Test Report

For

ANSI/CAN/UL9540A

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

[Unit Level]

Report Number:	**CQES221100023401**
Date of issue:	**2022-11-29**
Total number of pages:	**40**
Test object / Model:	**SMILE-BAT-8.2PHA**
Applicant's name:	**Alpha ESS Co., Ltd.**
Address:	**JiuHua Road 888, Nantong High-Tech Industrial Development Zone, Nantong, 226300 Jiangsu, China**

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Report Number:	CQES221100023401
Manufacturer:	Alpha ESS Co., Ltd.
Address:	JiuHua Road 888, Nantong High-Tech Industrial Development Zone, Nantong, 226300 Jiangsu, China
Factory：	Alpha ESS Co., Ltd.
Address:	JiuHua Road 888, Nantong High-Tech Industrial Development Zone, Nantong, 226300 Jiangsu, China
Test object / Model:	SMILE-BAT-8.2PHA
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:	2022-10-31
Sample No.:	M1 to M6
Test Period:	2022-11-01 to 2022-11-05
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.
Confidential level:	☒ Strictly Confidential ☐ Private and Confidential ☐ Public

Tested by / Witness by

Ryan Hu
Project Engineer

Reviewed by

Jerry Xiao
Technical Manager

[Summary of Test results]

Cell Level Test
Cell model: LF32
Report No.:
64.280.21.60128.01

Cell Design:	LF32
Thermal Runaway Methodology:	External heating
Cell Surface Temperature at Gas venting:	174.1°C
Cell Surface Temperature at Thermal Runaway:	245.3°C
Gas Composition:	Hydrocarbon, H_2, CO_2, CO
Lower Flammability Limit:	4.6 % at 26°C, 3.8 % at 173°C
Burning Velocity:	110.8 cm/s
Pmax:	1.37 MPa at 23°C
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: N/A
Report No.: N/A

Module Design:	N/A
Thermal Runaway Methodology:	N/A
External Flaming:	N/A
Locations of Flame Venting:	N/A
Flying Debris:	N/A
Peak Heat Release Rate:	N/A
Gas Generation and Composition:	N/A
Thermal Runaway are Contained by the Module Design or not:	N/A
Cell Vent Gas is Flammable or not:	N/A
Other Description:	N/A
Test Video File:	N/A

Unit Level Test
Unit model: SMILE-BAT-8.2PHA
Report No.:
CQES221100023401

Unit Design:	SMILE-BAT-8.2PHA
Thermal Runaway Methodology:	External heating
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. Temperature Rise on Wall Surfaces:	54.3°C
Thermal Runaway are Contained by the Unit Design or not:	Contained by the Unit Design
Cell Vent Gas is Flammable or not:	Flammable
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.

[Test object Description]

Table 1: Description of component cell

Model:	LF32	
Manufacturer:	EVE Power Co., Ltd	
Nominal capacity:	32 Ah	
Nominal voltage:	3.2 V	
Chemistry:	Lithium ion, $LiFePO_4$	
Maximum charge current:	38.4 A	
Maximum discharge current:	38.4 A	
Maximum charge voltage:	3.65 V	
Cut-off Voltage:	3.65 V	
Charge temperature range:	2.5 V	
Discharge temperature range:	0°C to 55°C	
External dimensions:	-20°C to 55°C	
Weight:	L*W*H: (26.7±1.0) mm*(148.3±1.0) mm*(94.7±1.0) mm	
UL 1973 compliant:	☒ Yes / ☐ No	Reference: Report No. SZES210700467861, issued by SGS
UL 9540A report provide:	☒ Yes / ☐ No	Reference: Report No. 64.280.21.60128.01, issued by TUV SUD

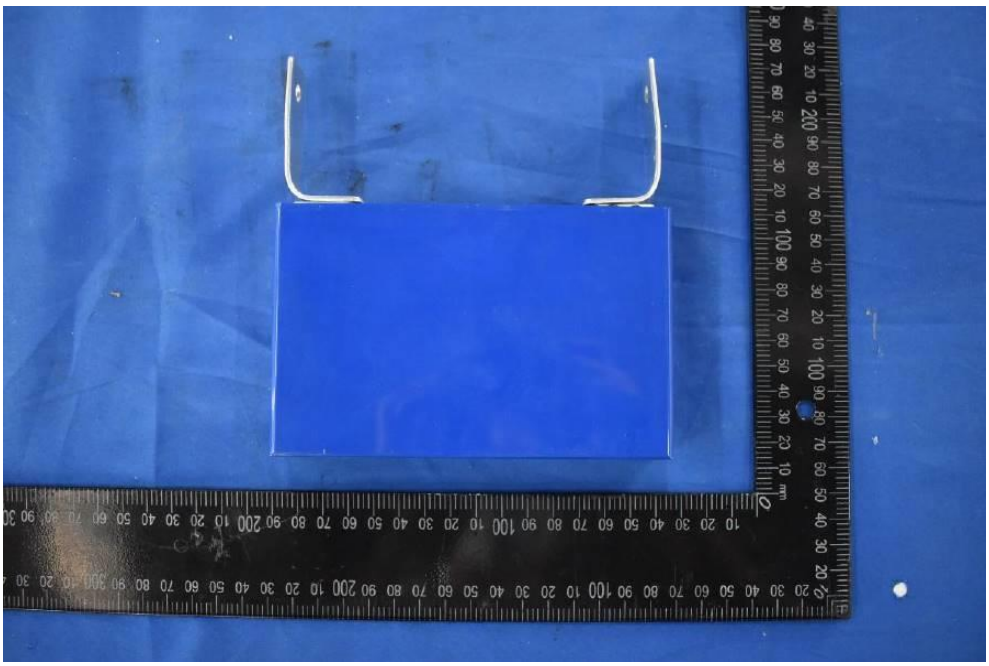


Figure 1. View of component cell

Table 2: Description of battery system

Model:	SMILE-BAT-8.2PHA	
Manufacturer:	Alpha ESS Co., Ltd.	
Nominal capacity:	32 Ah	
Nominal voltage:	256 V	
Module designation:	(1P16S)5S	
Maximum charge current:	38.4 A	
Maximum discharge current:	38.4 A	
Maximum charge voltage:	288 V	
Cut-off Voltage:	240 V	
Charge temperature range:	0°C to 50°C	
Discharge temperature range:	-20°C to 50°C	
Unit configuration:	Each battery system consists of one BMS and five battery modules connected in series, housed by a metal cabinet. Each battery module consists of 16 Lithium-ion cells connected in 1P16S.	
External dimensions:	580 mm x 213 mm x 820 mm	
Weight:	89 kg	
Fire suppression system contain	☐ Yes / ☒ No	Reference: N/A
UL 1973 compliant:	☐ Yes / ☐ No	Reference: N/A
UL 9540 compliant:	☐ Yes / ☐ No	Reference: N/A

Supplementary information:

1. Manufacturer claims that the two battery systems can be stacked at final installation. The test was conducted on a unit which was composed of two battery systems in stack.
2. Each battery system can be installed with 1 to 6 parallel. Maximum capacity (in 6 parallel) is used as representative system configuration in this test case.

