

Test Report

For

ANSI/CAN/UL9540A

**Test Method for Evaluating Thermal Runaway Fire
Propagation in Battery Energy Storage Systems**

[Unit Level]

Report Number: CQES240200009301

Date of issue: 2024-02-07

Total number of pages: 48

Test object / Model: L3 HVR-60

Applicant's name: Portable Solar LLC d/b/a Sol-Ark

Address: 805 Central Expwy S Allen, TX 75013, USA



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Report Number: CQES240200009301
Manufacturer:
Address:
Factory:
Address:
Test object / Model: L3 HVR-60
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: Original date: 2023-11-16
Sample No.: M1, M2, M3, M4
Test Period: Original date: 2023-12-26 to 2023-12-27
Issuing Laboratory: SGS-CEC New Energy Technology (Chongqing) Co., Ltd.
Address: Building 13 & 14, No. 1839, Ranjun Road, Shuangfu Street, Jiangjin District, Chongqing, China
Testing location: SGS-CEC New Energy Technology (Chongqing) Co., Ltd.
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Test Result: Refer to summary of test results page for details.
Remark: Test results reported relate only to the items being tested.

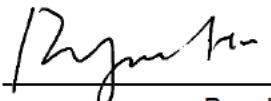
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Confidential level: ☐ Private and Confidential
☐ Public

Tested by / Witness by

Reviewed by


 Kyle Tian
 Project Engineer


 Ryan Hu
 Report Reviewer



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[Summary of Test results]

Cell Level Test
Cell model: [REDACTED]
Report No: 4790509108

Cell Design:	[REDACTED]
Thermal Runaway Methodology:	External heating
Cell Surface Temperature at Gas venting:	181°C
Cell Surface Temperature at Thermal Runaway:	230°C
Gas Composition:	H ₂ , CO ₂ , CO, Hydrocarbon
Lower Flammability Limit:	8.25 Vol% at ambient temperature, 6.73 Vol% at 181°C
Burning Velocity:	97.8 cm/s
Pmax:	0.70533 MPa
Thermal Runaway was Induced in the Cell or not:	Induced
Cell Vent Gas is Flammable or not in Air:	Flammable

Module Level Test
Module model: L3 HVR-5.1kWH
Report No: CQES240200010301

Module Design:	L3 HVR-5.1kWH
Thermal Runaway Methodology:	External heating using film heater
External Flaming:	External flaming observed
Locations of Flame Venting:	External Flame extension observed
Flying Debris:	No flying debris observed
Peak smoke release rate:	0.533 m ² /s
Gas Generation and Composition:	H ₂ , Hydrocarbon, CO ₂
Thermal Runaway are Contained by the Module Design or not:	Flaming propagation outside the enclosure were observed.
Cell Vent Gas is Flammable or not:	Flammable
Other Description:	N/A
Test Video file:	Archived by Applicant

Unit Level Test
Unit model: L3 HVR-60
Report No: CQES240200009301

Unit Design:	L3 HVR-60
Thermal Runaway Methodology:	External heating
External Flaming:	No external flaming observed
Locations of Flame Venting:	No flame venting observed
Flying Debris:	No flying debris observed
Explosion or not:	No explosion observed
Max. Surface Temperature of Module in Target BESS Unit:	11 °C
Max. Temperature Rise on Wall Surfaces:	0.1 °C
Thermal Runaway are Contained by the Unit Design or not:	Contained by the unit design
Cell Vent Gas is Flammable or not:	Flammable
Heat Flux in the Center of Egress:	N/A
The Concentration of Flammable Gas:	Mainly H ₂ , Hydrocarbon
Test Video File:	Archived by Applicant

Remark:

- This report only evaluated unit level test which is listed inside the dotted box.
- All test data were copied from original SGS report No. CQES231100057501, dated 2024-01-10, with following changes and/or additions:
 - Changed the applicant's name and address.
 - Changed battery system from '[REDACTED]' and '[REDACTED]' to model No. to L3 HVR-60.
 - Added page 10 external view photo of Battery system for model No.: L3 HVR-60.
 - Added peg 7 external view photo of Battery module for model No.: L3 HVR-5.1kWH.



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[Test object Description]

Table 1: Description of component cell

Model:		
Manufacturer:		
Nominal capacity:	102 Ah	
Nominal voltage:	3.2 V	
Chemistry:	Lithium-ion, LiFePO ₄	
Standard charge current:	50 A	
Standard discharge current:	50 A	
Maximum charge voltage:	3.9 V	
Cut-off Voltage:	1.9 V	
Charge temperature range:	0 to 65 °C	
Discharge temperature range:	-30 to 65 °C	
External dimensions:	T×W×H =(50.1±0.5) mm×(160.0±0.8) mm ×(115.7±0.5) mm	
Weight:	(1985±100) g	
UL 1973 compliant:	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: UL file No. MH63503
UL 9540A report provide:	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: UL test report No. 4790509108



Figure 1. View 01 of component cell



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Figure 2. View 02 of component cell



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Table 2: Description of battery module

Model:	L3 HVR-5.1kWH	
Manufacturer:		
Nominal capacity:	51.2 Ah	
Nominal voltage:	100 Vd.c.	
Maximum charge current:	100 A	
Maximum discharge current:	100 A	
Maximum charge voltage:	57.6 V	
Cut-off Voltage:	43.2 V	
Charge temperature range:	0 °C to 55 °C	
Discharge temperature range:	-20 °C to 55 °C	
Module configuration:	16S	
External dimensions:	570 mm x 495 mm x 135 mm	
Enclosure material:	Metal	
Weight:	Approx. 45.0kg	
UL 1973 compliant:	<input type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: N/A



Figure 3. View of battery module (GE-F-PACK5.1-D)



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Figure 3a. View of battery module to (L3 HVR-5.1kWH)



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Table 3: Description of battery unit

Model:	L3 HVR-60	
Manufacturer:		
Rated capacity:	100 Ah	200 Ah
Maximum charge current:	100 A	100 A
Maximum discharge current:	100 A	100 A
Standard charge current:	50 A	50 A
Standard discharge current:	50 A	50 A
Charge operating temperature:	0 to 55 °C	
Discharge operating temperature:	-20 to 55 °C	
Number of battery modules	12S	6S2P
Dimensions	735 mm * 1045 mm * 2235 mm	
Weight	Approx. 1015 kg	
Fire suppression system contain	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: Model No.: JAD300-U01UR UL Cer.: UL-CA-2328906-0
UL 1973 compliant:	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: SGS contract No.: 801898
UL 9540 compliant:	<input type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: N/A
Supplementary information: 1. GE-FH60 are battery systems consists of 12 battery modules and one control box in series. GE-FL60 are two battery systems in parallel as a group, 6 groups in series, cased by metallic enclosure. 2. Two battery unit models are identical except for series or parallel form of modules. 3. In this report, model L3 HVR-60 was tested as representative, and no further testing is considered necessary for other models.		



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Figure 4. View of battery unit ()



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Figure 4a. View of battery unit (L3 HVR-60)



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Figure 5. Internal view of battery unit (L3 HVR-60)



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Figure 6. External view of battery module

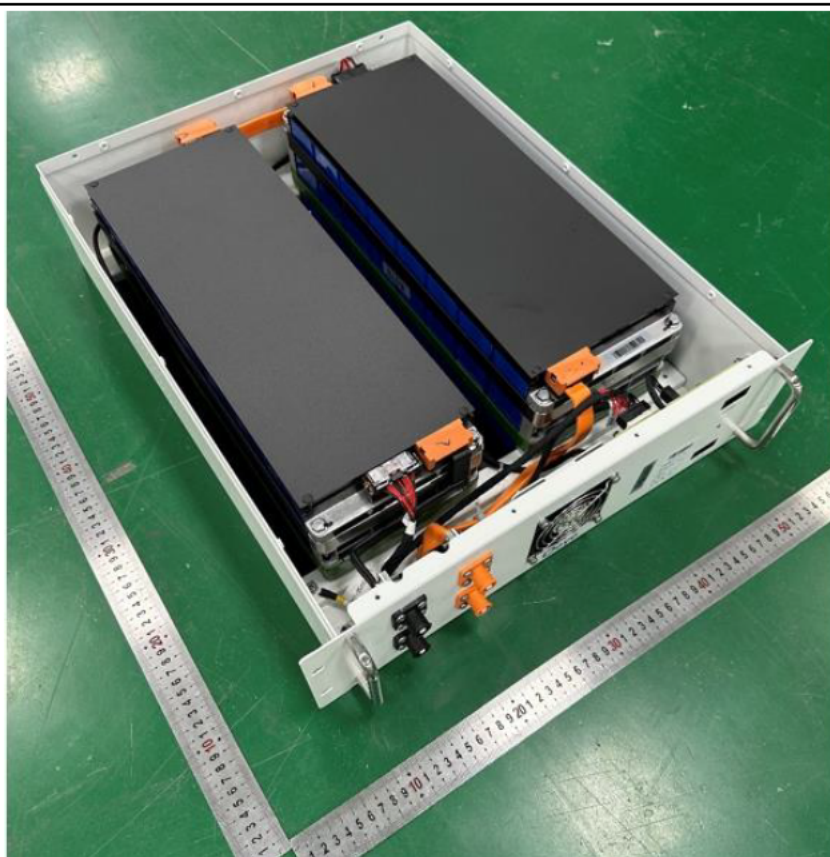


Figure 7. Internal view of battery module



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Figure 8. External view of control box



