

Test Report

For

ANSI/CAN/UL9540A

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

Report Number: CQES230900048501

Date of issue: 2023-10-16

Total number of pages: 47

Test object / Model: V-BOX-OC

Applicant's name: Shanghai PYTES Energy Co., Ltd.

**Address: No. 3492 Jinqian Road, Qingcun Town, Fengxian
District, Shanghai, China**



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Report Number: CQES230900048501

Manufacturer: Shanghai PYTES Energy Co., Ltd.

Address: No. 3492 Jinqian Road, Qingcun Town, Fengxian District, Shanghai, China

Factory: Shanghai PYTES Energy Co., Ltd.

Address: No. 3492 Jinqian Road, Qingcun Town, Fengxian District, Shanghai, China

Test object / Model: V-BOX-OC

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: 2023-09-26

Sample No.: M1 to M8

Test Period: 2023-10-07 to 2023-10-11

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.

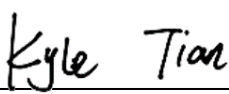
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Confidential level: ☐ Private and Confidential

☐ Public

Tested by / Witness by

Reviewed by



Kyle Tian
Project Engineer



Ryan Hu
Report Reviewer



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[Summary of Test results]

Cell Level Test
Cell model:
Report No.:
790342745

Cell Design:
Thermal Runaway Methodology: External heating using film heater
Cell Surface Temperature at Gas venting: 166 °C
Cell Surface Temperature at Thermal Runaway: 210 °C
Gas Composition: Mainly Hydrocarbon, CO, CO₂, H₂
Lower Flammability Limit: 6.95 % volume in air at the ambient temperature
5.95 % volume in air at 166°C
Burning Velocity: 125 cm/s
Pmax: 98.7 psig
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: V5°, V5°α
Report No:
CQES230800036801

Module Design: V5°, V5°α
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: 6.587 m²/s
Gas Generation and Composition: Mainly Hydrocarbon, CO, CO₂, H₂
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

Unit Level Test
Unit model: V-BOX-OC
Report No:
CQES230900048501

Unit Design: V-BOX-OC
Thermal Runaway Methodology: External heating using thin film
External Flaming: No external flaming observed
Locations of Flame Venting: No flame extension observed
Flying Debris: No flying debris observed
Explosion or not: No explosion observed
Max. Surface Temperature of Module in Target BESS Unit: 29.8 °C
Max. Temperature Rise on Wall Surfaces: 28.5 °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
Cheesecloth Indicator Flaming or not: No flaming or carbonizing of the cheesecloth indicator
Test Video File: Archived by Applicant

Remark:

This report only evaluated unit level test which is listed inside the dotted box.



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[Test object Description]

Table 1: Description of component cell

Model:		
Manufacturer:		
Nominal capacity:	100 Ah	
Nominal voltage:	3.2 Vd.c.	
Chemistry:	Lithium ion, LiFePO ₄	
Maximum charge current:	100 A	
Discharge current:	100 A	
Maximum charge voltage:	3.65 Vd.c.	
Cut-off Voltage:	2.5 Vd.c.	
Charge temperature range:	-10 to 60 °C	
Discharge temperature range:	-20 to 60 °C	
External dimensions:	52.3±1 mm by 148.4±1 mm by 119.0±1 mm.	
Weight:	1.93±0.15kg	
UL 1973 compliant:	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: UL File No.: MH64238
UL 9540A report provide:	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: UL test report: 4790342745



Figure 1. View of component cell



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Table 2: Description of battery module

Model:	V5°, V5°α	
Manufacturer:	Shanghai PYTES Energy Co., Ltd.	
Nominal capacity:	100 Ah	
Nominal voltage:	51.2 Vd.c.	
Standard Charge current:	50 A	
Standard Discharge current:	50 A	
Maximum charge voltage:	57.6 Vd.c.	
Cut-off Voltage:	44.8 Vd.c.	
Charge temperature range:	-10 to 55 °C	
Discharge temperature range:	-10 to 55 °C	
Module configuration:	1P16S	
External dimensions:	W483mm * D530mm * H140mm	
Enclosure material:	Iron	
Weight:	46.2kg	
UL 1973 compliant:	<input checked="" type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: TÜV SUD Cert. No. U10 003364 0018 Rev. 00 Test report No.: 64280236026301

Supplementary information:

1. Modules V5° and V5°α are identical except for Model No., external connector.

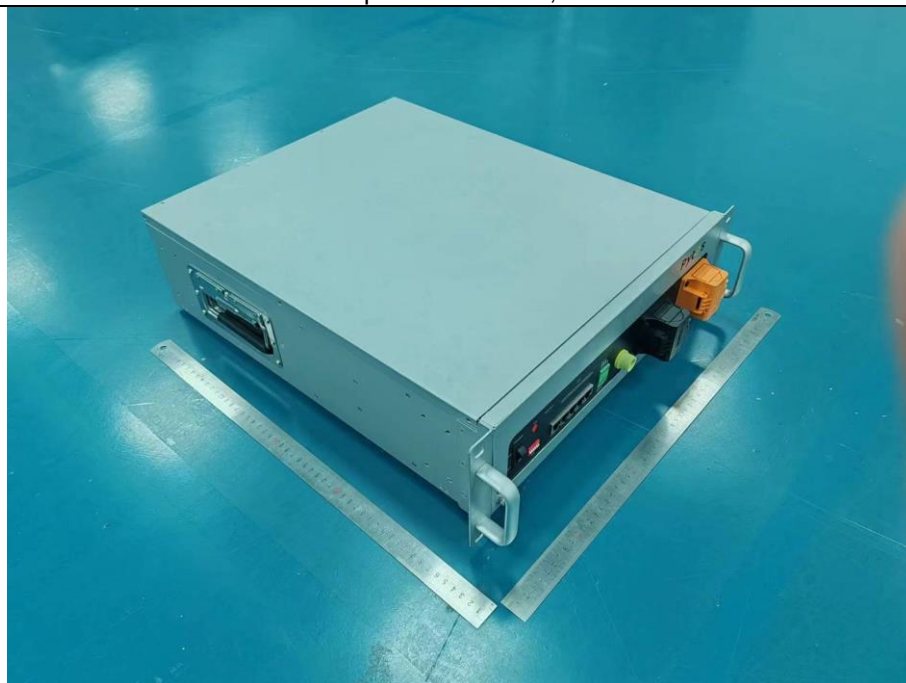


Figure 2. View of battery module (Model No.: V5°)



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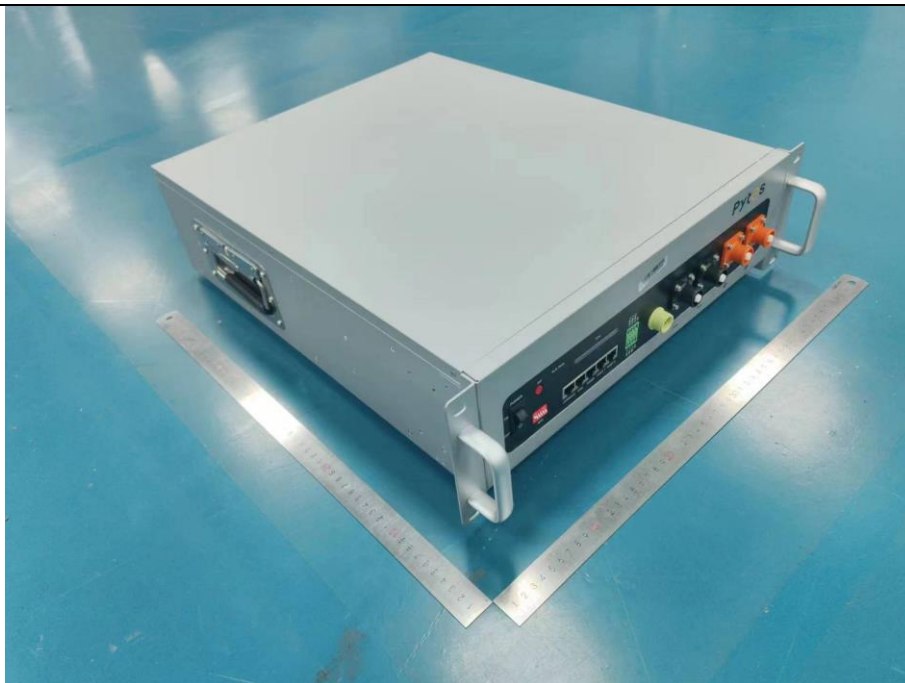


Figure 3. View of battery module (Alternative structure, Model No.: V5°α)



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Table 3: Description of battery unit