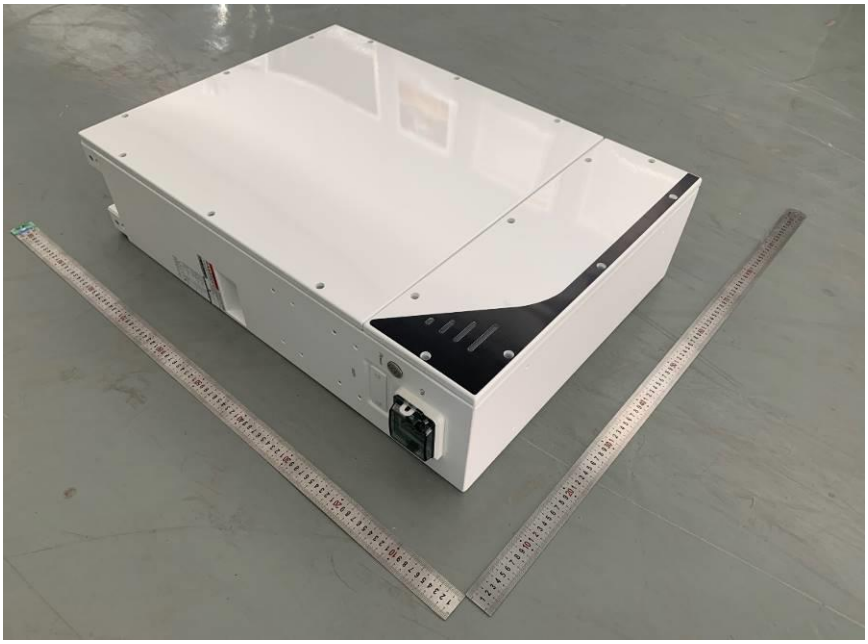


Figure 2. Overview of battery unit

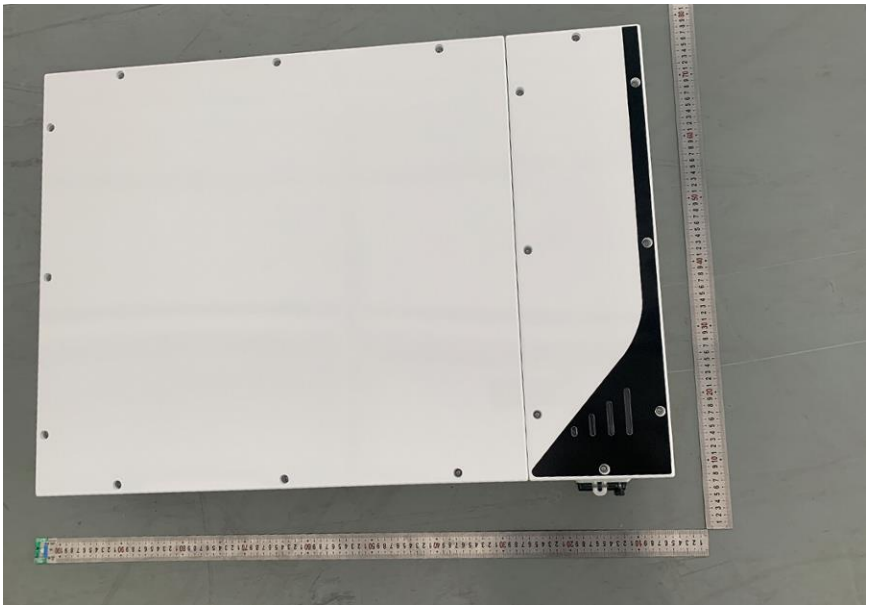


Figure 3. Front view of battery unit

Figure 4. Interview of battery unit

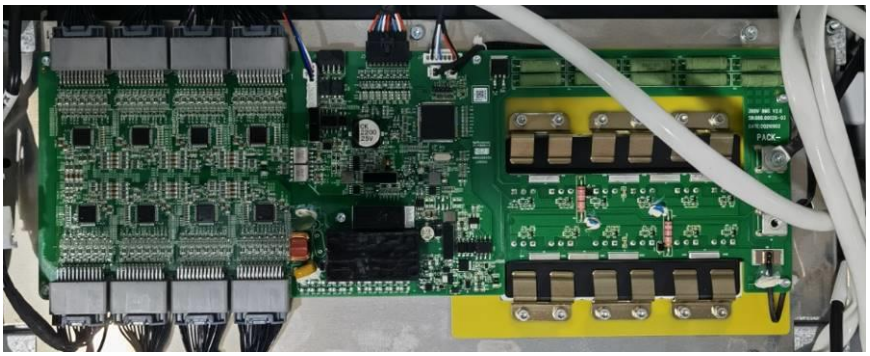


Figure 5. View of BMS

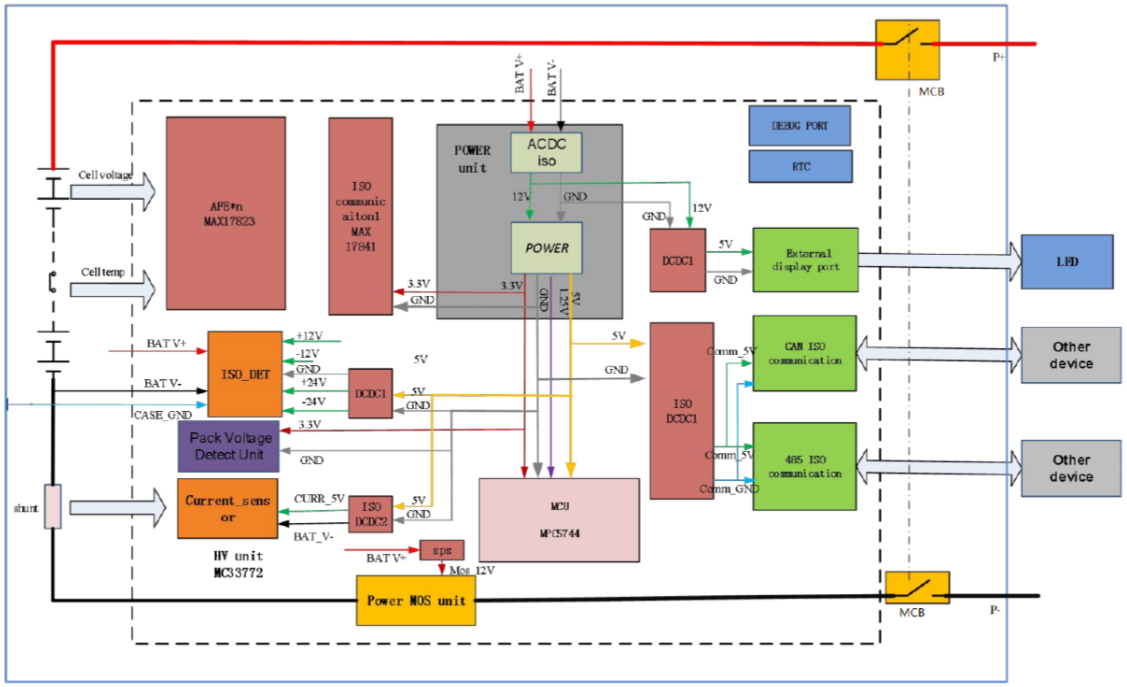


Figure 6. Electrical configuration of battery system

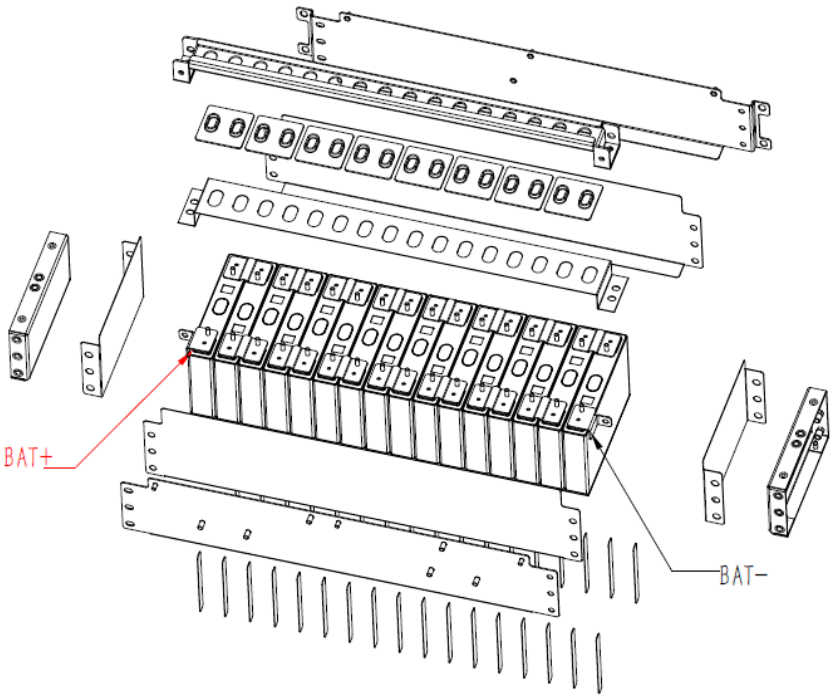


Figure 7. Schematic configuration of battery module

[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.

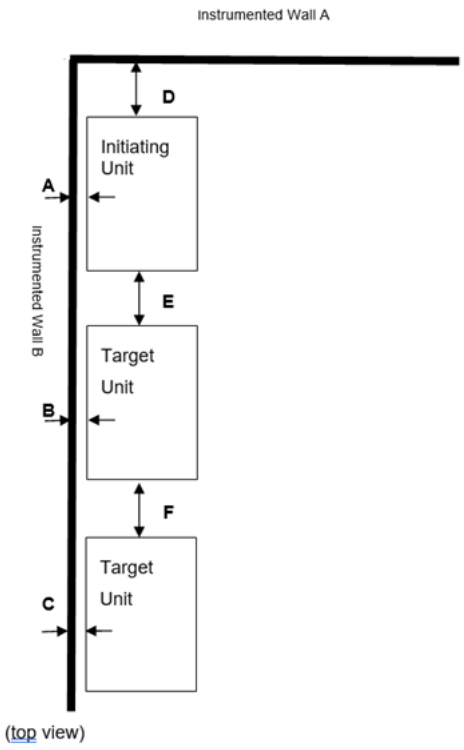
If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT. If the BESS unit is provided with an optional integral fire suppression system, the system shall not be provided on the DUT.

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 3: Integral fire suppression system information

Integral fire suppression system information	No integral fire suppression system
Standard or optional	☐ Standard / ☐ optional / ☒ N/A
Test with fire suppression or not	☐ Yes / ☒ No

Table 4: BESS installations/ Test configurations

Description :		
☐ a) Indoor floor mounted non-residential use BESS		
☒ b) Indoor floor mounted residential use BESS		
☐ c) Outdoor ground mounted non-residential use BESS		
☐ d) Outdoor ground mounted residential use BESS		
☐ e) Indoor wall mounted non-residential use BESS		
☐ f) Indoor wall mounted residential use BESS		
☐ g) Outdoor wall mounted non-residential use BESS		
☐ h) Outdoor wall mounted residential use BESS		
☐ i) Rooftop garage non-residential use BESS		
☐ j) Open garage non-residential use BESS		
Test configurations for Indoor floor mounted residential use BESS		
	A	17 mm
	B	17 mm
	C	17 mm
	D	100 mm
	E	100 mm
	F	100 mm
	G	-- mm
	H	-- mm

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:
a) The BESS units and the instrumented wall sections; and
b) 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.