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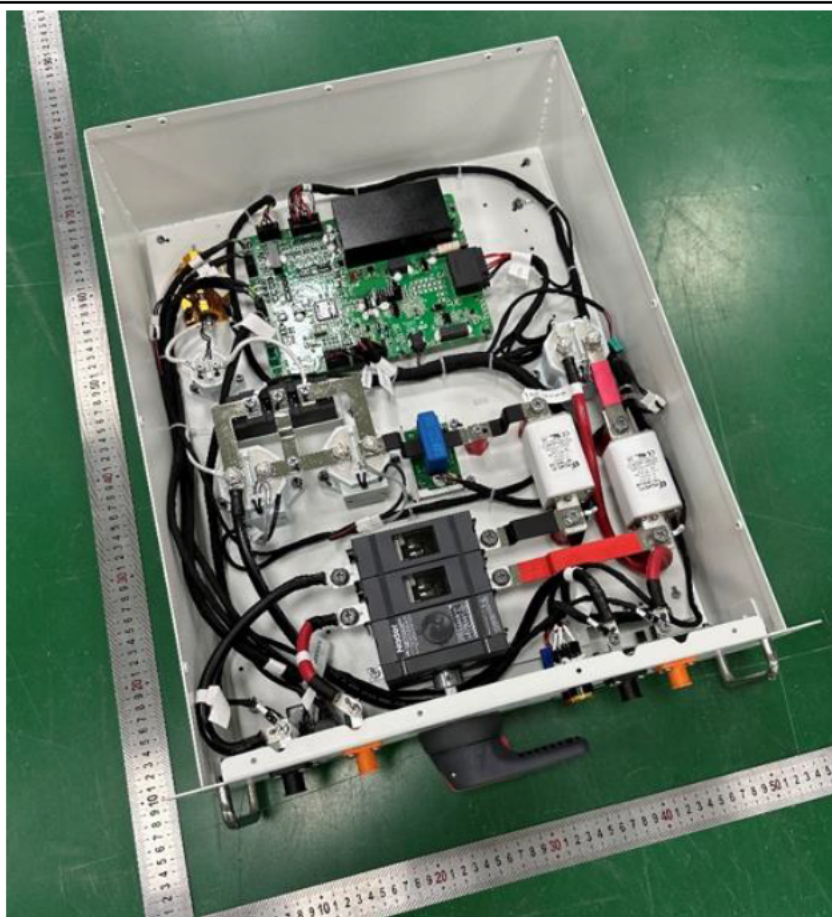


Figure 9. Internal view of control box



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[Description of thermal runaway methodology]

Sample and test configuration

The unit level test shall be conducted with BESS (Battery Energy Storage System) units installed as described in the manufacturer's instructions and this section.

The unit level test requires one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation. Tests conducted for indoor floor mounted installations shall be considered representative of both indoor floor mounted and outdoor ground mounted installations with fire propagation hazards and separation distances between initiating and target units representative of the installation. Tests shall be conducted indoors with fire propagation hazards and separation distances between initiating and target units representative of the installation. The results of such tests shall be considered to also represent an outdoor installation.

Depending upon the configuration and design of the BESS (e.g. the BESS is composed of multiple separate parts within separate enclosures), this testing to determine fire characterization can be done at the battery system level. The suitability of this approach shall be determined based upon the overall design of the BESS and an analysis of the battery system as representative of the overall BESS for fire characterization concerns.

The initiating BESS unit shall contain components representative of a BESS unit in a complete installation. Combustible components that interconnect the initiating and target BESS units shall be included.

Target BESS units shall include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components. The target BESS unit module enclosures do not need to contain cells.

The initiating BESS unit shall be at the maximum operating state of charge (MOSOC), in accordance with the manufacturer's specifications, for conducting the tests in this standard. After charging and prior to testing, the initiating BESS shall rest for a maximum period of 8 h at room ambient.

If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT. If the BESS unit is provided with an optional integral fire suppression system, the system shall not be provided on the DUT.

Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing. This does not include a fire suppression control in accordance with UL 840 that is external to the BESS, but provided as part of an integral fire suppression system.

Table 4: Integral fire suppression system information

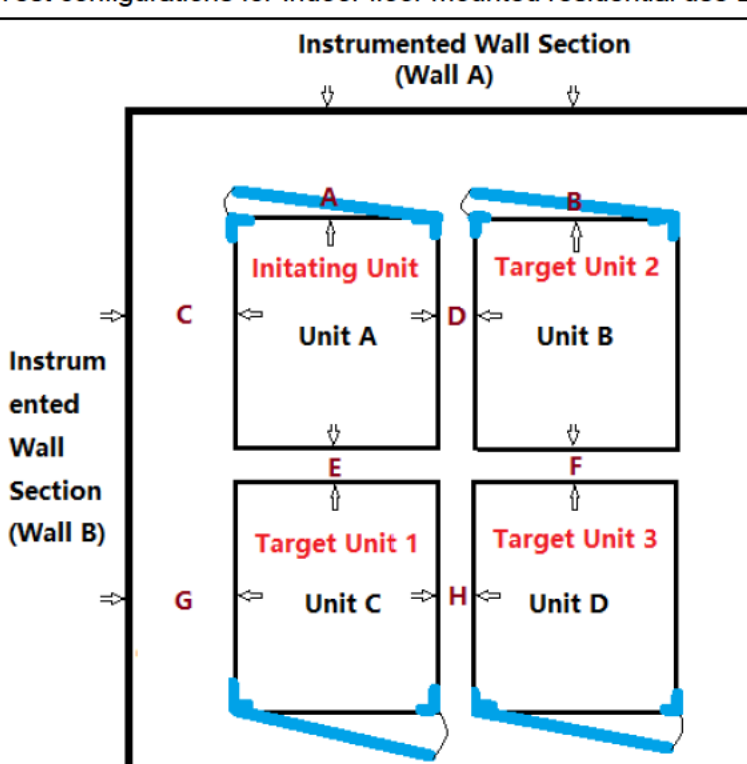
Integral fire suppression system information	Aerosol unit Model No.: JAD300-U01UR Manufacturer: Hebei Jiandun Fire Technology Co., Ltd.
Standard or optional	<input checked="" type="checkbox"/> Standard / <input type="checkbox"/> optional / <input type="checkbox"/> N/A
Test with fire suppression or not	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No



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Table 5: BESS installations/ Test configurations

Description: N/A		
<input checked="" type="checkbox"/> a) Indoor floor mounted non-residential use BESS		
<input type="checkbox"/> b) Indoor floor mounted residential use BESS		
<input type="checkbox"/> c) Outdoor ground mounted non-residential use BESS		
<input type="checkbox"/> d) Outdoor ground mounted residential use BESS		
<input type="checkbox"/> e) Indoor wall mounted non-residential use BESS		
<input type="checkbox"/> f) Indoor wall mounted residential use BESS		
<input type="checkbox"/> g) Outdoor wall mounted non-residential use BESS		
<input type="checkbox"/> h) Outdoor wall mounted residential use BESS		
<input type="checkbox"/> i) Rooftop garage non-residential use BESS		
<input type="checkbox"/> j) Open garage non-residential use BESS		
Test configurations for Indoor floor mounted residential use BESS		
	A	600 mm
	B	600 mm
	C	600 mm
	D	100 mm
	E	100 mm
	F	100 mm
	G	600 mm
	H	100 mm



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Unit level Test method description

☒ Test method – Indoor floor mounted BESS units

Samples and test configurations are in accordance with Table 5. During the test, the test room environment shall be controlled to prevent drafts that may affect test results. At the start of the test, the room ambient temperature shall not be less than 10°C (50°F) nor more than 32°C (90°F).

Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units shall be closed, latched and locked at the beginning and duration of the test.

The initiating BESS unit shall be positioned adjacent to two instrumented wall sections.

Instrumented wall sections shall extend not less than 1.6 ft (0.49 m) horizontally beyond the exterior of the target BESS units.

The surface of the instrumented wall sections shall be covered with 16-mm (5/8-in) gypsum wall board and painted flat black. The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.

The light transmission in the calorimeter's exhaust duct 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.

The chemical and convective heat release rates shall be measured for the duration of the test. The heat release rate measurement system shall be calibrated using an atomized heptane diffusion burner. The calibration shall be performed using flows of 3.8, 7.6, 11.4 and 15.2 L/min (1, 2, 3 and 4 gpm) of heptane.

The convective heat release rate shall be measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct. the convective heat release rate shall be calculated using the following equation:

$$HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^T C_p dT$$

The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation.

Separation distances shall be specified by the manufacturer for distance between:

- The BESS units and the instrumented wall sections; and
- Adjacent BESS units.

Wall surface temperature measurements shall be collected for BESS intended for installation in locations with combustible construction. If the intended installation is composed completely of noncombustible construction in which wall assemblies, cables, wiring and any other combustible materials are not to be present in the BESS installation, then the report should note that the installation shall contain no combustible construction and that surface temperature rises can be deemed not applicable.

