimeter shall be measured using a white light source and photo detector for the duration of the test, and the smoke release rate shall be calculated.

Smoke release rate shall be calculated as follows:

$$SRR = 2.303 \left(\frac{V}{D} \right) \log_{10} \left(\frac{I_o}{I} \right)$$



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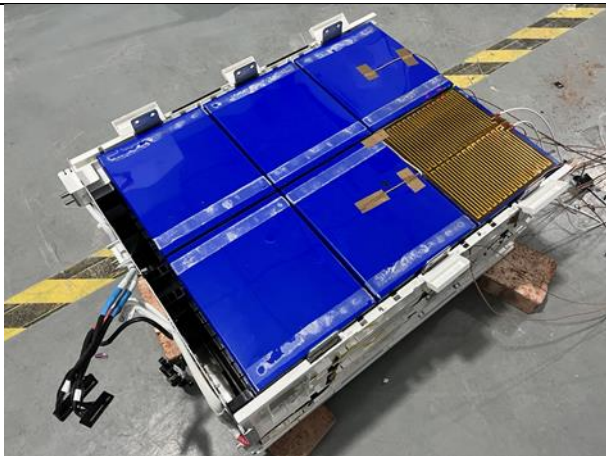
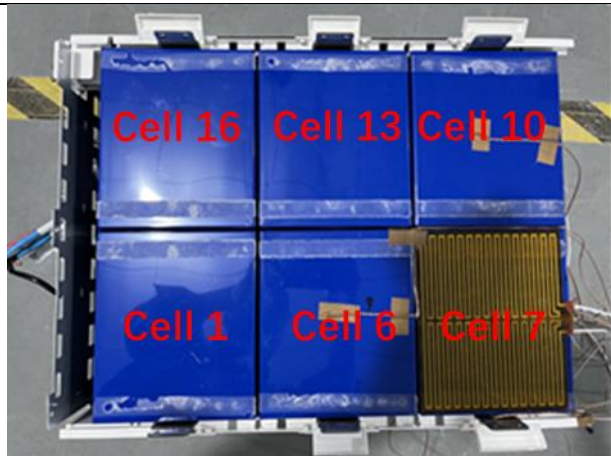
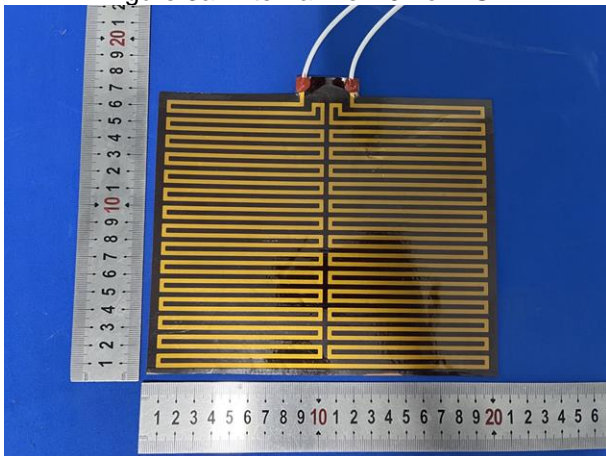
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Test configuration description

Thermal runaway initiation method used including number and locations of cells for initiating thermal runaway
<p>Initiation method: External heating method was used for initiating thermal runaway. By controlling the input power of the heaters, a surface heating rate of 4°C (9°F) to 7°C (12.6°F) per minute was achieved. Max. power of the film heater was 430 W.</p>
<p>Number of cells for initiating thermal runaway:</p> <p><input checked="" type="checkbox"/> Single cell 280 Ah (total capacity)</p> <p><input type="checkbox"/> Multiple cell Ah (total capacity)</p>
<p>Locations of cells for initiating thermal runaway: The battery module consists of 18 cells, which are connected in series. Cell 7 (as shown in Figure 3b) is selected as the initiating cell. Two film heaters were placed on large surfaces of cell 7.</p>
Other description : N/A
<div>  </div> <div> <p>Figure 3a. Internal view 01 of DUT.</p> </div> <div>  </div> <div> <p>Figure 3b. Internal view 02 of DUT.</p> </div> <div>  </div> <div> <p>Figure 3c. View of external heater.</p> </div>