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 m^2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in^2) 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 cell to exhibit thermal runaway be demonstrated by heating the cells with externally applied heaters. 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 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:
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.

Test configuration description

Illustration of initial BESS unit
Description : N/A

Figure 8. View of the initiating BESS unit before test

Illustration of initial module in BESS
Description: N/A

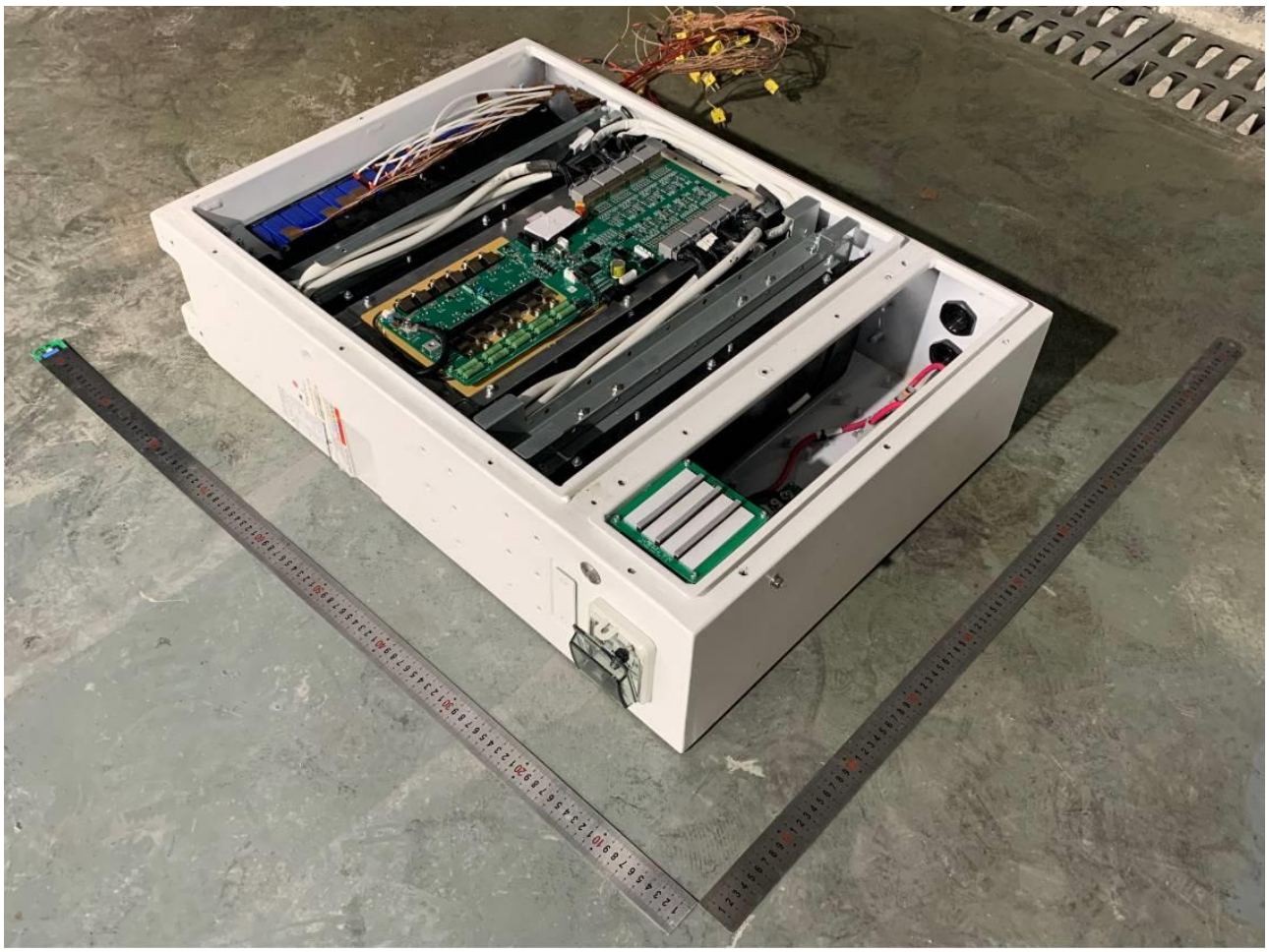


Figure 9. Internal view of the initiating BESS unit before test

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 film 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 within the test module. Max. power of the film heater is 170W.
Number of cells for initiating thermal runaway: ☒ Multiple cell 3*32 Ah (total capacity)
Locations of cells and module for initiating thermal runaway within the BESS unit: Two battery systems were stacked as a BESS unit. Each battery system consists of a BMS and 5 battery modules (marked as SM1, SM2, SM3, SM4, SM5, as shown in Figure 11a) connected in series, housed by a metal cabinet. Each battery module consists of 16 Lithium-ion cells in 1P16S. Module 1 in the lower battery system was selected as the initiating module (as shown in Figure 10b). Four film heaters were placed between the large surfaces of Cell 07, Cell 08, Cell 09, Cell 10 and Cell 11. Cell 08, Cell 09 and Cell 10 were selected as the initiating cells (as shown in Figure 11b).
Other description : N/A

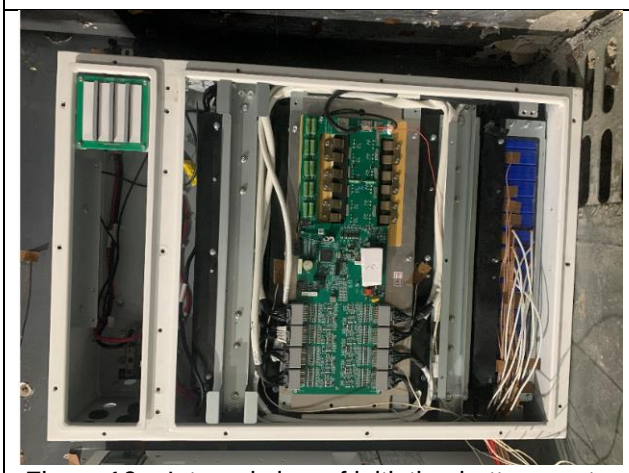


Figure 10a. Internal view of initiating battery system.