Wall surface temperatures shall be measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller, Type-K exposed junction thermocouples. The thermocouples for measuring the temperature on wall surfaces shall be horizontally positioned in the wall locations anticipated to receive the greatest thermal exposure from the initiating BESS unit.



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Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires. The thermocouple tip shall be depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement and held in thermal contact with the surface at that point by the use of pressure-sensitive paper tape.

Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall:

- a) Both are collinear with the vertical thermocouple array;
- b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and
- c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.

Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:

- a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and
- b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.

For non-residential use BESS, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge positioned at the mid height of the initiating unit in the center of the accessible means of egress.

No. 24-gauge or smaller, Type-K exposed junction thermocouples shall be installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module. Each non-initiating module enclosure within the initiating BESS unit shall be instrumented with at least one No. 24-gauge or smaller Type-K thermocouple(s) to provide data to monitor the thermal conditions within non-initiating modules. Additional thermocouples shall be placed to account for convoluted enclosure interior geometries.

For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator. The cheesecloth shall be untreated cotton cloth running 26 – 28 m²/kg with a count of 28 – 32 threads in either direction within a 6.45 cm² (1 in²) area.

An internal fire condition in accordance with the module level test shall be created within a single module in the initiating BESS unit:

- a) The position of the module shall be selected to present the greatest thermal exposure to adjacent modules (e.g. above, below, laterally), based on the results from the module level test; and
- b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same as that used to initiate and propagate thermal runaway within the module level test.

Thermal runaway methodology for module level test:

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

The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct. 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 2.0 m(6.6 ft), or equivalent gas analyzer. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.

The hydrocarbon content of the vent gas shall be measured using flame ionization detection.

The test shall be terminated if:



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- a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;
- b) The fire propagates to adjacent units or to adjacent walls; or
- c) A condition hazardous to test staff or the test facility requires mitigation.

For residential use systems, the gas collection data gathered shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.



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Test configuration description



Figure 10a. View 01 of BESS units in testing room



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Illustration of initiating BESS unit

Description: N/A



Figure 10b. View 02 of BESS units in testing room



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Illustration of initiating module in BESS

Description: Module 7 was selected as initiating module.



Figure 10c. View of initiating module in initiating BESS unit



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Thermal runaway initiation method used including number and locations of cells for initiating thermal runaway

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 until cell thermal runaway occurs. Max. power of the film heaters is 194W.

Number of cells for initiating thermal runaway:

Single cell 100 Ah

Locations of cells for initiating thermal runaway:

The battery module consists of 16 cells, which are connected in series. Cell 13 (as shown in Figure 11b & 12) was selected as the initiating cell. Two film heater was placed on large surfaces of cell 13.

Other description : N/A

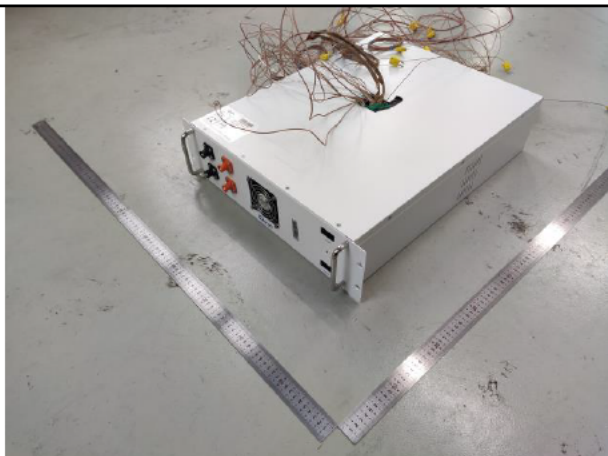


Figure 11a. External view of initiating module.

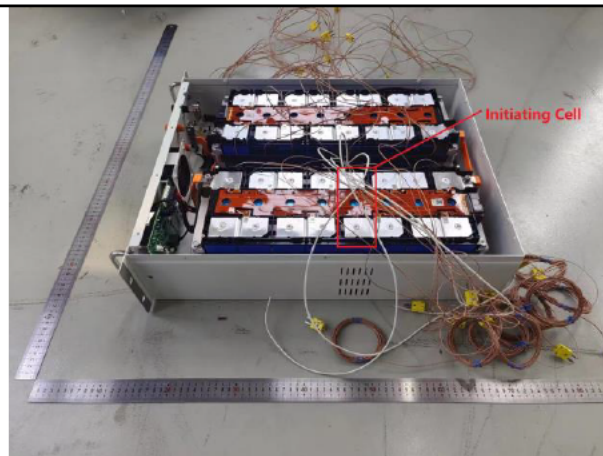


Figure 11b. Internal view of initiating module.

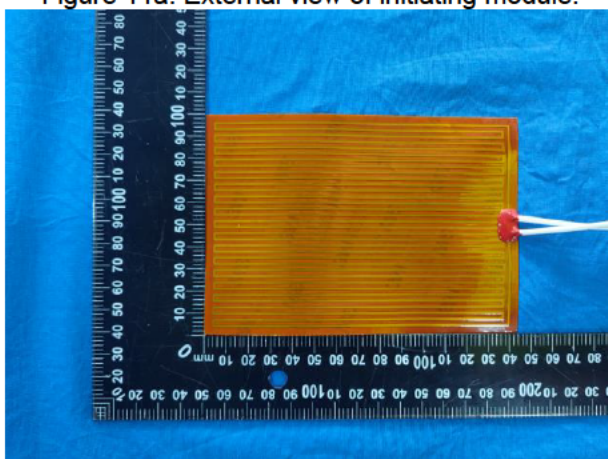


Figure 11c. View of external heater.



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Illustration of external heaters and thermocouple locations in initiating module

Description : N/A

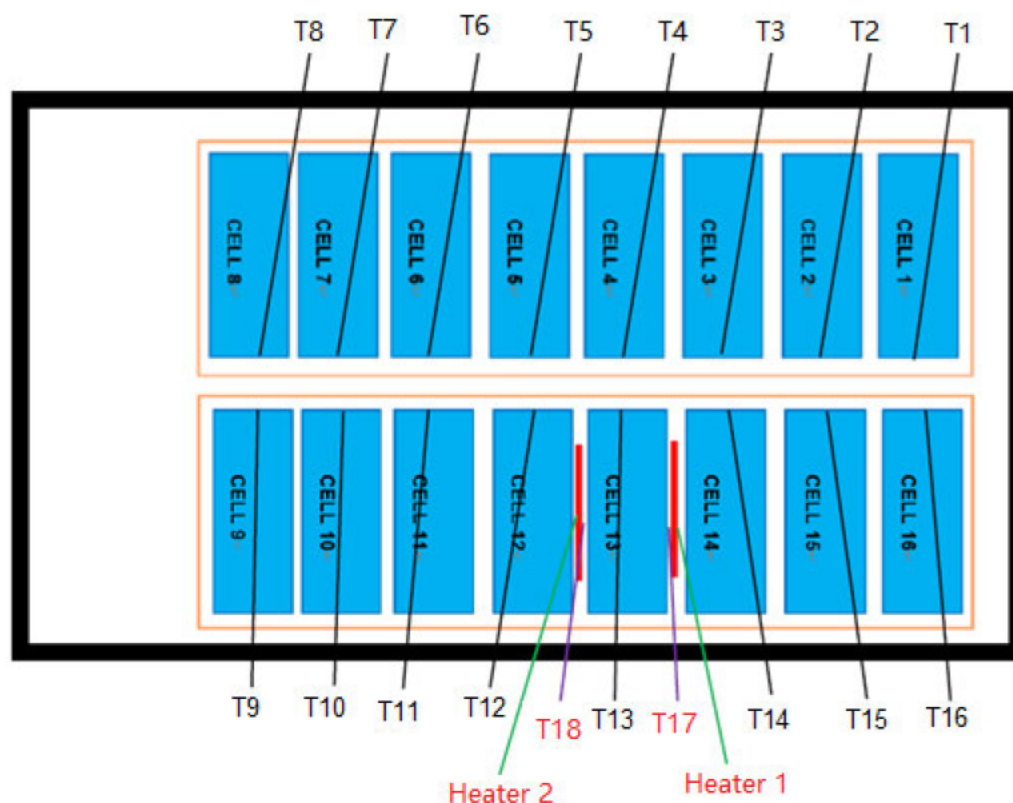


Figure 12. Schematic diagram of external heater and thermocouple locations in the initiating module. (T1-T18 represent thermocouple 1 to 18, and H1, H2 represent heater 1 and heater 2.)



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Positioning of units within testing room

Test Start Time: 2023-12-26 20:14:51

Initial Ambient Test Temperature: 11.5°C

Initial Relative Humidity: 53.6%RH

Description: N/A



Figure 13. View of positioning of BESS units in testing room.