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Illustration of external heater and thermocouple location

Description: N/A

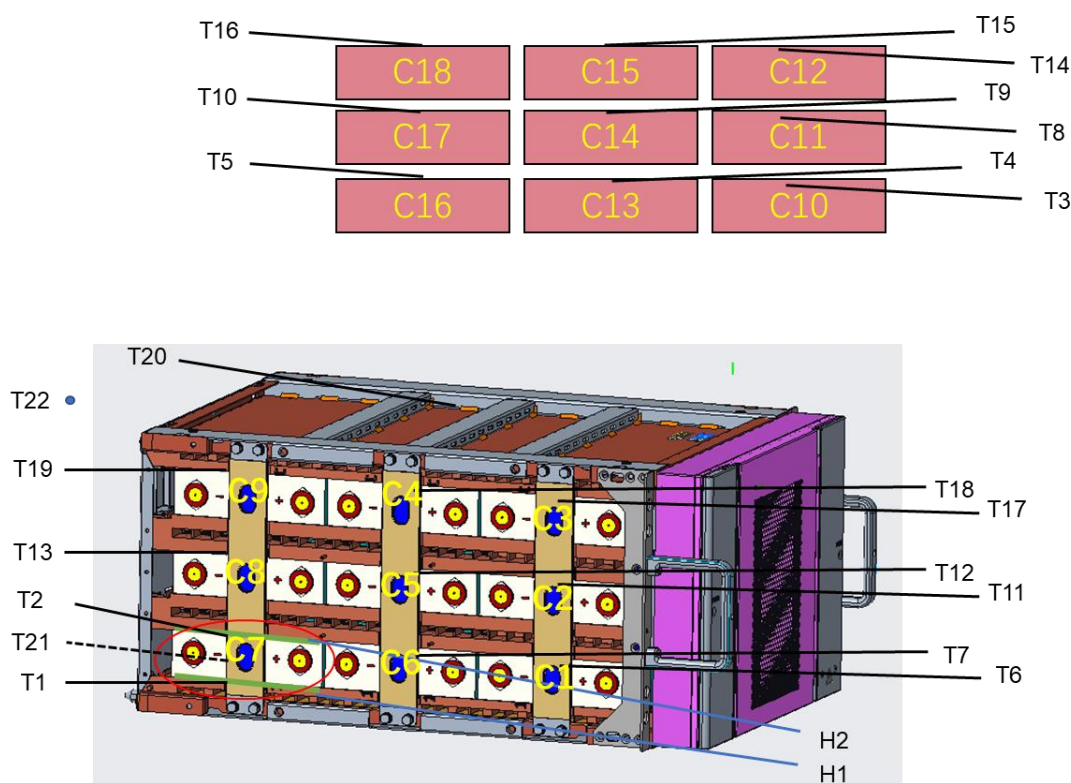


Figure 4. Schematic illustration of film heaters and thermocouple locations in initial module (T1 to T22 means thermocouples T1 to T22. H1 and H2 means Film heater 1 and Film heater 2. View from side.).