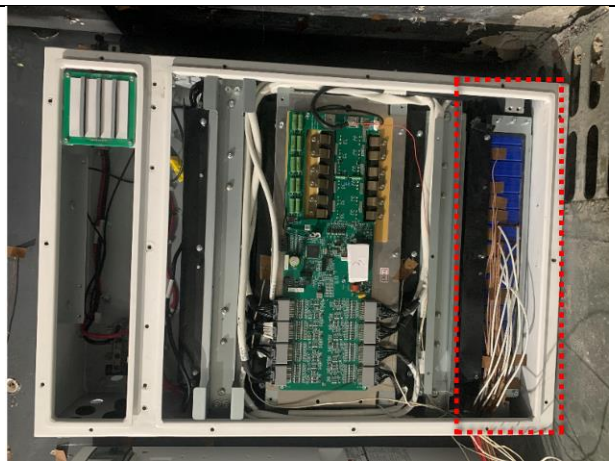


Figure 10b. Internal view of initiating module.

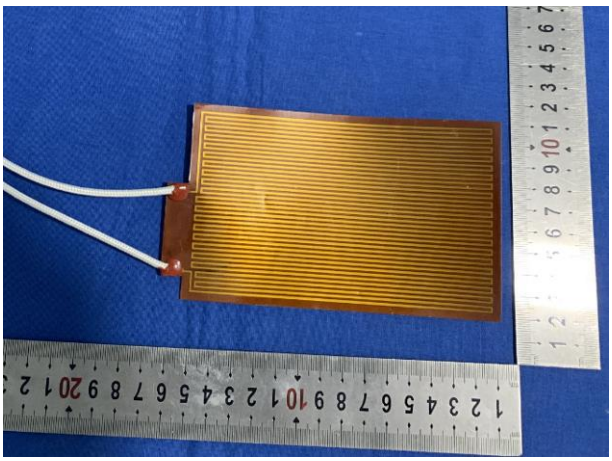


Figure 10c. View of external film heater.

Illustration of external heater and thermocouple location in initial module
Description : Sub-module 1 (as shown in Figure 11a within red box) was selected as the initiating module. The 4 film heaters were placed between the large surfaces of Cell 07, Cell 08, Cell 09, Cell 10 and Cell 11

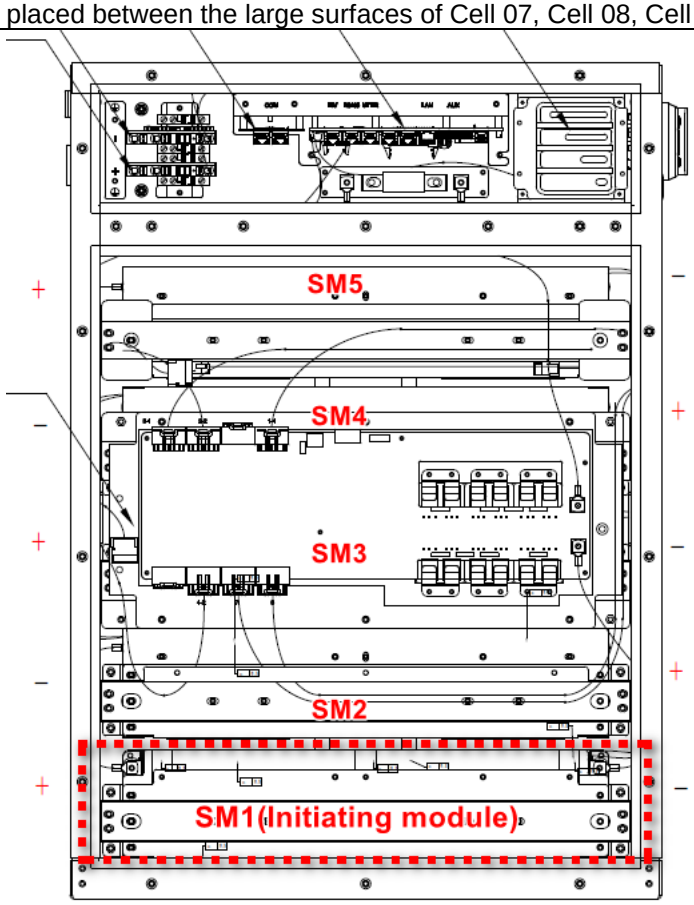


Figure 11a. Schematic illustration of battery system.

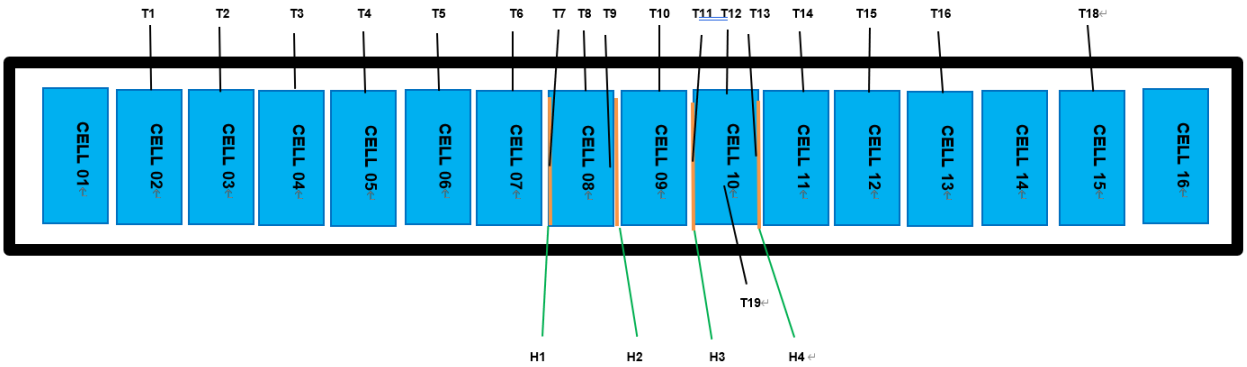


Figure 11b. Schematic illustration of film heaters and thermocouple locations in the initiating module SM1(T1 to T16, T18 means thermocouples T1 to T16, T18. H1 to H4 means Film heater 1 to Film heater 4. View from top.).