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Table 6: Thermocouple placement

Thermocouple ID	Description of location	Remark
CH2004	Side surface B of Cell 1	T1, in initiating module
CH2005	Side surface B of Cell 2	T2, in initiating module
CH2006	Side surface B of Cell 3	T3, in initiating module
CH2007	Side surface B of Cell 4	T4, in initiating module
CH2008	Side surface B of Cell 5	T5, in initiating module
CH2009	Side surface B of Cell 6	T6, in initiating module
CH2101	Side surface B of Cell 8	T8, in initiating module
CH2102	Side surface A of Cell 9	T9, in initiating module
CH2103	Side surface A of Cell 10	T10, in initiating module
CH2104	Side surface A of Cell 11	T11, in initiating module
CH2105	Side surface A of Cell 12	T12, in initiating module
CH2106	Side surface A of Cell 13	T13, in initiating module
CH2107	Side surface A of Cell 14	T14, in initiating module
CH2108	Side surface A of Cell 15	T15, in initiating module
CH2109	Side surface A of Cell 16	T16, in initiating module
CH2110	Large surface of cell 13, between cell surface and Heater 1	T17, in initiating module
CH2201	Large surface of cell 13, between cell surface and Heater 2	T18, in initiating module
CH2304	Ambient temperature	AT
CH2202	Top enclosure of module 6 in unit A	UA1
CH2203	Front enclosure of module 6 in unit A	UA2
CH2204	Top enclosure of module 7 in unit A	UA3
CH2205	Front enclosure of module 7 in unit A	UA4
CH2206	Top enclosure of module 8 in unit A	UA5
CH2207	Front enclosure of module 8 in unit A	UA6
CH2208	Right side enclosure of module 6 in unit B	UB1
CH2209	Right side enclosure of module 7 in unit B	UB2
CH2210	Right side enclosure of module 8 in unit B	UB3



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CH2301	Rear surface of module 6 in unit C	UC1
CH2302	Rear surface of module 7 in unit C	UC2
CH2303	Rear surface of module 8 in unit C	UC3
CH0001	No. 1 of Instrumented Wall A	WA 1
CH0002	No. 2 of Instrumented Wall A	WA 2
CH0003	No. 3 of Instrumented Wall A	WA 3
CH0004	No. 4 of Instrumented Wall A	WA 4
CH0005	No. 5 of Instrumented Wall A	WA 5
CH0006	No. 6 of Instrumented Wall A	WA 6
CH0007	No. 7 of Instrumented Wall A	WA 7
CH0008	No. 8 of Instrumented Wall A	WA 8
CH0009	No. 9 of Instrumented Wall A	WA 9
CH0010	No. 10 of Instrumented Wall A	WA 10
CH0101	No. 11 of Instrumented Wall A	WA 11
CH0102	No. 12 of Instrumented Wall A	WA 12
CH0103	No. 13 of Instrumented Wall A	WA 13
CH0104	No. 14 of Instrumented Wall A	WA 14
CH0105	No. 15 of Instrumented Wall A	WA 15
CH0106	No. 16 of Instrumented Wall A	WA 16
CH0107	No. 17 of Instrumented Wall A	WA 17
CH0108	No. 18 of Instrumented Wall A	WA 18
CH0109	No. 19 of Instrumented Wall A	WA 19
CH0110	No. 20 of Instrumented Wall A	WA 20
CH0201	No. 21 of Instrumented Wall A	WA 21
CH0202	No. 22 of Instrumented Wall A	WA 22
CH0203	No. 23 of Instrumented Wall A	WA 23
CH0204	No. 24 of Instrumented Wall A	WA 24
CH0205	No. 25 of Instrumented Wall A	WA 25
CH0206	No. 26 of Instrumented Wall A	WA 26
CH0207	No. 27 of Instrumented Wall A	WA 27
CH0208	No. 28 of Instrumented Wall A	WA 28
CH0209	No. 29 of Instrumented Wall A	WA 29



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CH0210	No. 30 of Instrumented Wall A	WA 30
CH0301	No. 31 of Instrumented Wall A	WA 31
CH0302	No. 32 of Instrumented Wall A	WA 32
CH0303	No. 33 of Instrumented Wall A	WA 33
CH0304	No. 34 of Instrumented Wall A	WA 34
CH0305	No. 35 of Instrumented Wall A	WA 35
CH0306	No. 36 of Instrumented Wall A	WA 36
CH0307	No. 37 of Instrumented Wall A	WA 37
CH0308	No. 38 of Instrumented Wall A	WA 38
CH0309	No. 39 of Instrumented Wall A	WA 39
CH0310	No. 40 of Instrumented Wall A	WA 40
CH0401	No. 41 of Instrumented Wall A	WA 41
CH0402	No. 42 of Instrumented Wall A	WA 42
CH0403	No. 43 of Instrumented Wall A	WA 43
CH0404	No. 44 of Instrumented Wall A	WA 44
CH0405	No. 45 of Instrumented Wall A	WA 45
CH0406	No. 46 of Instrumented Wall A	WA 46
CH0407	No. 47 of Instrumented Wall A	WA 47
CH0408	No. 48 of Instrumented Wall A	WA 48
CH0409	No. 49 of Instrumented Wall A	WA 49
CH0410	No. 50 of Instrumented Wall A	WA 50
CH0501	No. 51 of Instrumented Wall A	WA 51
CH0502	No. 52 of Instrumented Wall A	WA 52
CH0503	No. 53 of Instrumented Wall A	WA 53
CH0504	No. 54 of Instrumented Wall A	WA 54
CH0505	No. 55 of Instrumented Wall A	WA 55
CH0506	No. 56 of Instrumented Wall A	WA 56
CH0507	No. 57 of Instrumented Wall A	WA 57
CH0508	No. 58 of Instrumented Wall A	WA 58
CH0509	No. 59 of Instrumented Wall A	WA 59
CH0510	No. 60 of Instrumented Wall A	WA 60
CH1001	No. 61 of Instrumented Wall A	WA 61



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CH1002	No. 62 of Instrumented Wall A	WA 62
CH1003	No. 63 of Instrumented Wall A	WA 63
CH1004	No. 1 of Instrumented Wall B	WB1
CH1005	No. 2 of Instrumented Wall B	WB2
CH1006	No. 3 of Instrumented Wall B	WB3
CH1007	No. 4 of Instrumented Wall B	WB4
CH1008	No. 5 of Instrumented Wall B	WB5
CH1009	No. 6 of Instrumented Wall B	WB6
CH1010	No. 7 of Instrumented Wall B	WB7
CH1101	No. 8 of Instrumented Wall B	WB8
CH1102	No. 9 of Instrumented Wall B	WB9
CH1103	No. 10 of Instrumented Wall B	WB10
CH1104	No. 11 of Instrumented Wall B	WB11
CH1105	No. 12 of Instrumented Wall B	WB12
CH1106	No. 13 of Instrumented Wall B	WB13
CH1107	No. 14 of Instrumented Wall B	WB14
CH1108	No. 15 of Instrumented Wall B	WB15
CH1109	No. 16 of Instrumented Wall B	WB16
CH1110	No. 17 of Instrumented Wall B	WB17
CH1201	No. 18 of Instrumented Wall B	WB18
CH1202	No. 19 of Instrumented Wall B	WB19
CH1203	No. 20 of Instrumented Wall B	WB20
CH1204	No. 21 of Instrumented Wall B	WB21
CH1205	No. 22 of Instrumented Wall B	WB22
CH1206	No. 23 of Instrumented Wall B	WB23
CH1207	No. 24 of Instrumented Wall B	WB24
CH1208	No. 25 of Instrumented Wall B	WB25
CH1209	No. 26 of Instrumented Wall B	WB26
CH1210	No. 27 of Instrumented Wall B	WB27
CH1301	No. 28 of Instrumented Wall B	WB28
CH1302	No. 29 of Instrumented Wall B	WB29
CH1303	No. 30 of Instrumented Wall B	WB30



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CH1304	No. 31 of Instrumented Wall B	WB31
CH1305	No. 32 of Instrumented Wall B	WB32
CH1306	No. 33 of Instrumented Wall B	WB33
CH1307	No. 34 of Instrumented Wall B	WB34
CH1308	No. 35 of Instrumented Wall B	WB35
CH1309	No. 36 of Instrumented Wall B	WB36
CH1310	No. 37 of Instrumented Wall B	WB37
CH1401	No. 38 of Instrumented Wall B	WB38
CH1402	No. 39 of Instrumented Wall B	WB39
CH1403	No. 40 of Instrumented Wall B	WB40
CH1404	No. 41 of Instrumented Wall B	WB41
CH1405	No. 42 of Instrumented Wall B	WB42
CH1406	No. 43 of Instrumented Wall B	WB43
CH1407	No. 44 of Instrumented Wall B	WB44
CH1408	No. 45 of Instrumented Wall B	WB45
CH1409	No. 46 of Instrumented Wall B	WB46
CH1410	No. 47 of Instrumented Wall B	WB47
CH1501	No. 48 of Instrumented Wall B	WB48
CH1502	No. 49 of Instrumented Wall B	WB49
CH1503	No. 50 of Instrumented Wall B	WB50
CH1504	No. 51 of Instrumented Wall B	WB51
CH1505	No. 52 of Instrumented Wall B	WB52
CH1506	No. 53 of Instrumented Wall B	WB53
CH1507	No. 54 of Instrumented Wall B	WB54
CH1508	No. 55 of Instrumented Wall B	WB55
CH1509	No. 56 of Instrumented Wall B	WB56
CH1510	No. 57 of Instrumented Wall B	WB57
CH2001	No. 58 of Instrumented Wall B	WB58
CH2002	No. 59 of Instrumented Wall B	WB59
CH2003	No. 60 of Instrumented Wall B	WB60

Thermocouple information:
Type K, 24AWG



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[Description of test results]

Table 7: Overview of test timeline and key events

Time (HH: MM: SS)	Relative Time (HH: MM: SS)	Event ID	Event	Description	Photo Reference
20:14:51	00:00:00	E1	Test Start	--	--
20:18:37	00:03:46	E2	Heater 1 and heater 2 energized	--	--
21:12:49	00:57:58	E3	Initiating Cell Venting	Smoke release observed.	Figure 19
21:14:09	00:59:18	E4	Thermal Runaway Onset	Thermal runaway confirmed through temperature curve. Smoke release observed. Heaters de-energized.	Figure 20
23:14:51	03:00:00	E5	Test Termination	--	--
Test Start Time: 2023-12-26 20:14:51					

Chemical heat release rate versus time

Description: No flaming extension observed outside the DUT.