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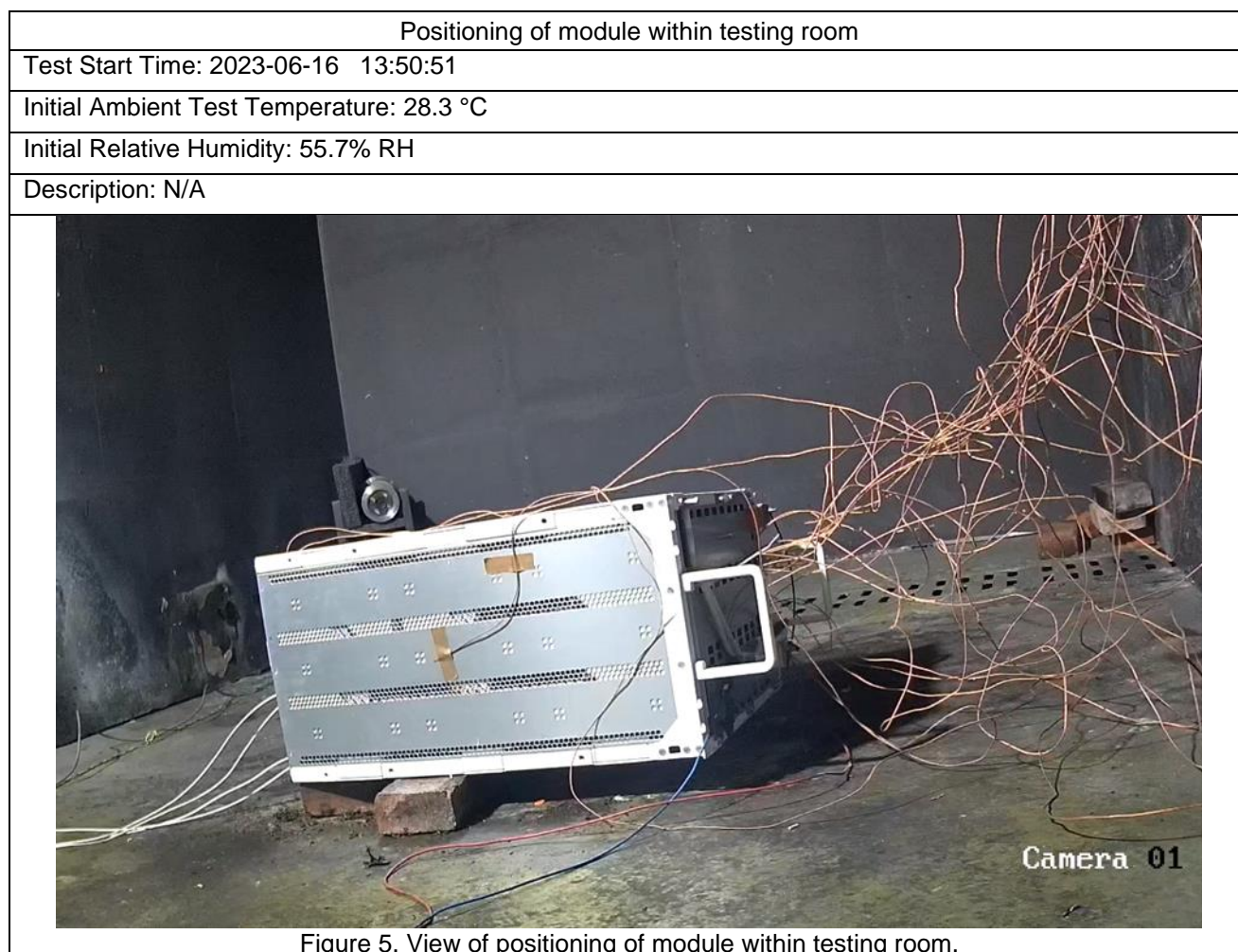


Table 4: Thermocouple placement

Thermocouple ID	Description of location	Remark
CH4001	Center of surface between Cell 7 and Heater 1	T1
CH4002	Center of surface between Cell 7 and Heater 2	T2
CH4003	Front surface of Cell 10, near the upper panel of the module	T3
CH4004	Front surface of Cell 13, near the upper panel of the module	T4
CH4005	Front surface of Cell 16, near the upper panel of the module	T5
CH4006	Front surface of Cell 1, near the upper panel of the module	T6
CH4007	Front surface of Cell 6, near the upper panel of the module	T7
CH4008	Front surface of Cell 11, near the upper panel of the module	T8
CH4009	Front surface of Cell 14, near the upper panel of the module	T9
CH4010	Front surface of Cell 17, near the upper panel of the module	T10