Positioning of units within testing room
Test Start Time: 2022-11-04 16:01:08
Initial Ambient Test Temperature: 18.8 °C
Initial Relative Humidity: 57.0%
Description: N/A

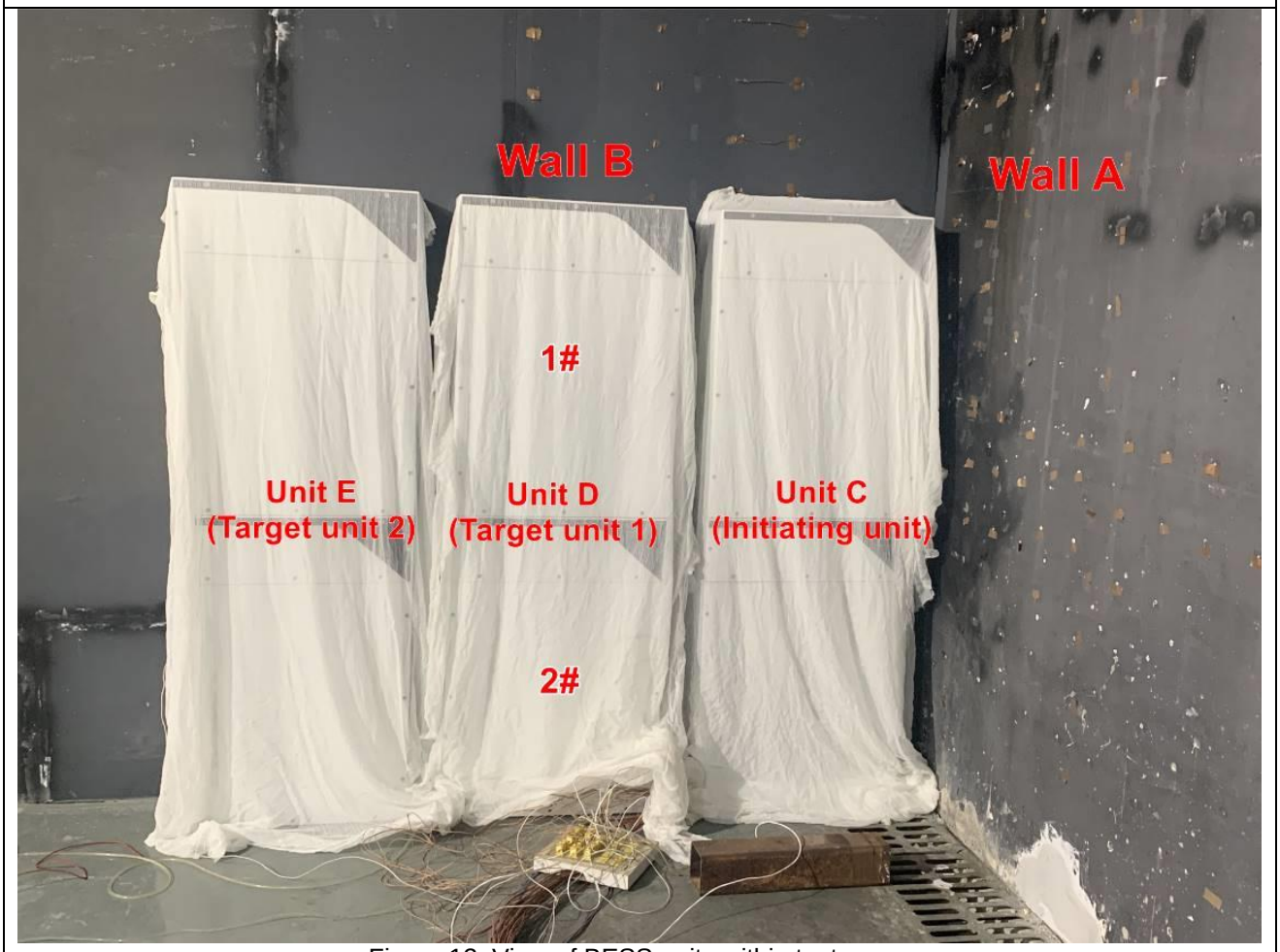


Figure 12. View of BESS units within test room.

Table 5: Thermocouple placement

Thermocouple ID	Description of location	Remark
CH2201	Side surface of Cell 02	T1, in initiating module
CH2202	Side surface of Cell 03	T2, in initiating module
CH2203	Side surface of Cell 04	T3, in initiating module
CH2204	Side surface of Cell 05	T4, in initiating module
CH2205	Side surface of Cell 06	T5, in initiating module
CH2406	Side surface of Cell 07	T6, in initiating module
CH2207	Center of face between Cell 07 and Heater 1	T7, in initiating module
CH2208	Side surface of Cell 08	T8, in initiating module
CH2209	Center of face between Cell 08 and Heater 2	T9, in initiating module
CH2210	Side surface of Cell 9	T10, in initiating module
CH2301	Center of face between Cell 09 and Heater 3	T11, in initiating module
CH2302	Side surface of Cell 10	T12, in initiating module
CH2303	Center of face between Cell 10 and Heater 4	T13, in initiating module
CH2304	Side surface of Cell 11	T14, in initiating module
CH2305	Side surface of Cell 12	T15, in initiating module
CH2407	Side surface of Cell 13	T16, in initiating module
CH2307	Side surface of Cell 15	T18, in initiating module
CH2310	Surface of module 2	In initiating unit
CH2401	Surface of module 3	In initiating unit
CH2402	Surface of module 4	In initiating unit
CH2405	Ambient temperature	--
CH0001	No. 1 of instrumented wall A	WA1
CH0002	No. 2 of instrumented wall A	WA2
CH1109	No. 3 of instrumented wall A	WA3
CH0004	No. 4 of instrumented wall A	WA4
CH0005	No. 5 of instrumented wall A	WA5
CH0006	No. 6 of instrumented wall A	WA6
CH0007	No. 7 of instrumented wall A	WA7
CH0008	No. 8 of instrumented wall A	WA8
CH0009	No. 9 of instrumented wall A	WA9