Model:	V-BOX-OC	
Manufacturer:	Shanghai PYTES Energy Co., Ltd.	
Nominal capacity:	400 Ah	
Nominal voltage:	51.2 Vd.c.	
Standard Charge current:	200 A	
Standard Discharge current:	200 A	
Maximum Charge current:	400 A	
Maximum Discharge current:	400 A	
Maximum charge voltage:	57.6 Vd.c.	
Cut-off Voltage:	44.8 Vd.c.	
Charge temperature range:	-10 to 55 °C	
Discharge temperature range:	-10 to 55 °C	
Number of modules	4 modules with parallel connection	
Dimensions:	L645mm×W395mm×H1396mm	
Weight:	273.8 kg	
IP Code	IP55	
Enclosure material:	Iron	
Fire suppression system contain	<input type="checkbox"/> Yes / <input checked="" type="checkbox"/> No	Reference: N/A
UL 1973 compliant:	<input type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: N/A
UL 9540 compliant:	<input type="checkbox"/> Yes / <input type="checkbox"/> No	Reference: N/A



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Figure 4. Front View of battery system



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Figure 5. Side View of battery system



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Figure 6. Internal View of battery system



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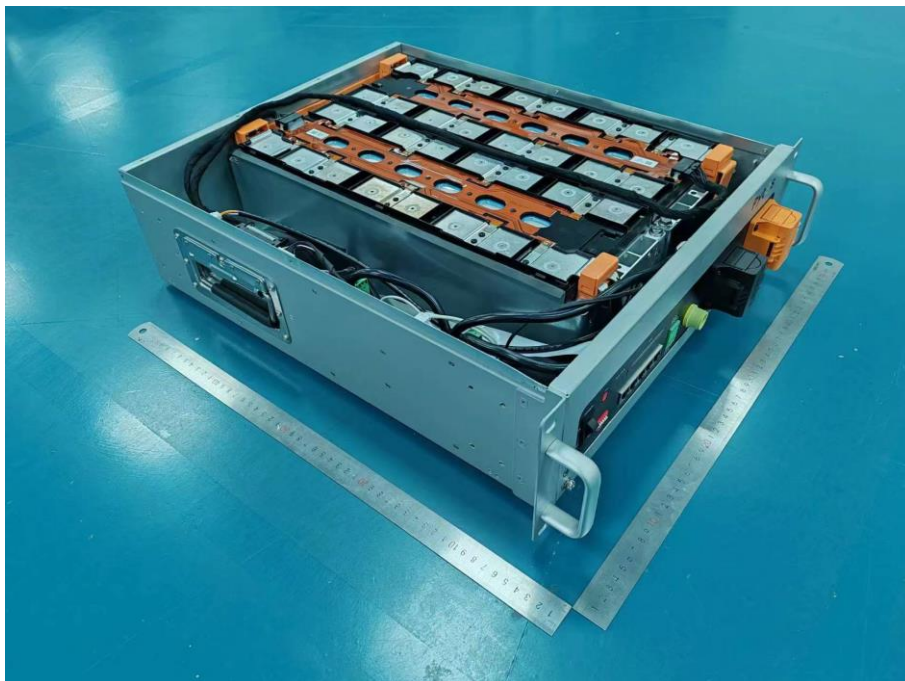


Figure 7a. Interview of battery module (Module No.: V5°)



Figure 7b. Interview of battery module (Alternative structure, Module No.: V5°α)



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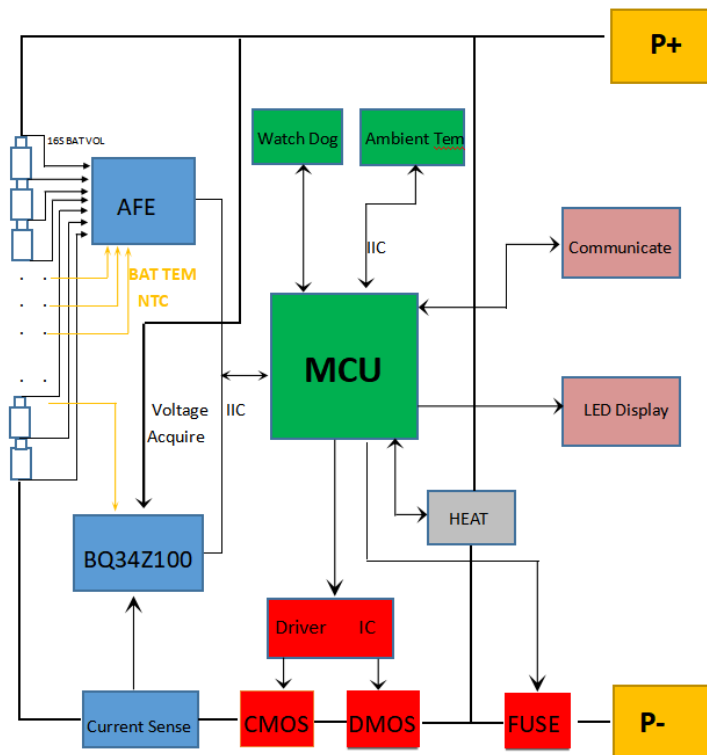
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NTC acquisition point 7/8 12/13 15/16 bat

Figure 8. Electrical Schematic diagram



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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	N/A
Standard or optional	<input type="checkbox"/> Standard / <input type="checkbox"/> optional / <input checked="" type="checkbox"/> N/A
Test with fire suppression or not	<input type="checkbox"/> Yes / <input checked="" type="checkbox"/> No



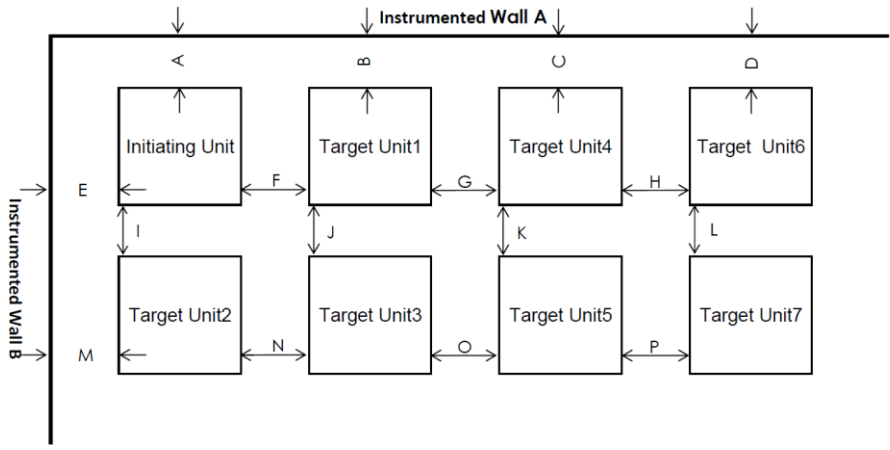
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Table 5: BESS installations/ Test configurations

Description : N/A																																			
<input checked="" type="checkbox"/> a) Indoor floor mounted non-residential use BESS																																			
<input checked="" type="checkbox"/> b) Indoor floor mounted residential use BESS																																			
<input checked="" type="checkbox"/> c) Outdoor ground mounted non-residential use BESS																																			
<input checked="" 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 checked="" type="checkbox"/> j) Open garage non-residential use BESS																																			
Test configurations for Indoor floor mounted residential use BESS																																			
		<table border="1"> <tr><td>A</td><td>25.4mm</td><td>I</td><td>25.4mm</td></tr> <tr><td>B</td><td>25.4mm</td><td>J</td><td>25.4mm</td></tr> <tr><td>C</td><td>25.4mm</td><td>K</td><td>25.4mm</td></tr> <tr><td>D</td><td>25.4mm</td><td>L</td><td>25.4mm</td></tr> <tr><td>E</td><td>25.4mm</td><td>M</td><td>25.4mm</td></tr> <tr><td>F</td><td>25.4mm</td><td>N</td><td>25.4mm</td></tr> <tr><td>G</td><td>25.4mm</td><td>O</td><td>25.4mm</td></tr> <tr><td>H</td><td>25.4mm</td><td>P</td><td>25.4mm</td></tr> </table>		A	25.4mm	I	25.4mm	B	25.4mm	J	25.4mm	C	25.4mm	K	25.4mm	D	25.4mm	L	25.4mm	E	25.4mm	M	25.4mm	F	25.4mm	N	25.4mm	G	25.4mm	O	25.4mm	H	25.4mm	P	25.4mm
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G	25.4mm	O	25.4mm																																
H	25.4mm	P	25.4mm																																



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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 heaters. 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

Illustration of initial BESS unit	
Description: N/A	
	
Figure 9. View of initiating and target BESS Units in testing room	



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Illustration of initial module in BESS

Description: Module 3 located at the lower left of battery system was selected as initial module in initiating BESS unit.