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CH4101	Front surface of Cell 2, near the upper panel of the module	T11
CH4102	Front surface of Cell 5, near the upper panel of the module	T12
CH4103	Front surface of Cell 8, near the upper panel of the module	T13
CH4104	Front surface of Cell 12, near the upper panel of the module	T14
CH4105	Front surface of Cell 15, near the upper panel of the module	T15
CH4106	Front surface of Cell 18, near the upper panel of the module	T16
CH4107	Front surface of Cell 3, near the upper panel of the module	T17
CH4109	Front surface of Cell 4, near the upper panel of the module	T18
CH4110	Front surface of Cell 9, near the upper panel of the module	T19
CH4201	Upper surface of the module	T20
CH4203	Module side surface	T21
CH4204	Ambient temperature	T22
CH1-1-1	Total Voltage of Module	V1
Thermocouple information: Type K 24 AWG		



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[Description of test results]

Table 5: Overview of test timeline and key events

Time (HH: MM: SS)	Relative Time (HH: MM: SS)	Event ID	Event	Description	Photo Reference
13:50:51	00:00:00	E1	Test Start	--	Figure 9
13:51:01	00:00:11	E2	Heaters Energized	--	Figure 10
14:30:48	00:39:58	E3	Initiating Cell Venting	--	Figure 11
14:45:31	00:54:41	E4	Onset of Thermal Runaway ()	Smoke venting observed from module enclosure. All Heaters de-energized	Figure 12
20:18:28	06:27:38	E5	Test Termination	--	Figure 13
Test Start Time: 2023-06-16 13:50:51					



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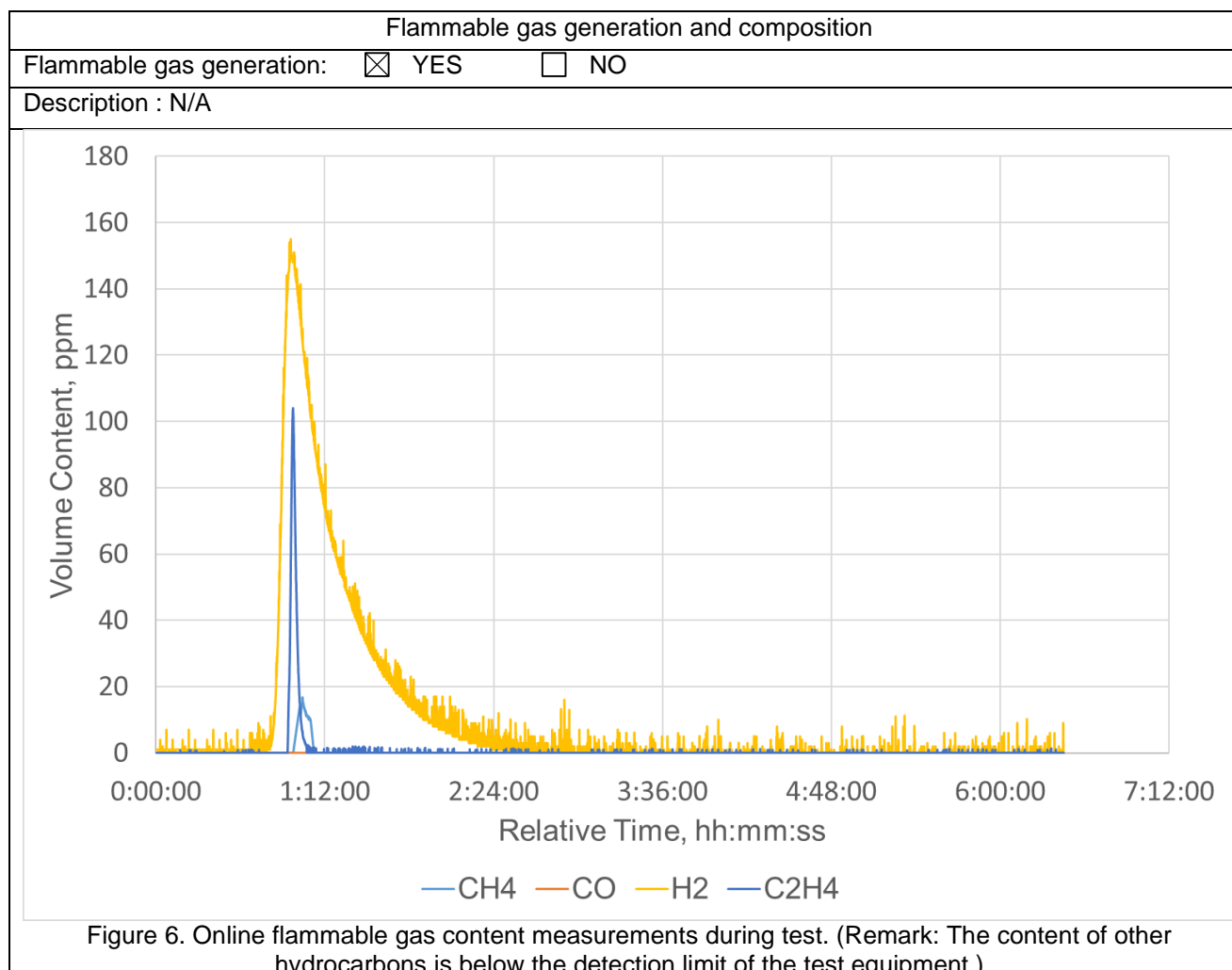
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Heat release rate versus time
Description: No flaming combustion observed outside test module.
N/A