CH0010	No. 10 of instrumented wall A	WA10
CH0101	No. 11 of instrumented wall A	WA11
CH0102	No. 12 of instrumented wall A	WA12
CH0103	No. 13 of instrumented wall A	WA13
CH0104	No. 14 of instrumented wall A	WA14
CH0105	No. 15 of instrumented wall A	WA15
CH0106	No. 16 of instrumented wall A	WA16
CH0107	No. 17 of instrumented wall A	WA17
CH0108	No. 18 of instrumented wall A	WA18
CH0109	No. 19 of instrumented wall A	WA19
CH0110	No. 20 of instrumented wall A	WA20
CH0201	No. 21 of instrumented wall A	WA21
CH0202	No. 22 of instrumented wall A	WA22
CH0203	No. 23 of instrumented wall A	WA23
CH0204	No. 24 of instrumented wall A	WA24
CH0409	No. 25 of instrumented wall A	WA25
CH0410	No. 26 of instrumented wall A	WA26
CH0501	No. 27 of instrumented wall A	WA27
CH0502	No. 28 of instrumented wall A	WA28
CH0503	No. 29 of instrumented wall A	WA29
CH0504	No. 30 of instrumented wall A	WA30
CH0505	No. 31 of instrumented wall A	WA31
CH0506	No. 32 of instrumented wall A	WA32
CH0507	No. 33 of instrumented wall A	WA33
CH0205	No. 1 of instrumented wall B	WB1
CH0206	No. 2 of instrumented wall B	WB2
CH0207	No. 3 of instrumented wall B	WB3
CH0208	No. 4 of instrumented wall B	WB4
CH0209	No. 5 of instrumented wall B	WB5
CH0210	No. 6 of instrumented wall B	WB6
CH0301	No. 7 of instrumented wall B	WB7
CH0302	No. 8 of instrumented wall B	WB8

CH0303	No. 9 of instrumented wall B	WB9
CH0304	No. 10 of instrumented wall B	WB10
CH0305	No. 11 of instrumented wall B	WB11
CH0306	No. 12 of instrumented wall B	WB12
CH0307	No. 13 of instrumented wall B	WB13
CH0308	No. 14 of instrumented wall B	WB14
CH0309	No. 15 of instrumented wall B	WB15
CH0310	No. 16 of instrumented wall B	WB16
CH0401	No. 17 of instrumented wall B	WB17
CH0402	No. 18 of instrumented wall B	WB18
CH0403	No. 19 of instrumented wall B	WB19
CH0404	No. 20 of instrumented wall B	WB20
CH0405	No. 21 of instrumented wall B	WB21
CH0406	No. 22 of instrumented wall B	WB22
CH0407	No. 23 of instrumented wall B	WB23
CH0408	No. 24 of instrumented wall B	WB24
CH2309	No. 25 of instrumented wall B	WB25
CH2308	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
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
CH2001	No. 36 of instrumented wall B	WB36
CH2002	No. 37 of instrumented wall B	WB37
CH2003	No. 38 of instrumented wall B	WB38
CH2004	No. 39 of instrumented wall B	WB39
CH2005	No. 40 of instrumented wall B	WB40

CH2006	No. 41 of instrumented wall B	WB41
CH2007	No. 42 of instrumented wall B	WB42
CH2008	No. 43 of instrumented wall B	WB43
CH2009	No. 44 of instrumented wall B	WB44
CH2404	Side surface of target unit D_1#	--
CH2403	Side surface of target unit D_2#	--
Thermocouple information: Type K, 24AWG.		

[Description of test results]

Table 6: Overview of test timeline and key events

Test start time: 2022-11-04 16:01:08					
Time (HH: MM: SS)	**Relative Time (HH: MM: SS)**	**Event ID**	**Event**	**Description**	**Photo Reference**
16:01:08	00:00:00	E1	Test Start	--	Figure 17
16:03:37	00:02:28	E2	Heater 1, 2, 3, 4 Energized	--	--
16:34:01	00:32:52	E3	Initiating Cell Venting (First release.)	Slight smoke release observed from initiating battery system enclosure.	Figure 18
16:34:44	00:33:34	E4	Initiating Cell Venting (Second release.)	Smoke release observed from initiating battery system enclosure.	Figure 19
16:35:15	00:34:06	E5	Initiating Cell Venting (Third release.)	Smoke release observed from initiating battery system enclosure.	Figure 20
16:35:46	00:34:37	E6	Thermal Runaway Onset (Forth Release)	Smoke release observed from initiating battery system enclosure. All Heaters de-energized	Figure 21
16:38:00	00:36:51	E7	Fifth Release	Smoke release observed from initiating battery system enclosure.	Figure 22
16:42:43	00:41:34	E8	Sixth Release	Smoke release observed from initiating battery system enclosure.	Figure 23
16:46:40	00:45:30	E9	Seventh Release	Smoke release observed from initiating battery system enclosure.	Figure 24
16:52:47	00:51:39	E10	Eighth Release	Smoke release observed from initiating battery system enclosure.	Figure 25
16:57:25	00:56:17	E11	Ninth Release	Smoke release observed from initiating battery system enclosure.	Figure 26
17:03:35	01:02:27	E12	Tenth Release	Smoke release observed from initiating battery system enclosure.	Figure 27
17:05:55	01:04:47	E13	Eleventh Release	Smoke release observed from initiating battery system enclosure.	Figure 28
19:48:44	03:47:36	E14	Test Termination	--	Figure 29

Chemical heat release rate versus time
Description: No flaming extension observed outside the initiating unit
N/A