N/A

Convective heat release rate versus time

Description: N/A

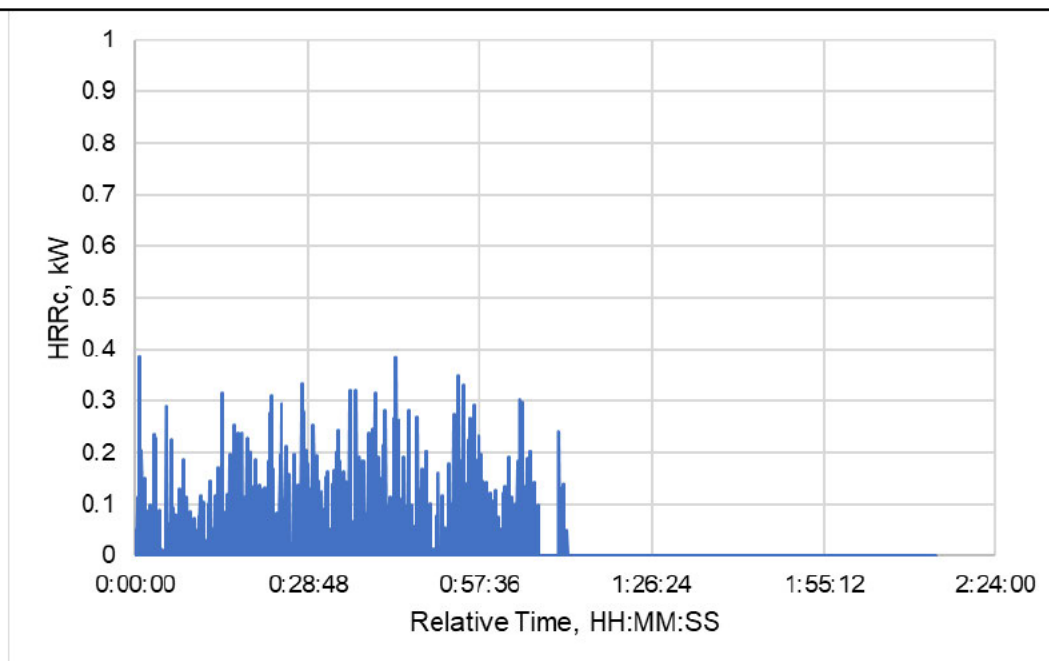


Figure 14. Convective heat release rate versus time



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Maximum incident heat flux on target wall surfaces and surface of target units

Description: N/A

Heat Flux ID	Description of location
CH3407	Surface of instrumented wall A, facing the front surface of module 6 in initiating unit
CH3408	Surface of instrumented wall A, facing the front surface of initiating module (module 7) in initiating unit
CH3409	Surface of instrumented wall B, facing the right sidesurface of module 6 in initiating unit
CH3410	Surface of instrumented wall B, facing the right side surface of initiating module (module 7) in initiating unit
CH3501	Rear side surface of module 7 in target unit (unit C)
CH3502	Right side surface of module 7 in target unit (unit B)



Figure 15. Incident heat flux on instrumented wall surfaces and target units



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Peak smoke release rate and total smoke release data

Description:

1. Peak smoke release rate is 0.486 m²/s during test.
2. Total smoke release is 128.96 m² during test.

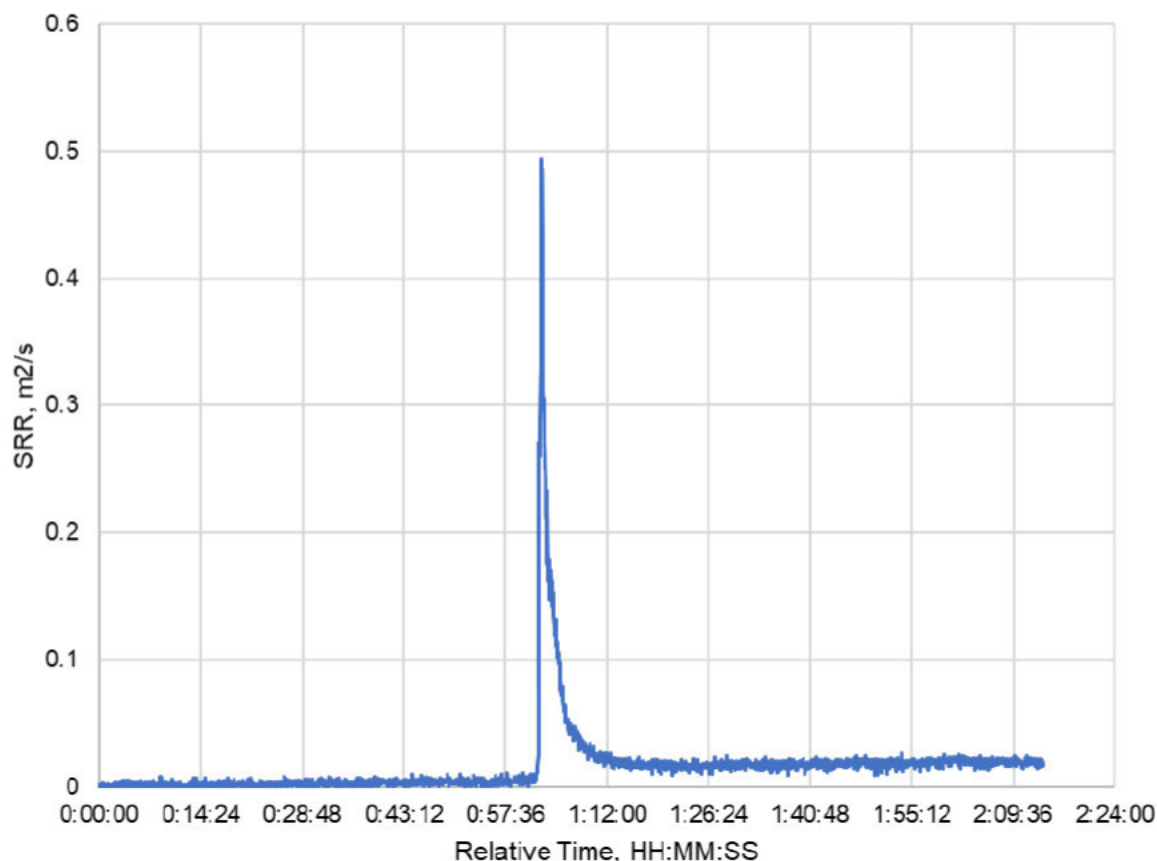


Figure 16. Smoke release rate versus time



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Flammable gas generation and composition