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Peak smoke release rate and total smoke release

Description : Peak smoke release rate is 19.112 m²/s during test.

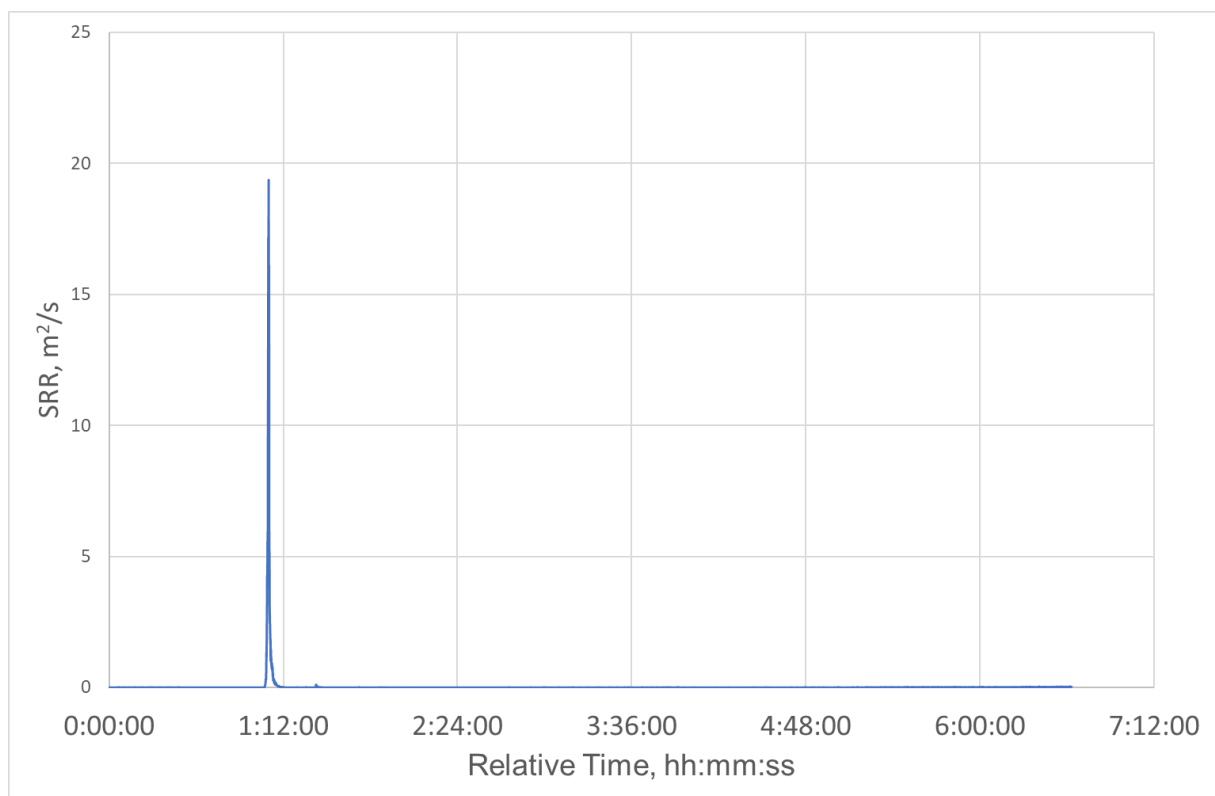


Figure 7. Smoke release rate versus time



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Identification/location of cell(s) that exhibited thermal runaway within the module
Cells(s) that exhibited thermal runaway: <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
Description : N/A


Figure 8. View of cells that exhibited thermal runaway after test.

Locations and visual estimations of flame extension and duration from the module
Flame extension: <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO
Description : No external flaming observed. No explosion observed. No flying debris observed.
N/A

Other observations during test
Description : N/A
N/A



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Table 6: Data during test

Model	SOC of Battery Module Before Test, (%)	OCV of Battery Module Before Test, (V dc)	Weight of Battery Module Before Test, (Kg)	Weight of Battery Module After Test, (Kg)	Battery Module Weight Loss Rate, (%)