Figure 10. View of initiating module in 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 heater 1 was 250 W, and Max. power of the film heater 2 was 250 W.

Number of cells for initiating thermal runaway:

☒ Single cell 100 Ah

Locations of cells and module for initiating thermal runaway within the BESS unit:

The battery system consists of four battery modules. Module 3 located at the lower left of battery system was selected as initial module in initiating BESS unit.

The battery module consists of 16 cells, which are connected in series. Cell 5 (as shown in Figure 11b within blue box) is selected as the initiating cell. Two film heaters were placed on large surfaces of cell 5.

Other description : N/A



Figure 11a. Internal view 01 of initiate module.

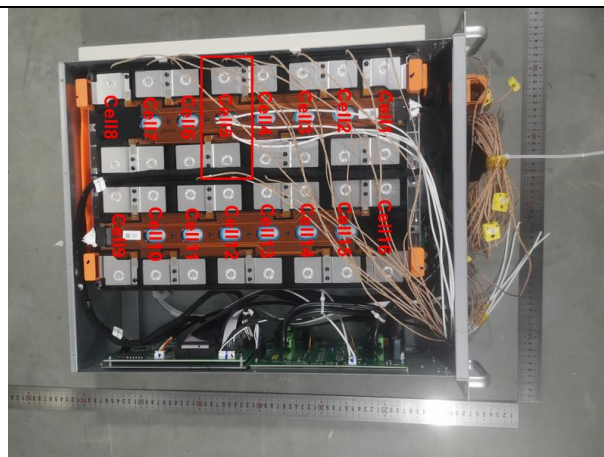


Figure 11b. Internal view 02 of initiate module.

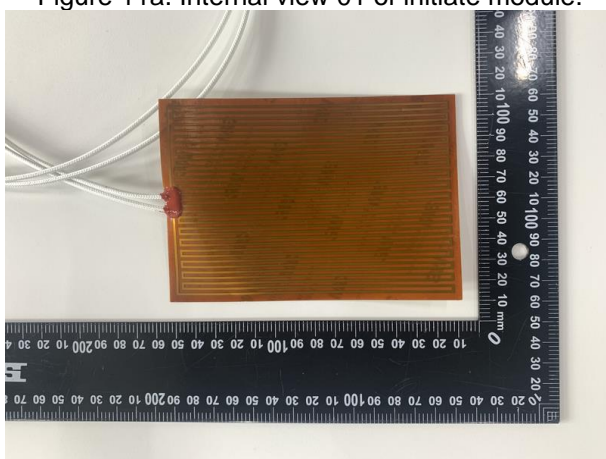


Figure 11c. View of external heater.



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Illustration of external heater and thermocouple location in initial module

Description : N/A

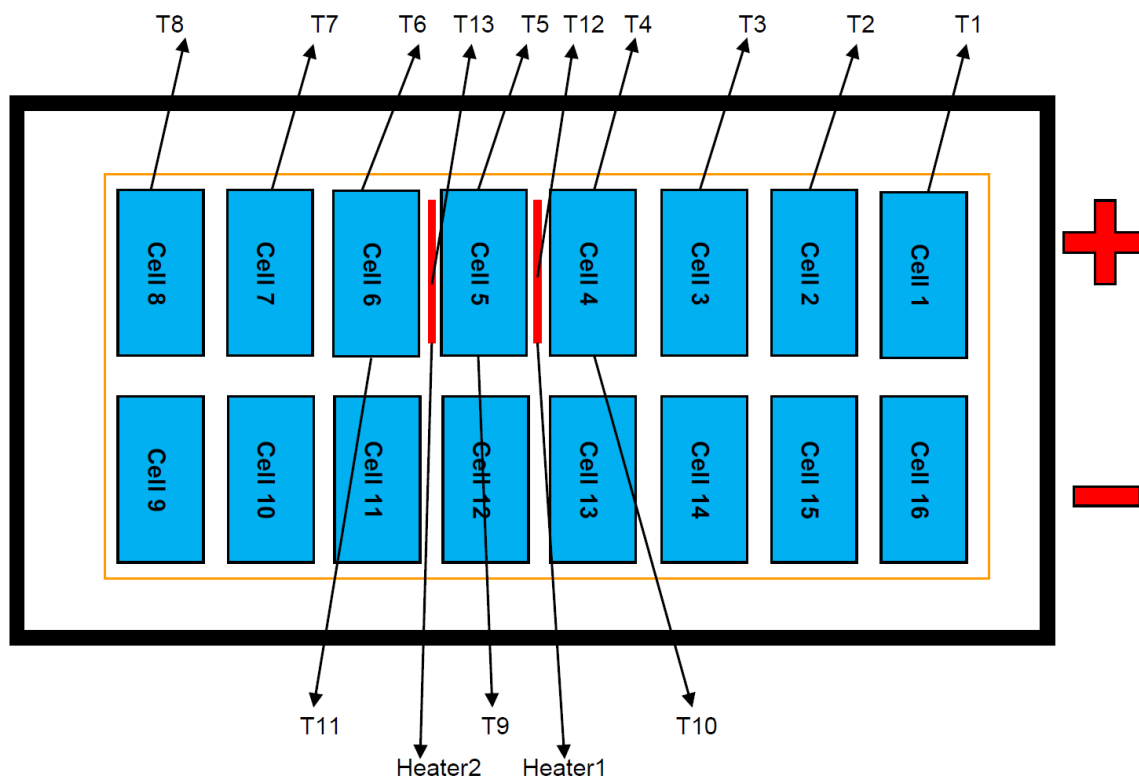


Figure 12. Schematic Illustration of film heaters and thermocouple locations in DUT (T1 to T13 means thermocouples T1 to T13. H1 and H2 means Film heater 1 and Film heater 2. View from top.).



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Positioning of units within testing room
Test Start Time: 2023-10-08 13:27:18
Initial Ambient Test Temperature: 20.4 °C
Initial Relative Humidity : 59.6%
Description: N/A



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



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Table 6: Thermocouple placement

Thermocouple ID	Description of location	Remark
CH2206	Ambient Temperature	--
CH2001	Side surface A of Cell 1	T1, in initiating module
CH2002	Side surface A of Cell 2	T2, in initiating module
CH2003	Side surface A of Cell 3	T3, in initiating module
CH2004	Side surface A of Cell 4	T4, in initiating module
CH2005	Side surface A of Cell 5	T5, in initiating module
CH2006	Side surface A of Cell 6	T6, in initiating module
CH2007	Side surface A of Cell 7	T7, in initiating module
CH2008	Side surface A of Cell 8	T8, in initiating module
CH2009	Side surface B of Cell 5	T9, in initiating module
CH2010	Side surface B of Cell 4	T10, in initiating module
CH2101	Side surface B of Cell 6	T11, in initiating module
CH2102	Center of face between Cell 5 and Heater 1	T12, in initiating module
CH2103	Center of face between Cell 5 and Heater 2	T13, in initiating module
CH2104	Module 1 in initiating unit	--
CH2105	Module 2 in initiating unit	--
CH2106	Module 3 in initiating unit	--
CH2107	Module 4 in initiating unit	--
CH2108	Module 1 in target unit 1	--
CH2109	Module 2 in target unit 1	--
CH2110	Module 3 in target unit 1	--
CH2201	Module 4 in target unit 1	--
CH2202	Module 1 in target unit 2	--
CH2203	Module 2 in target unit 2	--
CH2204	Module 3 in target unit 2	--
CH2205	Module 4 in target unit 2	--
CH0205	No. 1 of Instrumented Wall A	WA1
CH0206	No. 2 of Instrumented Wall A	WA2
CH0207	No. 3 of Instrumented Wall A	WA3
CH0208	No. 4 of Instrumented Wall A	WA4



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CH0209	No. 5 of Instrumented Wall A	WA5
CH0210	No. 6 of Instrumented Wall A	WA6
CH0301	No. 7 of Instrumented Wall A	WA7
CH0302	No. 8 of Instrumented Wall A	WA8
CH0303	No. 9 of Instrumented Wall A	WA9
CH0305	No. 10 of Instrumented Wall A	WA10
CH0306	No. 11 of Instrumented Wall A	WA11
CH0307	No. 12 of Instrumented Wall A	WA12
CH0308	No. 13 of Instrumented Wall A	WA13
CH0309	No. 14 of Instrumented Wall A	WA14
CH0310	No. 15 of Instrumented Wall A	WA15
CH0401	No. 16 of Instrumented Wall A	WA16
CH0402	No. 17 of Instrumented Wall A	WA17
CH0403	No. 18 of Instrumented Wall A	WA18
CH0404	No. 19 of Instrumented Wall A	WA19
CH0405	No. 20 of Instrumented Wall A	WA20
CH0406	No. 21 of Instrumented Wall A	WA21
CH0408	No. 22 of Instrumented Wall A	WA22
CH0409	No. 23 of Instrumented Wall A	WA23
CH0410	No. 24 of Instrumented Wall A	WA24
CH0501	No. 25 of Instrumented Wall A	WA25
CH0502	No. 26 of Instrumented Wall A	WA26
CH0503	No. 27 of Instrumented Wall A	WA27
CH0504	No. 28 of Instrumented Wall A	WA28
CH0505	No. 29 of Instrumented Wall A	WA29
CH0506	No. 30 of Instrumented Wall A	WA30
CH0507	No. 31 of Instrumented Wall A	WA31
CH0508	No. 32 of Instrumented Wall A	WA32
CH0509	No. 33 of Instrumented Wall A	WA33
CH0510	No. 34 of Instrumented Wall A	WA34
CH1001	No. 35 of Instrumented Wall A	WA35
CH1002	No. 36 of Instrumented Wall A	WA36