Flammable gas generation: ☒ YES ☐ NO

Description :N/A

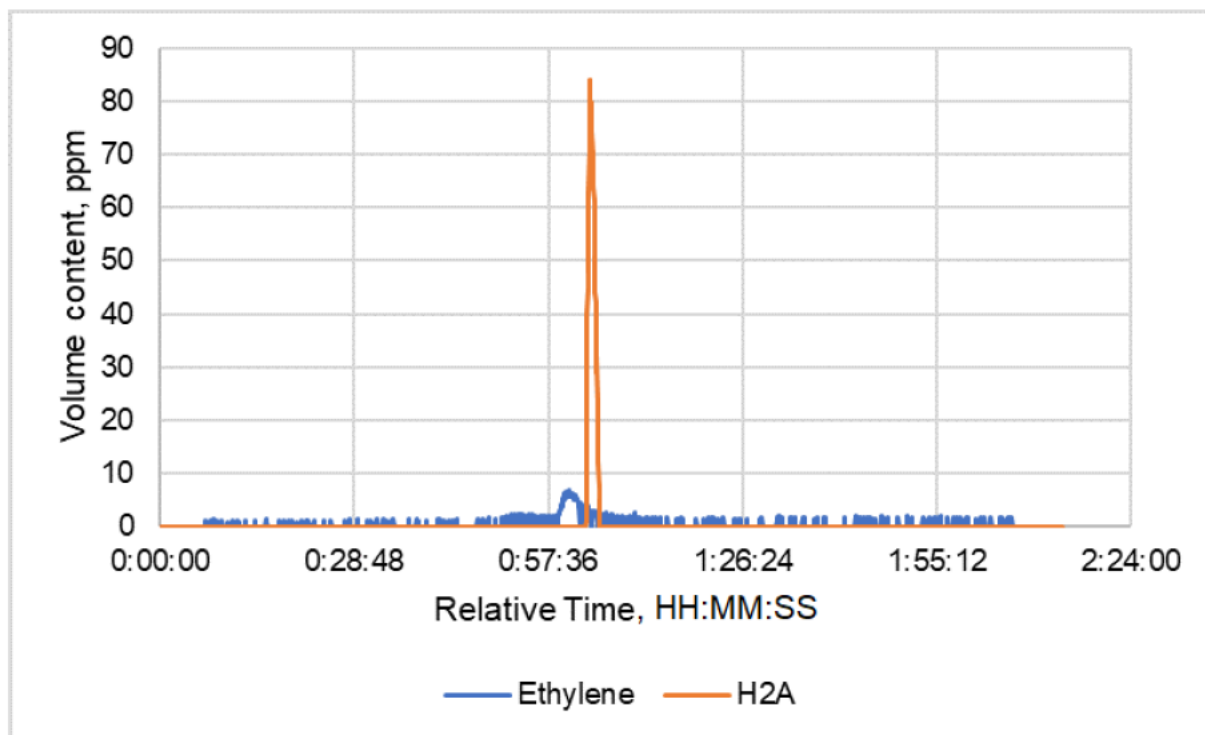


Figure 17. Online flammable gas content measurements during test. (Remark: The content of other hydrocarbons is below the detection limit of the test equipment.)



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Identification/location of module(s) that exhibited thermal runaway within the unit	
Module(s) that exhibited thermal runaway: <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	
Description : Thermal runaway only occurred in initiating mouldle.	
	

Figure 18. Location of cells that exhibited thermal runaway within the unit



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

Other observations during test
Description : No sparks, electrical arcs, flying debris and explosive discharge of gases observed.
<input type="checkbox"/> Sparks <input type="checkbox"/> Electrical arcs <input type="checkbox"/> Flying debris <input type="checkbox"/> Explosive discharge of gases <input type="checkbox"/> Other



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Table 8: Data during test

Module ID	OCV of Battery Module Before Test, (V dc)	OCV of Battery Module After Test, (V dc)	Observation Results
Module 1 (in initiating unit)	54.335	54.333	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 2 (in initiating unit)	54.323	54.321	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 3 (in initiating unit)	54.321	54.319	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 4 (in initiating unit)	54.318	54.316	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 5 (in initiating unit)	54.324	54.323	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 6 (in initiating unit)	54.323	54.319	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 7 (in initiating unit)	54.315	50.270	Gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 8 (in initiating unit)	54.324	54.316	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 9 (in initiating unit)	54.317	54.314	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 10 (in initiating unit)	54.324	54.321	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 11 (in initiating unit)	54.334	54.328	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 12 (in initiating unit)	54.336	54.333	No gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Measured Maximum Temperature Rise of Wall Surface			
Thermocouple ID	CH0502 (WA52)		
Measurements, (°C)	11.2°C (temperature rise: 0.1°C)		



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Location	Surface of Instrumented Wall A, facing the front surface of initiating unit
Limits: $\Delta T \leq 97^{\circ}\text{C}$	
Measured Maximum Surface Temperature of Modules within the Target BESS Units	
Thermocouple ID	CH2303 (UC3)
Measurements, ($^{\circ}\text{C}$)	11.0 $^{\circ}\text{C}$
Location	Rear surface of module 8 in unit C
Limits: $T_{\text{max.}} \leq 181^{\circ}\text{C}$ (Cell surface temperature at gas venting)	
Cheesecloth indicator used or not <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	
Description of cheesecloth indicator after test: .N/A	
Supplementary information: N/A	



Figure 19. Photo of event (E3) during test



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2023年12月26日 星期二 21:14:09



Camera 01

Figure 20. Photo of event (E4) during test



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Figure 21. Photo 01 of after test BESS units



Figure 21a. Photo 02 of after test BESS units



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Figure 21b. Photo 03 of after test_ BESS unit



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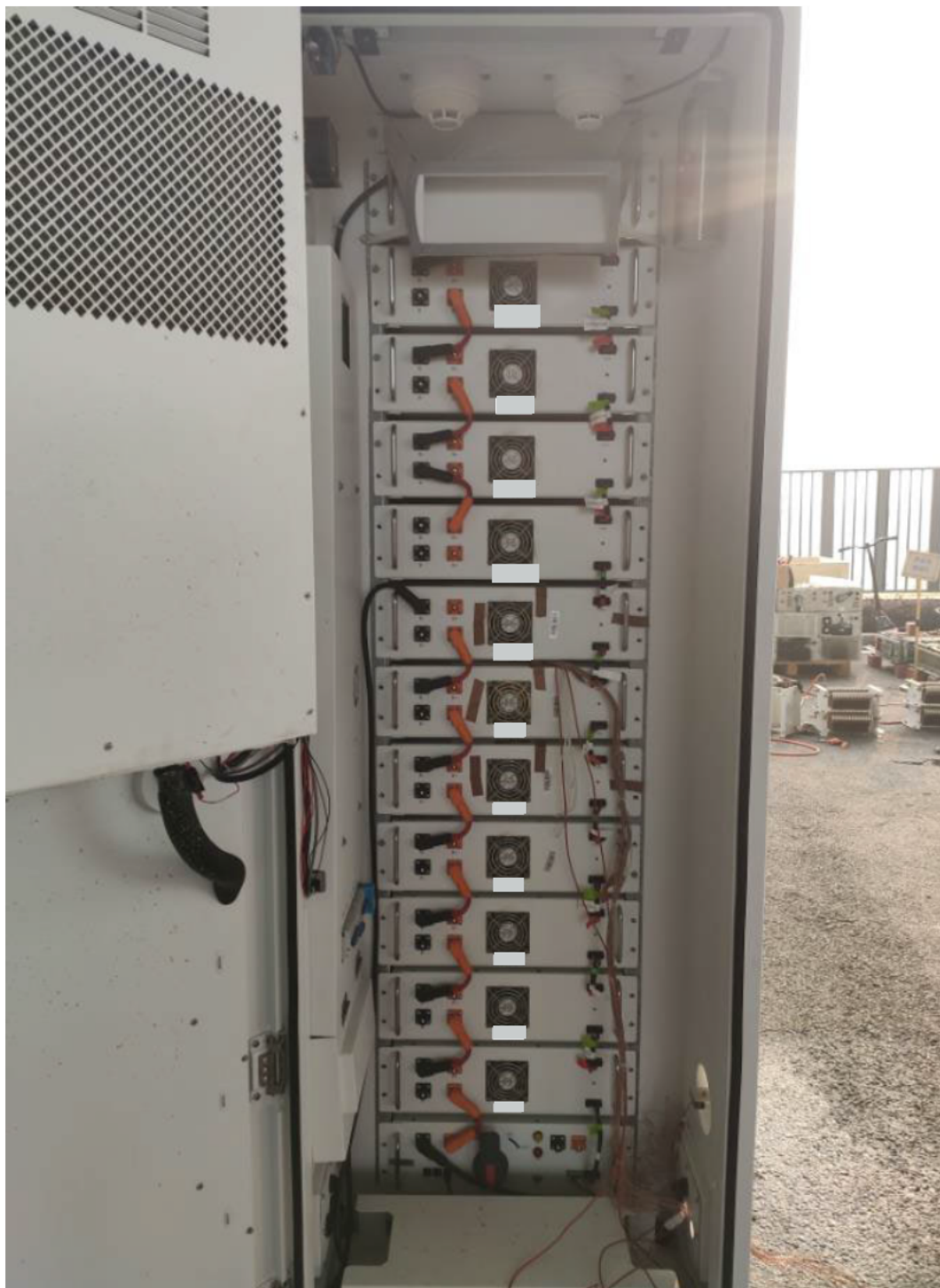