ESM-57280AS1	100%	60.080	123.54	120.08	2.8%
Peak Smoke Release Rate, (m²/s)	Observation Results				
19.112	Gas and smoke release observed from module enclosure. No external flaming observed. No explosion observed.				
Supplementary information:					
No additional thermal runaway events or re-ignition occurred during post-test observations of the test module.					



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Figure 9. photo of event (E1) during test



Figure 10. photo of event (E2) during test



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Figure 11. photo of event (E3) during test



Figure 12. photo of event (E4) during test



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Figure 13. photo of event (E5) during test



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Figure 14. Photo 01 of DUT after test



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Figure 15. Photo 02 of DUT after test



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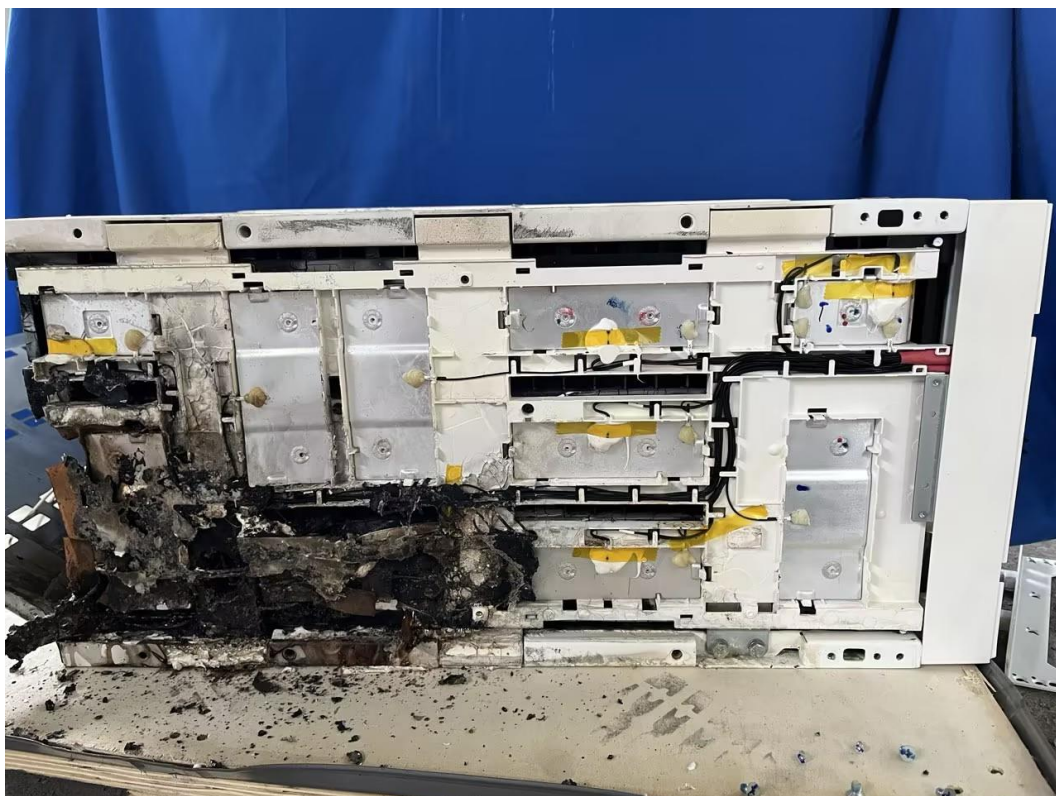