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CH1003	No. 37 of Instrumented Wall A	WA37
CH1004	No. 38 of Instrumented Wall A	WA38
CH1005	No. 39 of Instrumented Wall A	WA39
CH1006	No. 40 of Instrumented Wall A	WA40
CH1007	No. 41 of Instrumented Wall A	WA41
CH1008	No. 42 of Instrumented Wall A	WA42
CH1009	No. 43 of Instrumented Wall A	WA43
CH1010	No. 44 of Instrumented Wall A	WA44
CH1101	No. 45 of Instrumented Wall A	WA45
CH1102	No. 46 of Instrumented Wall A	WA46
CH1103	No. 47 of Instrumented Wall A	WA47
CH1104	No. 48 of Instrumented Wall A	WA48
CH1105	No. 49 of Instrumented Wall A	WA49
CH1106	No. 50 of Instrumented Wall A	WA50
CH1107	No. 51 of Instrumented Wall A	WA51
CH1108	No. 52 of Instrumented Wall A	WA52
CH1109	No. 53 of Instrumented Wall A	WA53
CH1110	No. 54 of Instrumented Wall A	WA54
CH0001	No. 1 of Instrumented Wall B	WB1
CH0002	No. 2 of Instrumented Wall B	WB2
CH0003	No. 3 of Instrumented Wall B	WB3
CH0004	No. 4 of Instrumented Wall B	WB4
CH0005	No. 5 of Instrumented Wall B	WB5
CH0006	No. 6 of Instrumented Wall B	WB6
CH0007	No. 7 of Instrumented Wall B	WB7
CH0008	No. 8 of Instrumented Wall B	WB8
CH0009	No. 9 of Instrumented Wall B	WB9
CH0010	No. 10 of Instrumented Wall B	WB10
CH0101	No. 11 of Instrumented Wall B	WB11
CH0102	No. 12 of Instrumented Wall B	WB12
CH0103	No. 13 of Instrumented Wall B	WB13
CH0104	No. 14 of Instrumented Wall B	WB14



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CH0106	No. 15 of Instrumented Wall B	WB15
CH0107	No. 16 of Instrumented Wall B	WB16
CH0108	No. 17 of Instrumented Wall B	WB17
CH0109	No. 18 of Instrumented Wall B	WB18
CH0110	No. 19 of Instrumented Wall B	WB19
CH0201	No. 20 of Instrumented Wall B	WB20
CH0202	No. 21 of Instrumented Wall B	WB21
CH0203	No. 22 of Instrumented Wall B	WB22
CH0204	No. 23 of Instrumented Wall B	WB23
CH1201	No. 24 of Instrumented Wall B	WB24
CH1202	No. 25 of Instrumented Wall B	WB25
CH1203	No. 26 of Instrumented Wall B	WB26
CH1204	No. 27 of Instrumented Wall B	WB27
CH1205	No. 28 of Instrumented Wall B	WB28
CH1206	No. 29 of Instrumented Wall B	WB29
CH1207	No. 30 of Instrumented Wall B	WB30
CH1208	No. 31 of Instrumented Wall B	WB31
CH1209	No. 32 of Instrumented Wall B	WB32
CH1210	No. 33 of Instrumented Wall B	WB33
CH1301	No. 34 of Instrumented Wall B	WB34
CH1302	No. 35 of Instrumented Wall B	WB35
CH1303	No. 36 of Instrumented Wall B	WB36
CH1304	No. 37 of Instrumented Wall B	WB37
CH1305	No. 38 of Instrumented Wall B	WB38
CH1306	No. 39 of Instrumented Wall B	WB39
CH1307	No. 40 of Instrumented Wall B	WB40
CH1308	No. 41 of Instrumented Wall B	WB41
CH1309	No. 42 of Instrumented Wall B	WB42
CH1310	No. 43 of Instrumented Wall B	WB43
CH1401	No. 44 of Instrumented Wall B	WB44
CH1402	No. 45 of Instrumented Wall B	WB45
CH1403	No. 46 of Instrumented Wall B	WB46



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CH1405	No. 48 of Instrumented Wall B	WB48
CH1406	No. 49 of Instrumented Wall B	WB49
CH1408	No. 50 of Instrumented Wall B	WB50
CH1409	No. 51 of Instrumented Wall B	WB51
CH1410	No. 52 of Instrumented Wall B	WB52
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
13:27:18	00:00:00	E1	Test Start	--	Figure 20
13:28:07	00:00:50	E2	Heaters Energized	--	Figure 21
14:02:33	00:35:16	E3	Initiating Cell Venting	--	Figure 22
14:16:43	00:49:25	E4	Thermal Runaway onset	Smoke venting observed from BESS unit enclosure. All Heaters de-energized.	Figure 23
14:30:40	01:03:22	E5	Second Release	Smoke venting observed from BESS unit enclosure	Figure 24
15:01:26	01:34:08	E6	Third Release	Smoke venting observed from BESS unit enclosure	Figure 25
15:05:50	01:38:32	E7	Fourth Release	Smoke venting observed from BESS unit enclosure	Figure 26
15:14:04	01:46:46	E8	Fifth Release	Smoke venting observed from BESS unit enclosure	Figure 27
20:20:17	06:52:59	E9	Test Termination	--	Figure 28
Test Start Time: 2023-10-08 13:27:18					



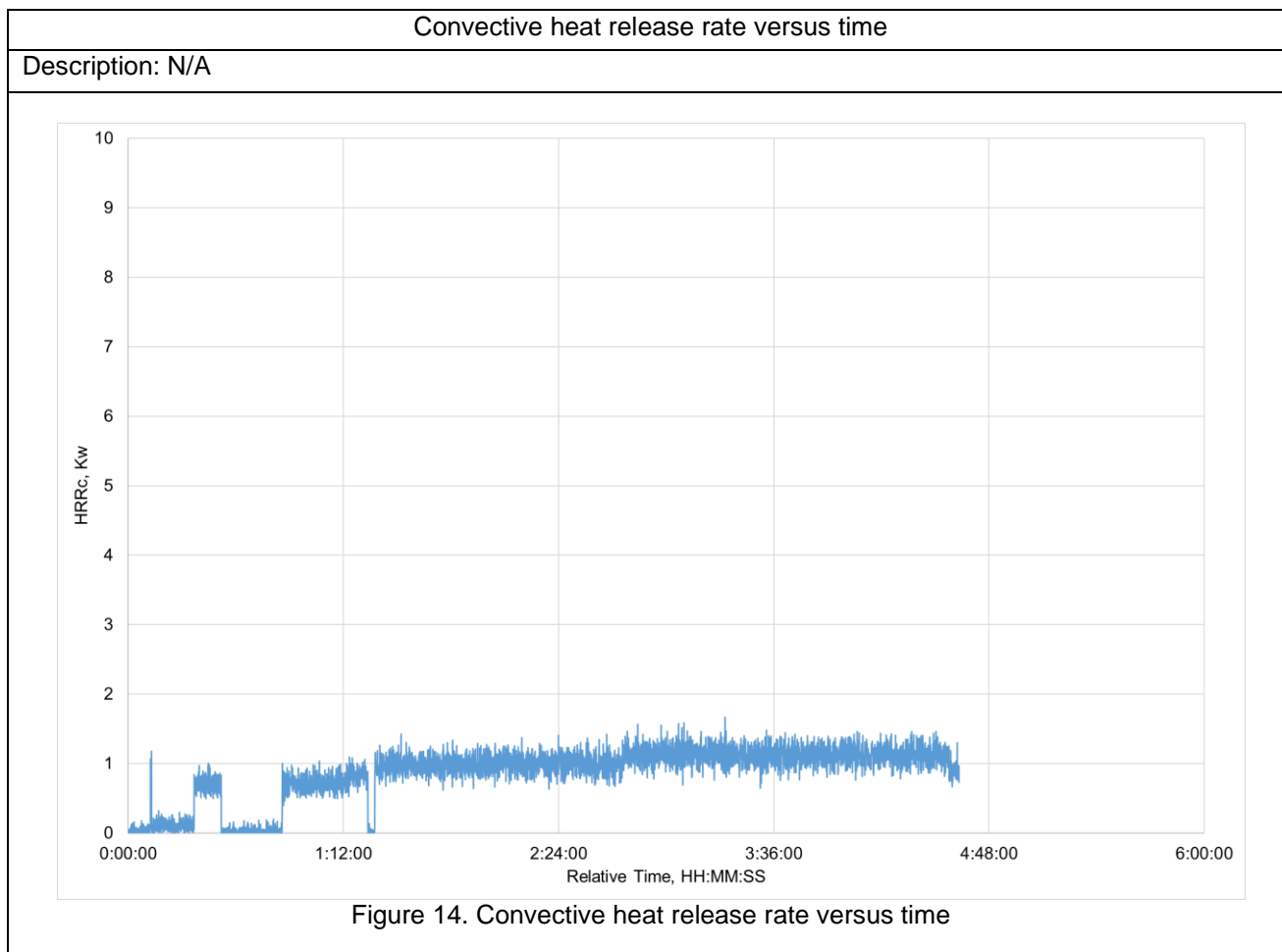
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Chemical heat release rate versus time
Description: No flaming combustion observed outside initiating BESS unit.
N/A