Figure 21c. Photo 04 of after test_ BESS unit



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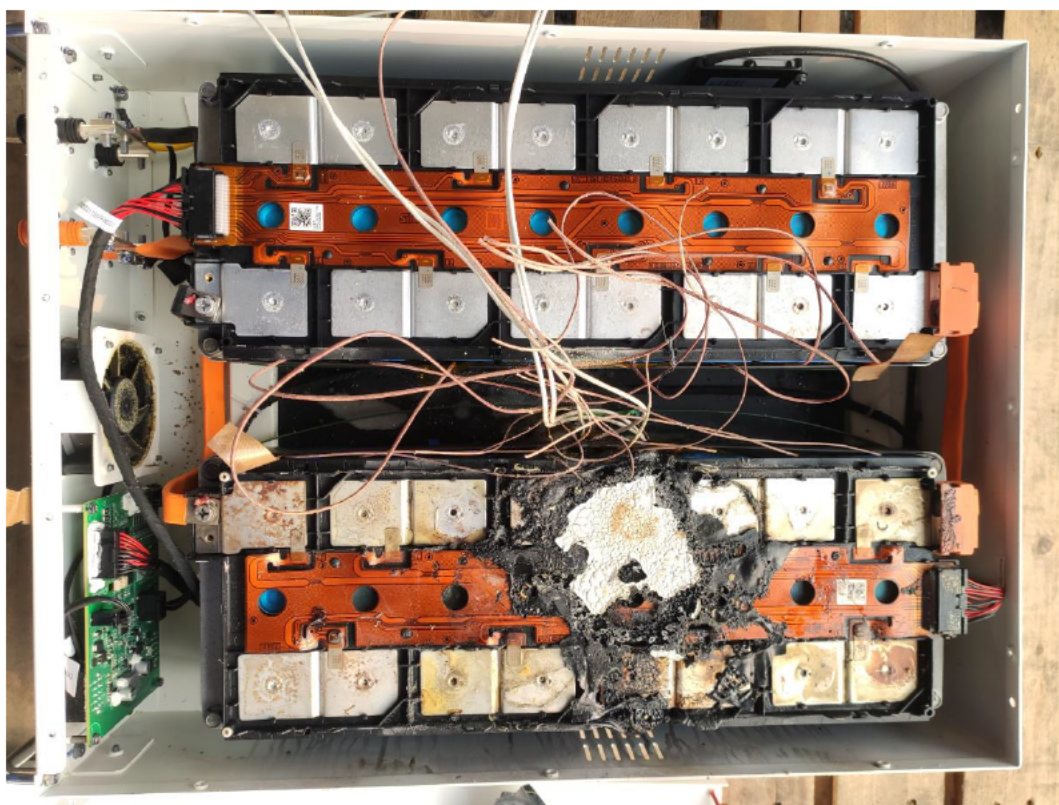


Figure 22. Photo 05 of after test_ initiating module



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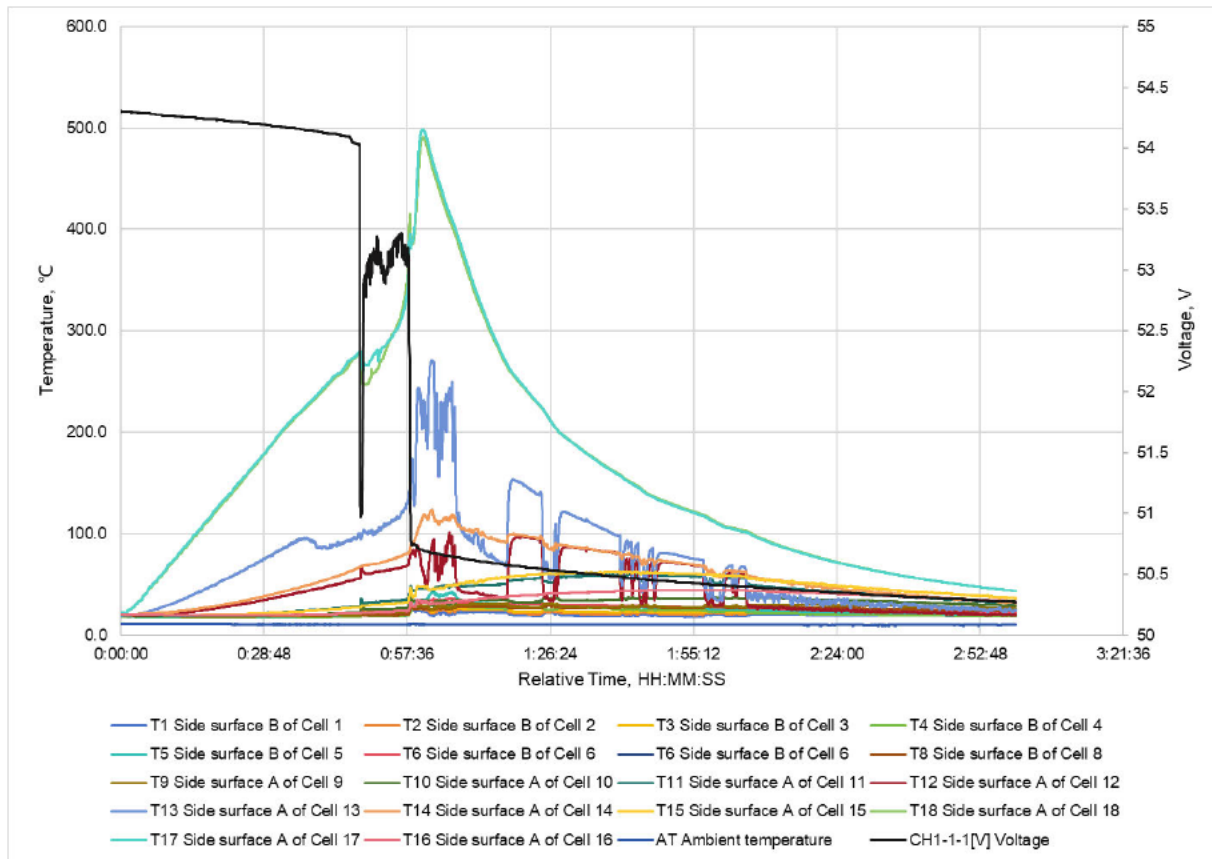


Figure 23. Temperature and voltage measurement results on the initiating module.



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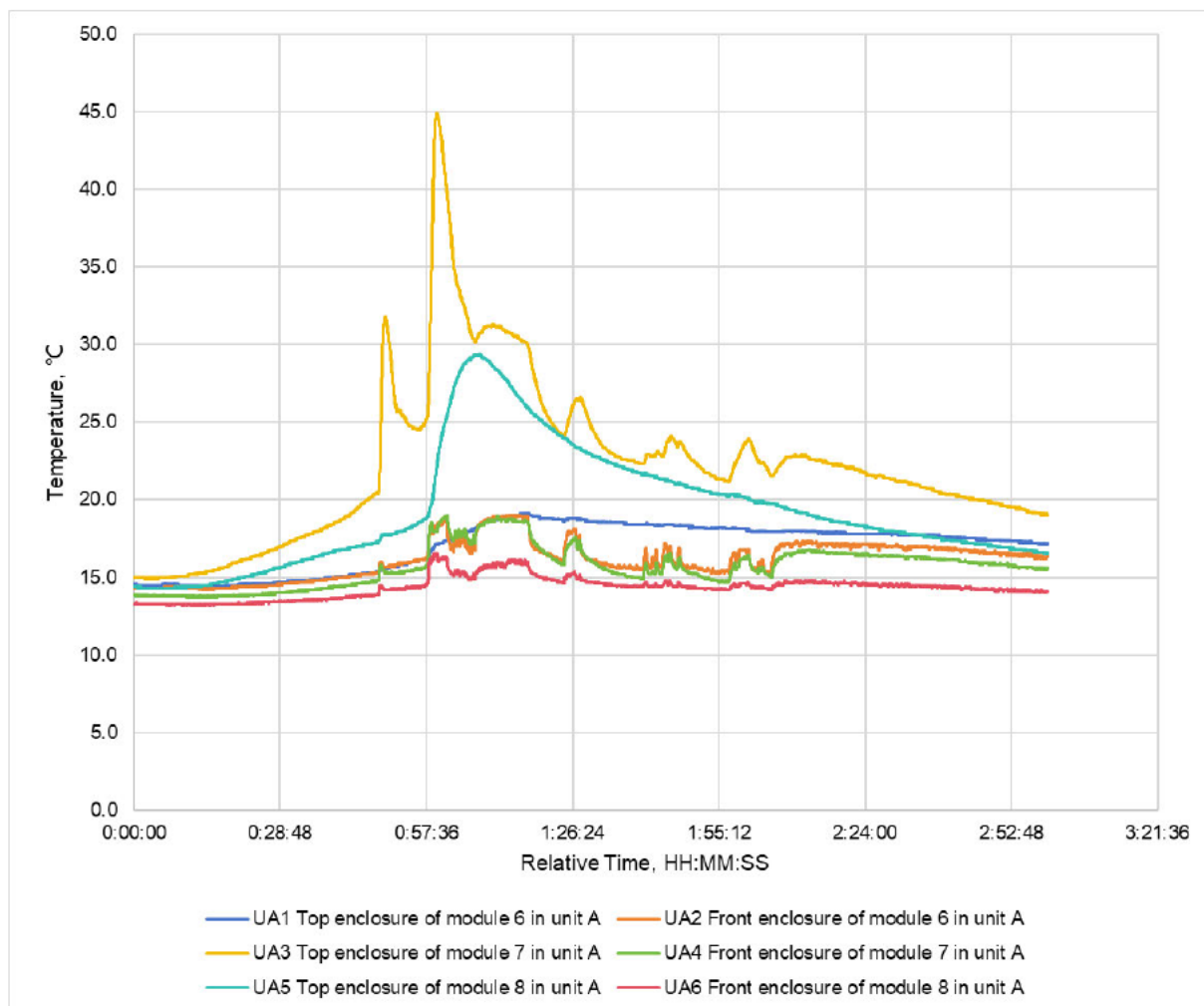


Figure 24. Temperature measurement results on the initiating unit.