Figure 16. Photo 03 of DUT after test



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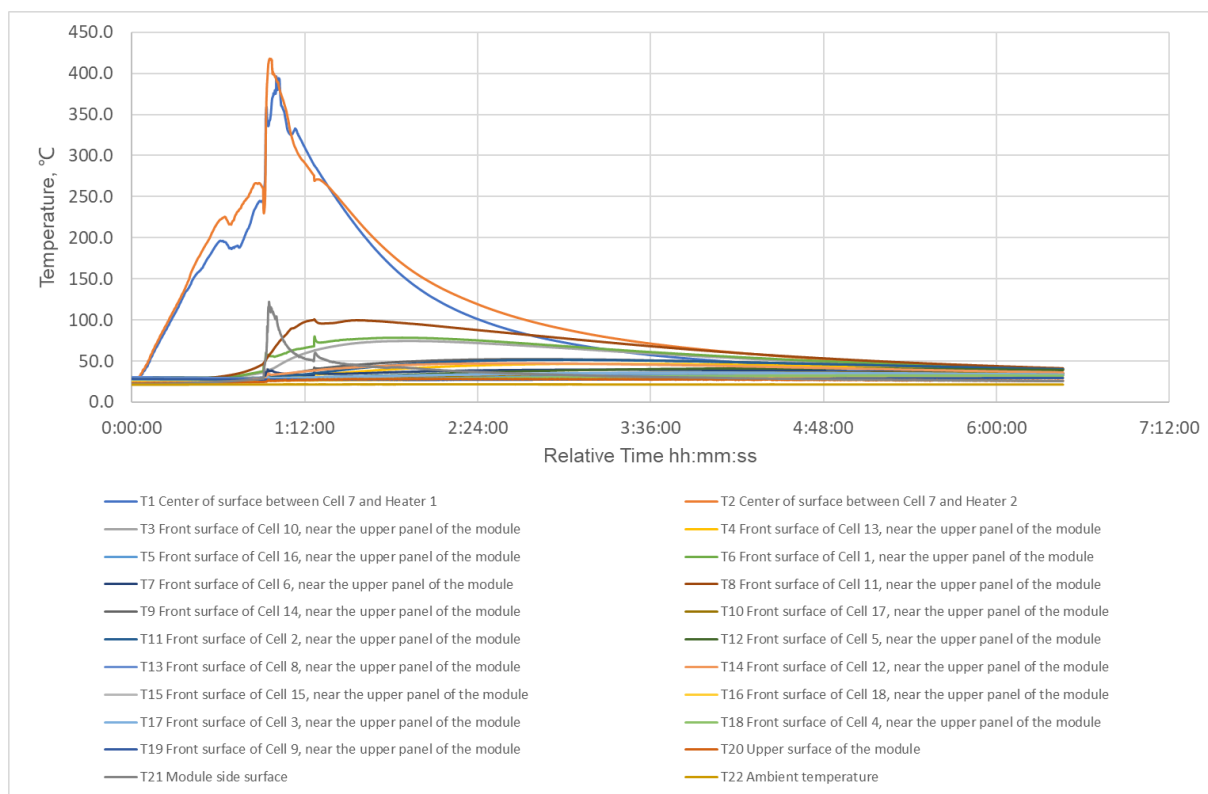


Figure17. Temperature measurements during test.