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Maximum incident heat flux on instrumented wall surfaces target units

Description :N/A

Heat Flux ID	Description of location
CH1503	Surface of instrumented wall A, facing the rear of module 1 in initiating unit
CH1504	Surface of instrumented wall A, facing the rear of module 3(initiating module) in initiating unit
CH1505	Surface of instrumented wall B, facing the left-side of module 1 in initiating unit
CH1506	Surface of instrumented wall B, facing the left-side of module 3(initiating module) in initiating unit
CH2501	Surface of module 3 in target unit 1, facing the right-side of module 4 in initiating unit
CH2503	Surface of module 4 in target unit 2, facing the front of module 3 in initiating unit

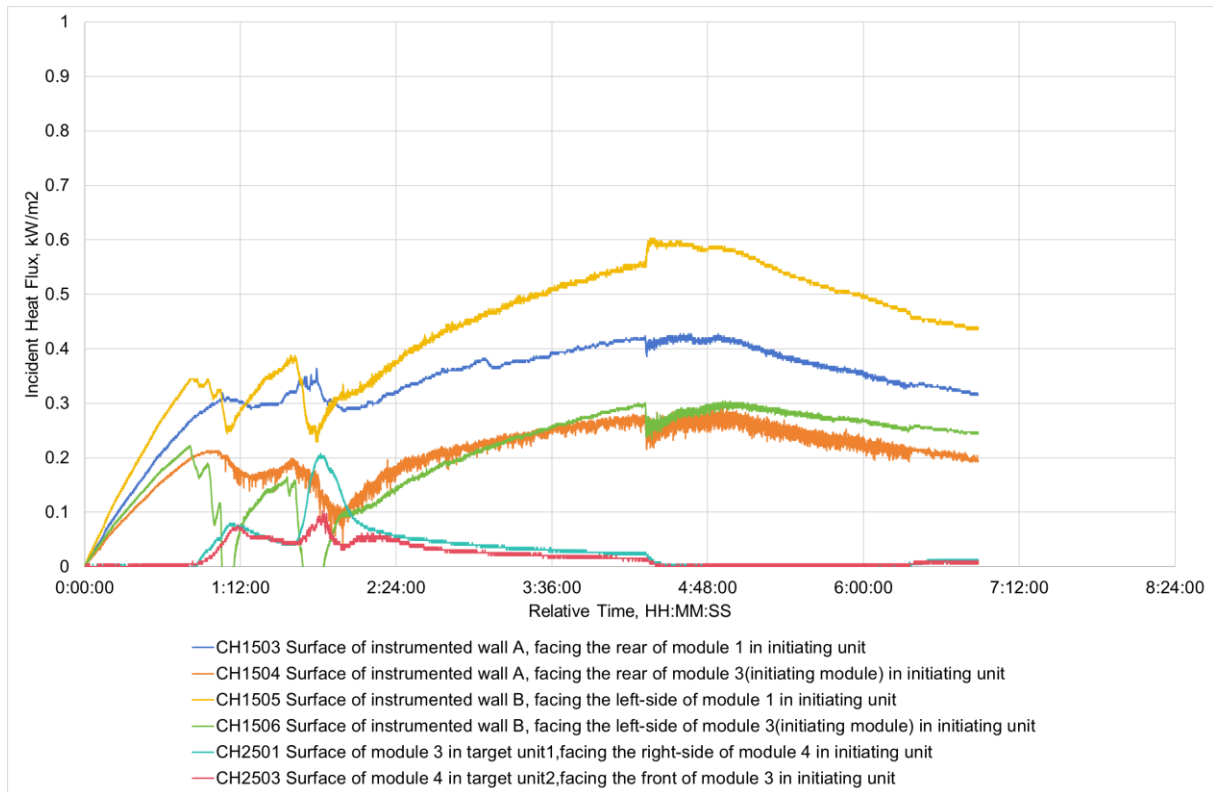


Figure 15. Incident heat flux on instrumented wall surfaces and target units



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Peak smoke release rate and total smoke release data

Description:

Peak smoke release rate is 0.291m²/s during test.

And total smoke is 137.28 m² during test.

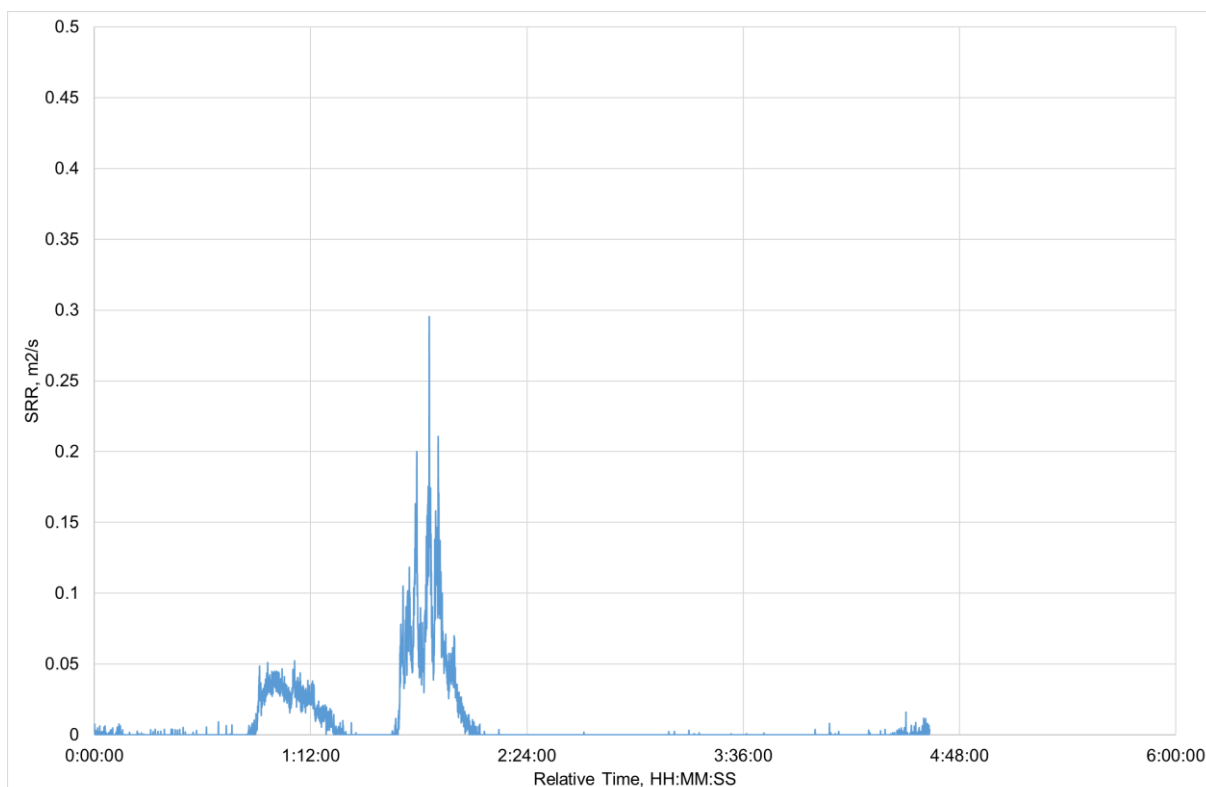


Figure 16. Smoke release rate versus time.