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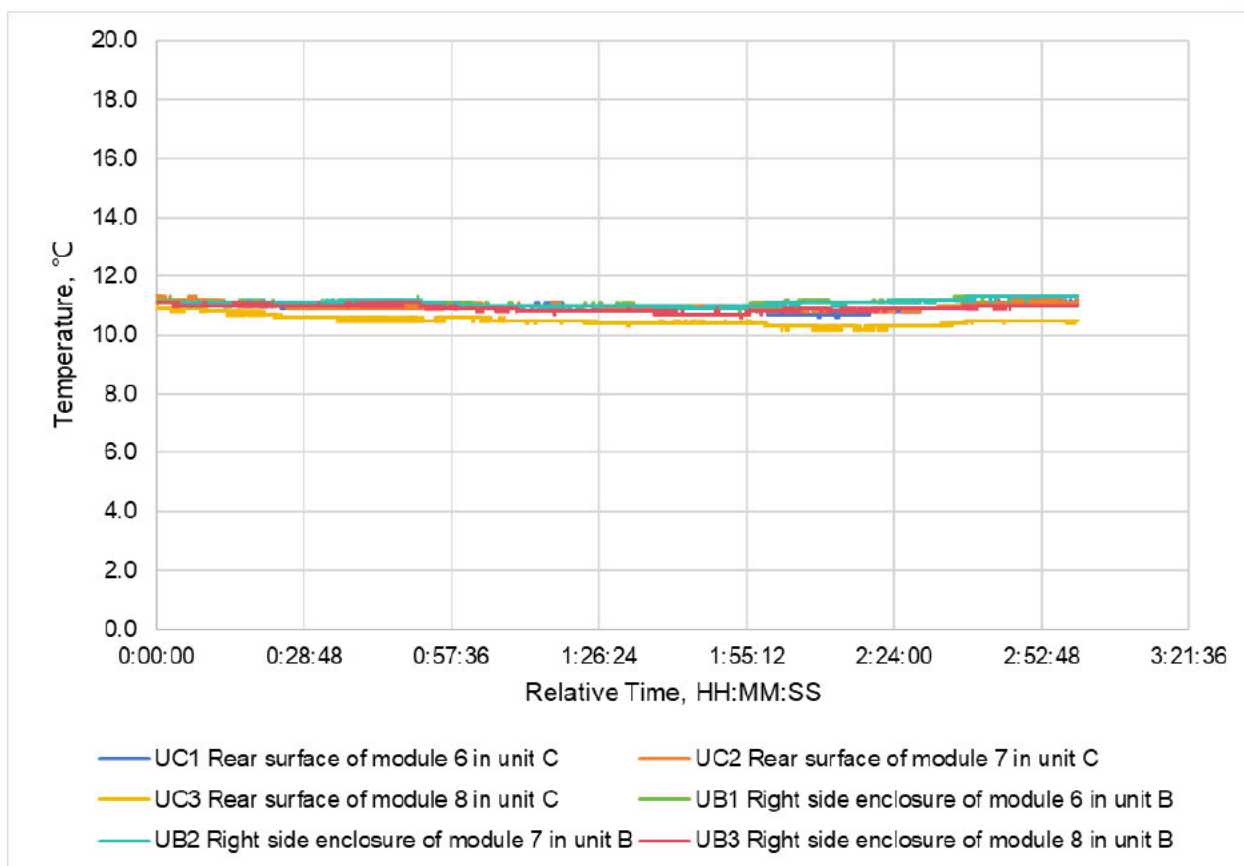


Figure 25. Temperature measurement results on target units.



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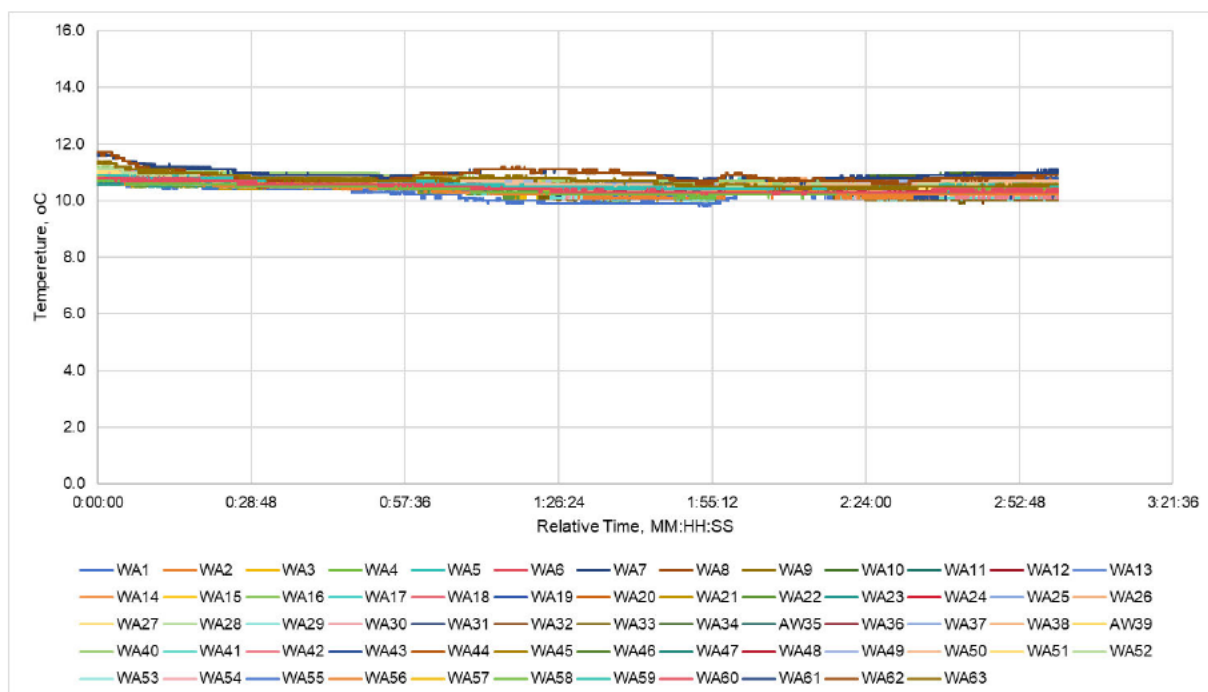


Figure 26. Temperature measurement results on wall A

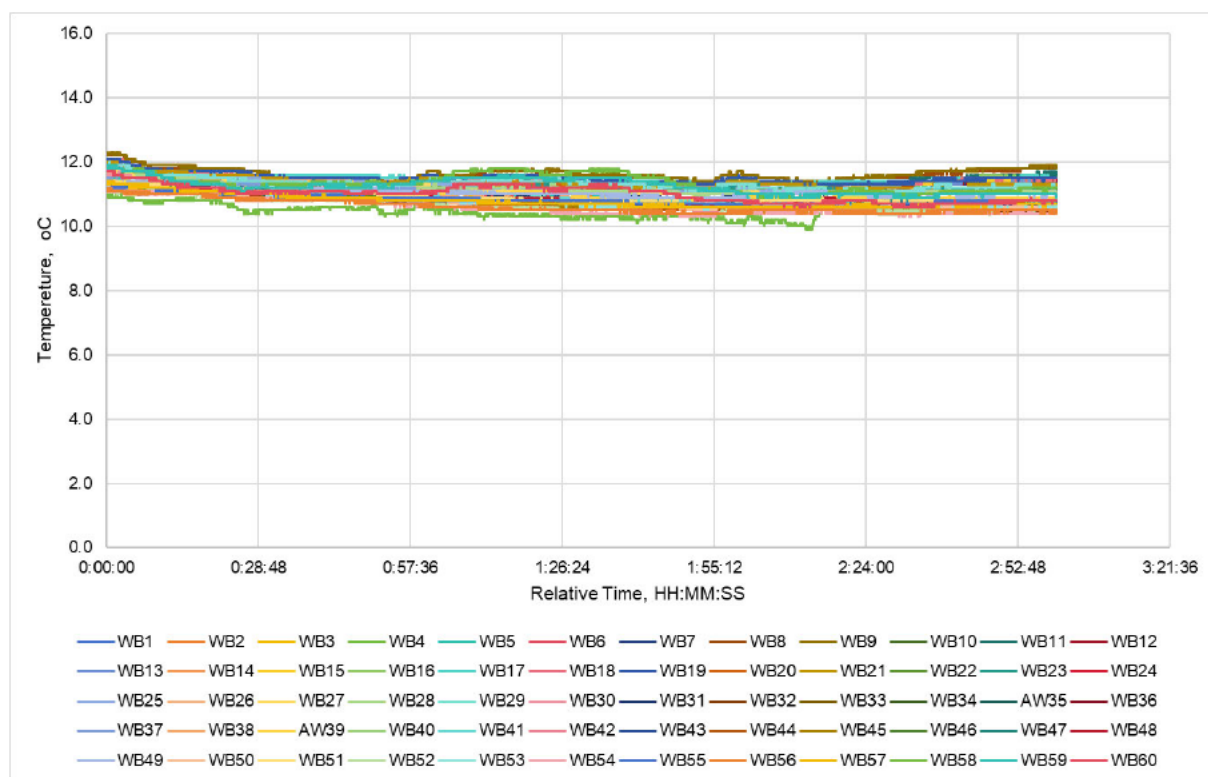


Figure 27. Temperature measurement results on wall B



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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.

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