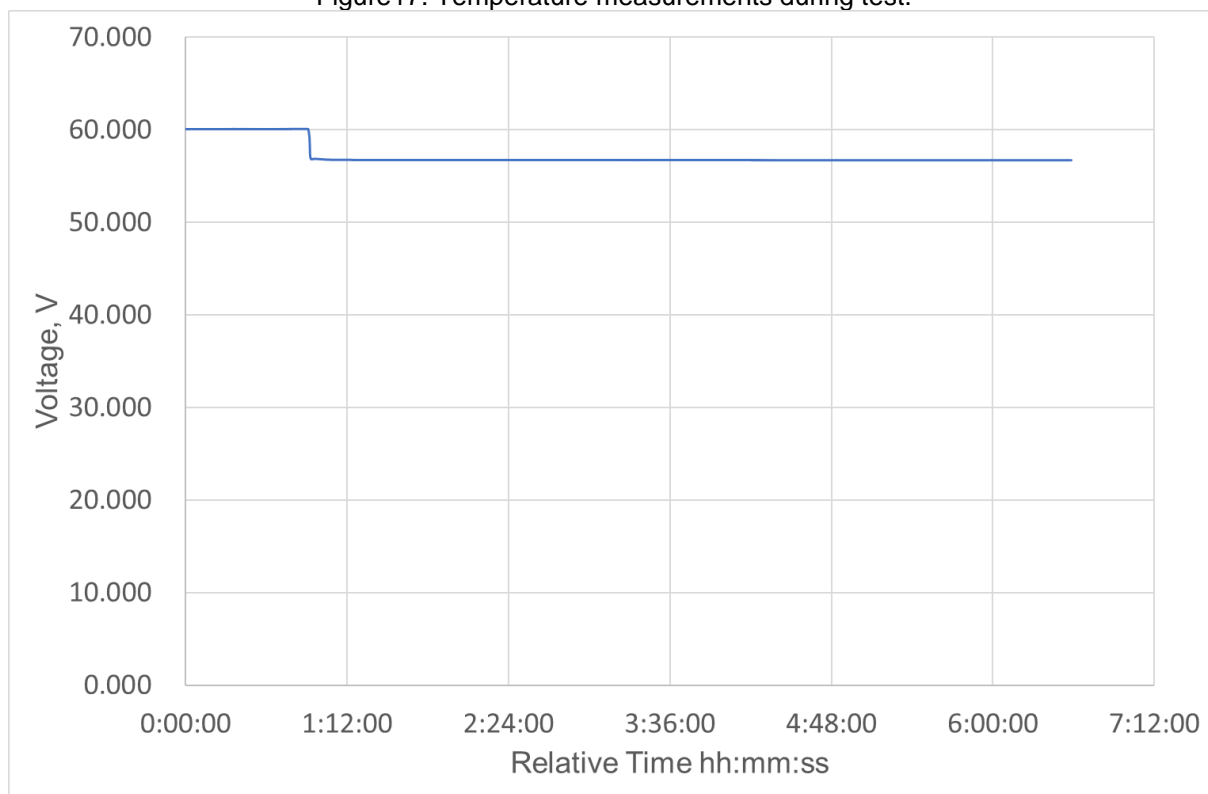


Figure18. Voltage measurements during test.



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2. According to the standard, instruction sheets and other texts required by the standard should be written in the official language(s) of the country in which the product is to be sold. The applicant should ensure that the product in future production fulfils the receptive standard requirements.
3. The components performed satisfactorily during testing and are considered to be suitable for use in the sample tested.

- - - End of Report - - -



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