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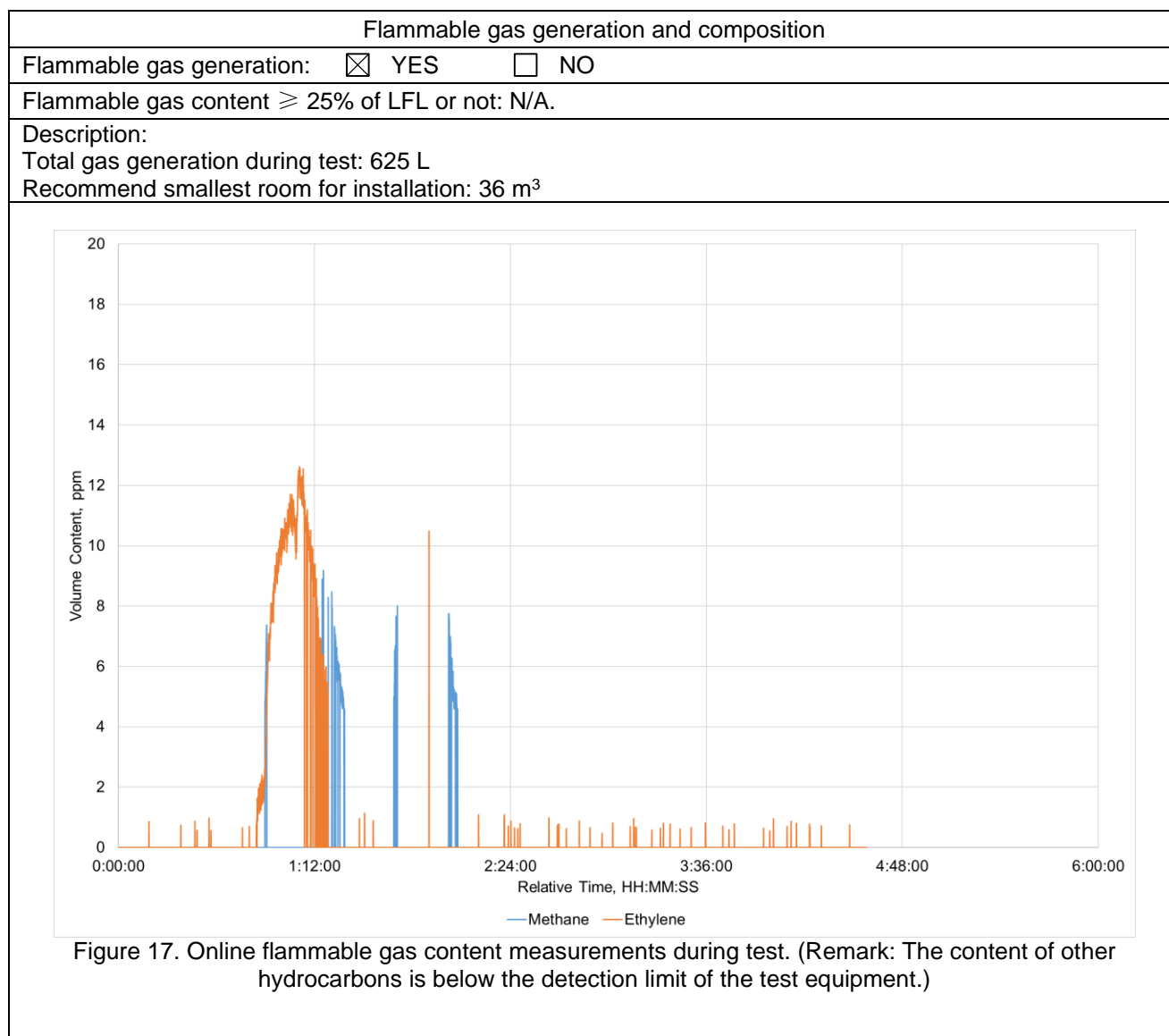
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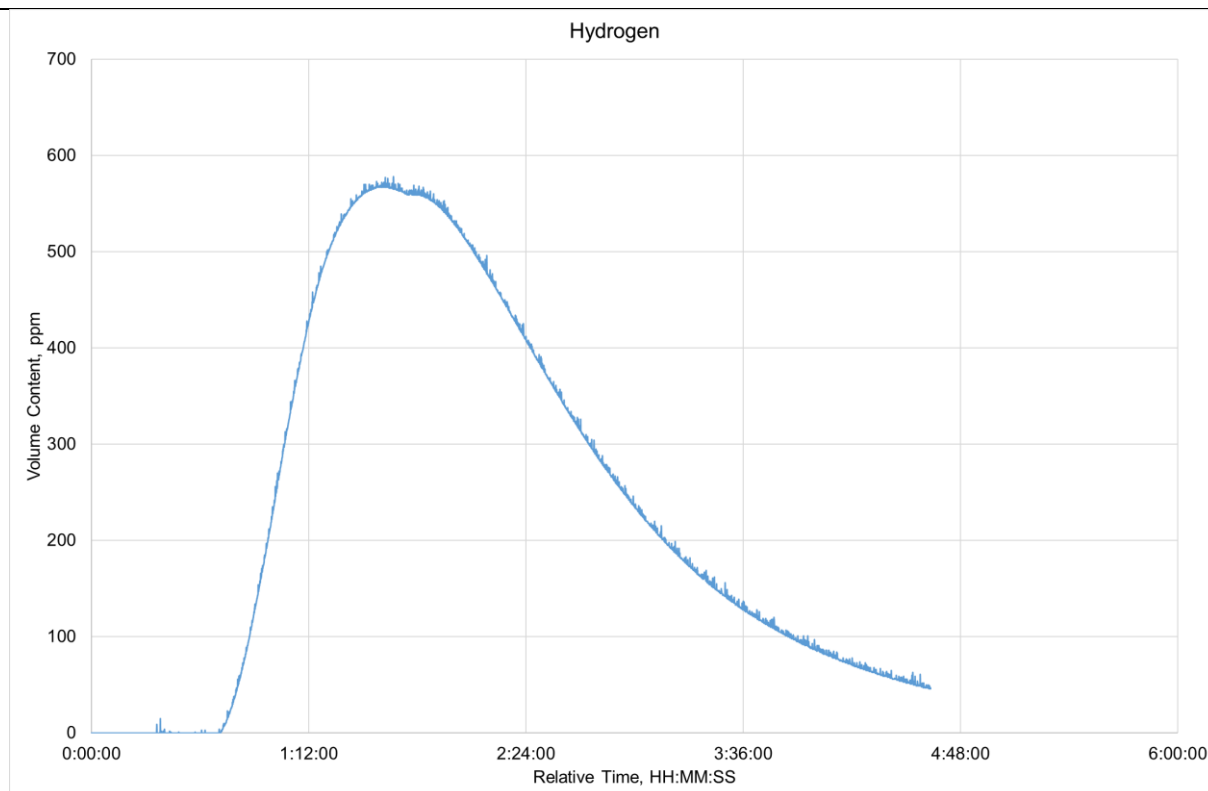


Figure 18. Online Hydrogen content measurements during test.



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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 : N/A	

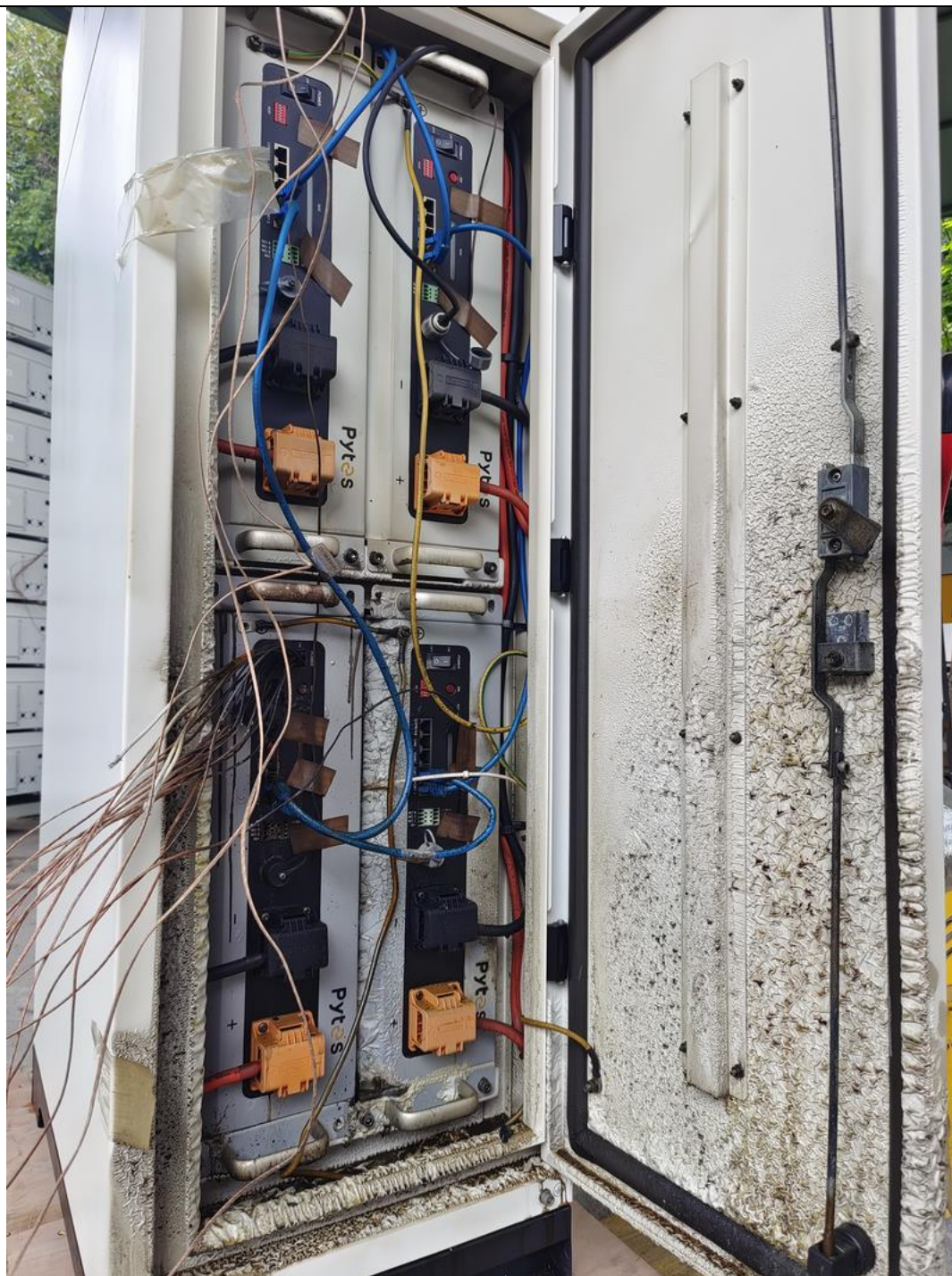


Figure 19. View of location of module that exhibited thermal runaway within the initiating unit



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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	



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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 (Within initiating unit)	53.348	53.336	No gas venting observed. No external flaming observed.
Module 2 (Within initiating unit)	53.341	53.339	No gas venting observed. No external flaming observed.
Module 3 (initiating module Within initiating unit)	53.343	0	Gas and smoke venting observed. No external flaming observed. No explosion observed.
Module 4 (Within initiating unit)	53.338	53.332	No gas venting observed. No external flaming observed.
Measured Maximum Temperature Rise of Instrumented Wall Surface			
Thermocouple ID	CH0204		
Measurements, (°C)	48.9°C (temperature rise: 28.5°C)		
Location	Surface of Instrumented Wall B, face the left surface of module 3 in initiating unit		
Limits: ΔT ≤ 97 °C			
Measured Maximum Surface Temperature of Modules within the Target BESS Units			
Thermocouple ID	CH2202		
Measurements, (°C)	29.8°C		
Location	Front surface of module 1 in target unit 2, face the front of module 1 in initiating unit		
Limits: Tmax. ≤166 °C (Cell surface temperature at gas venting)			
Cheesecloth indicator used or not <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No			
Description of cheesecloth indicator after test: No flaming or carbonizing of the cheesecloth indicator.			
Supplementary information: N/A			



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Figure 20. photo of event (E1) during test



Figure 21. photo of event (E2) during test



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Figure 22. photo of event (E3) during test



Figure 23. photo of event (E4) during test



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Figure 24. photo of event (E5) during test



Figure 25. photo of event (E6) during test



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Figure 26. photo of event (E7) during test



Figure 27. photo of event (E8) during test



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Figure 28. photo of event (E9) during test



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Figure 29. Photo 01 of after test_ BESS units (Initiating unit and target units) in test room



Figure 30. Photo 02 of after test_ BESS units (Initiating unit and target units) in test room



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Figure 31. Photo 03 of after test_ Initiating BESS unit with cheesecloth indicator



Figure 32. Photo 04 of after test_ Initiating BESS unit with removing cheesecloth indicator



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Figure 33. Photo 05 of after test_ Overview of initiating module



Figure 34. Photo 06 of after test_ Internal view of initiating module



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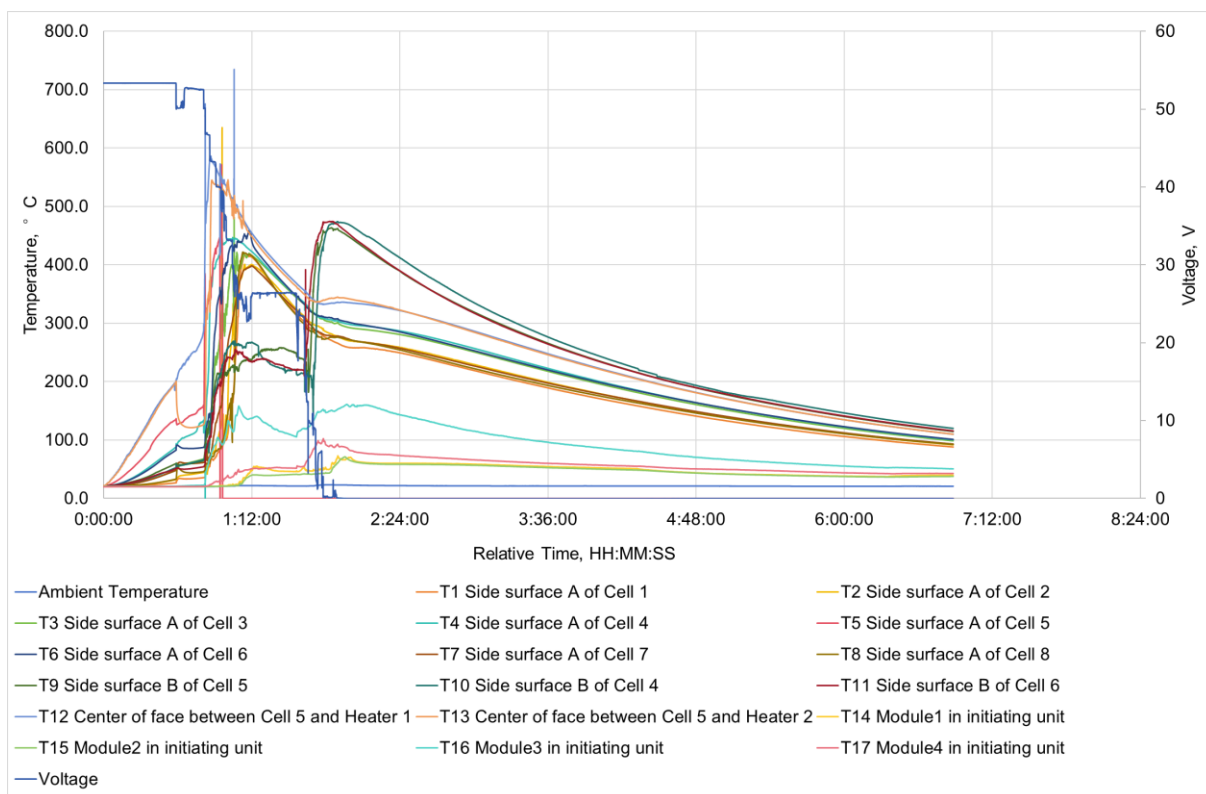


Figure 35. Temperature and voltage measurement results on the initiating BESS Unit

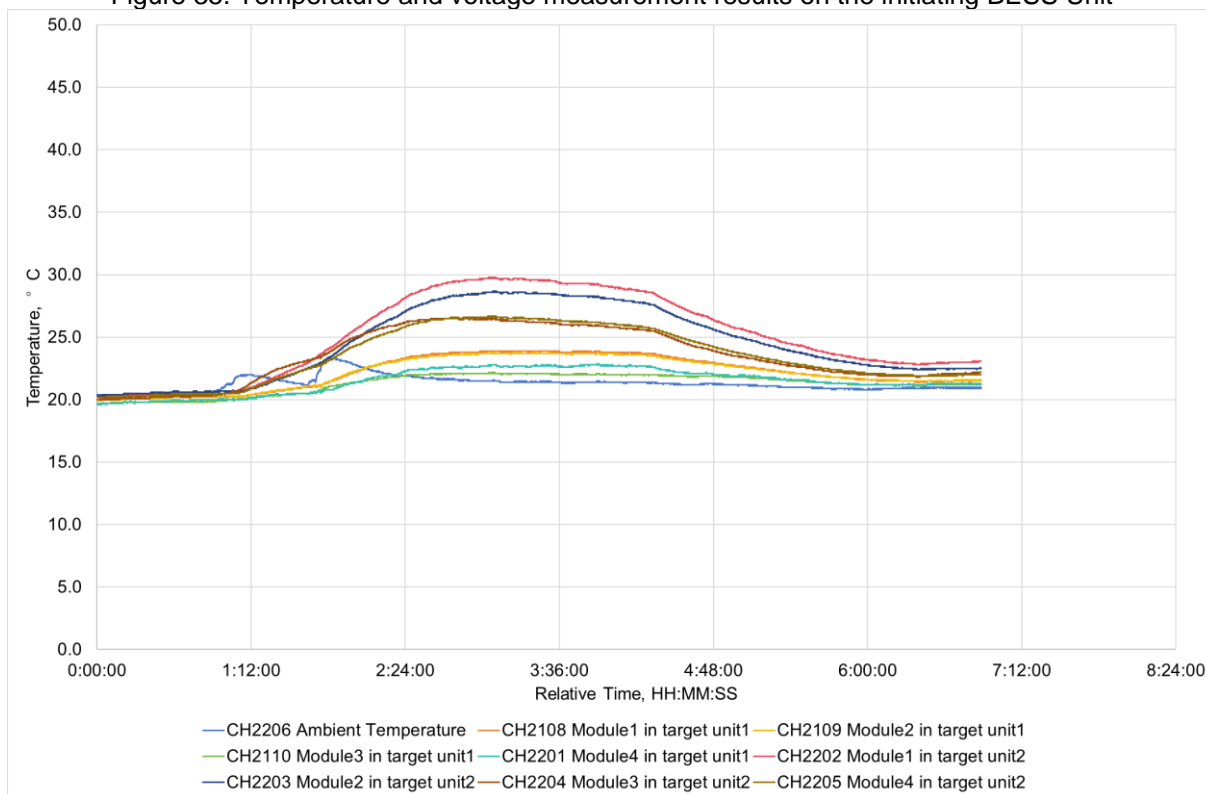


Figure 36. Temperature measurements in target BESS units



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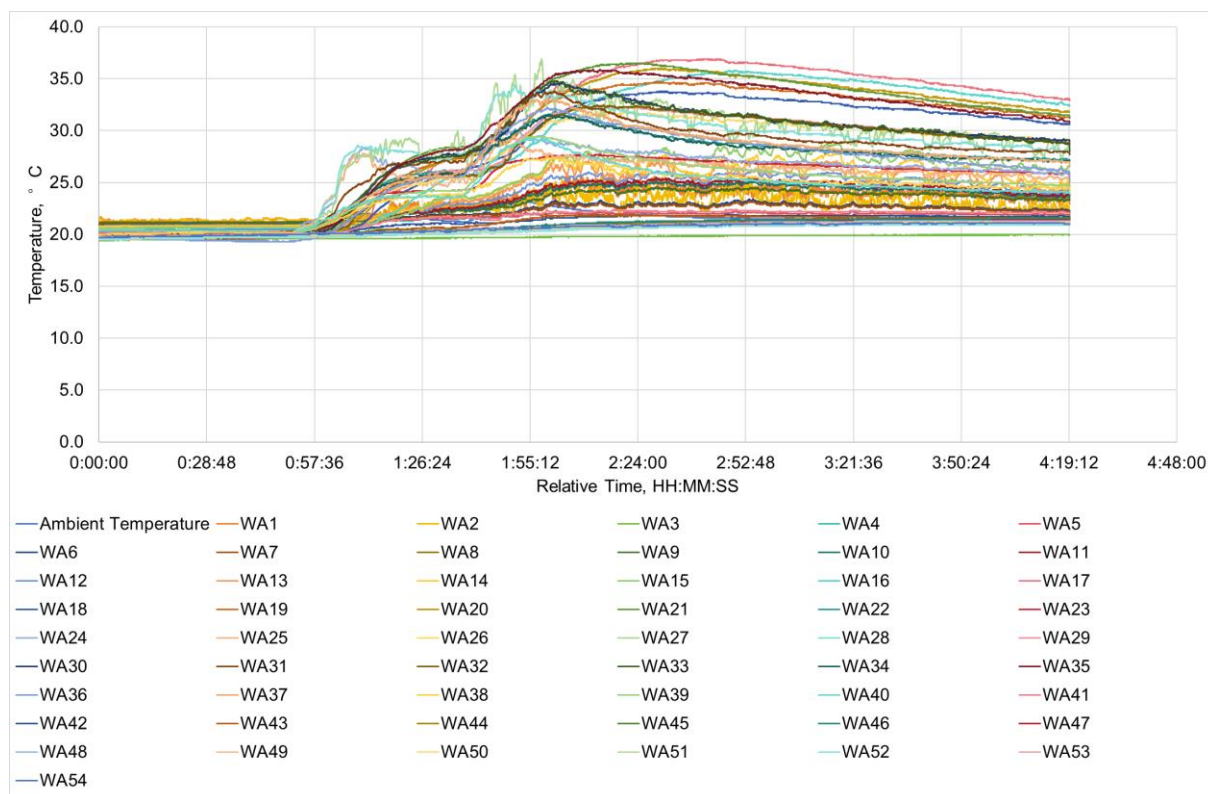


Figure 37. Temperature measurement results on wall A.

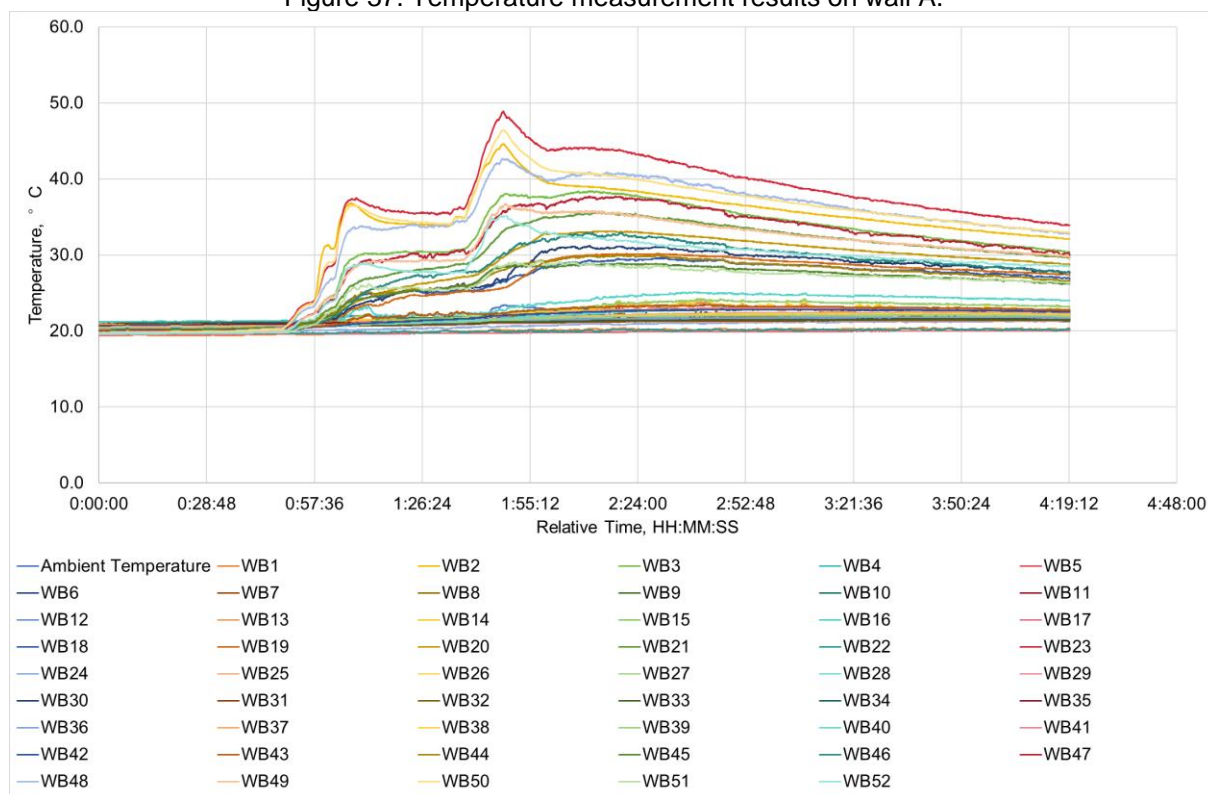


Figure 38. Temperature measurement results on wall B.



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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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