Convective heat release rate versus time
Description: N/A

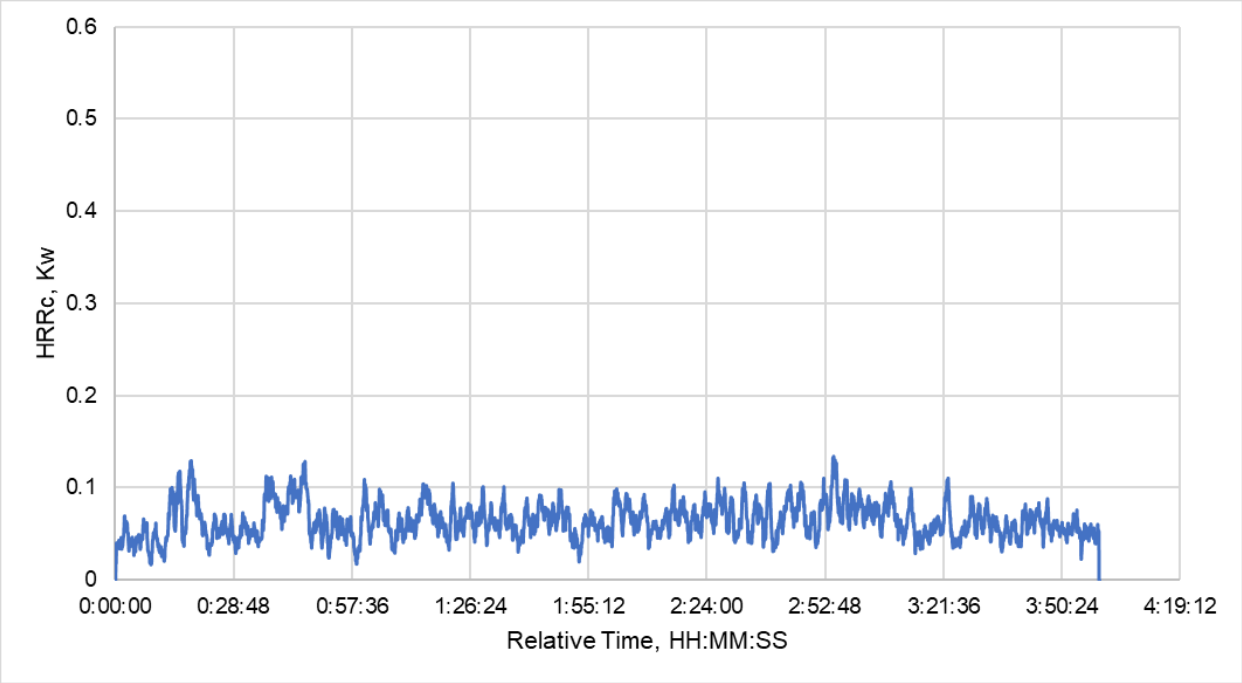


Figure 13. Convective heat release rate versus time

Maximum incident heat flux on instrumented wall surfaces, target unit and front of initiating unit.

Description : N/A

CH1401	Surface of instrumented wall A, facing the right surface of initiating module
CH1402	Surface of instrumented wall A, facing the right surface of module 2 in initiating unit
CH1403	Surface of instrumented wall B, facing the rear surface of initiating module
CH1404	Surface of instrumented wall B, facing the rear surface of module 2 in initiating unit
CH1405	100mm from the front surface of initiating unit
CH1406	Surface of target unit D_2#, facing the left surface of initiating unit

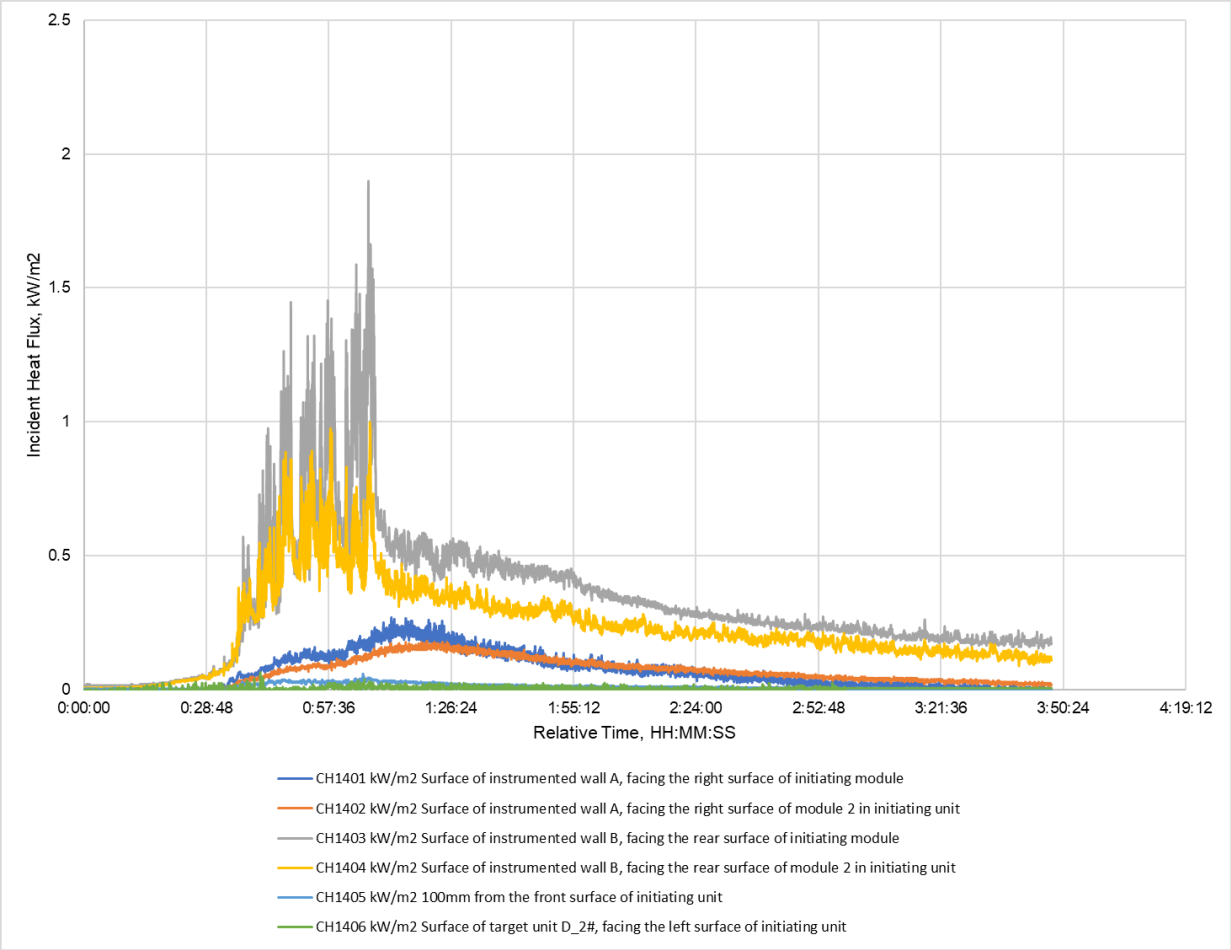


Figure 14. Incident heat flux on instrumented wall surfaces, target unit and front of initiating unit.

Peak smoke release rate and total smoke release data
Description: Peak smoke release rate is 0.054m²/s during test.

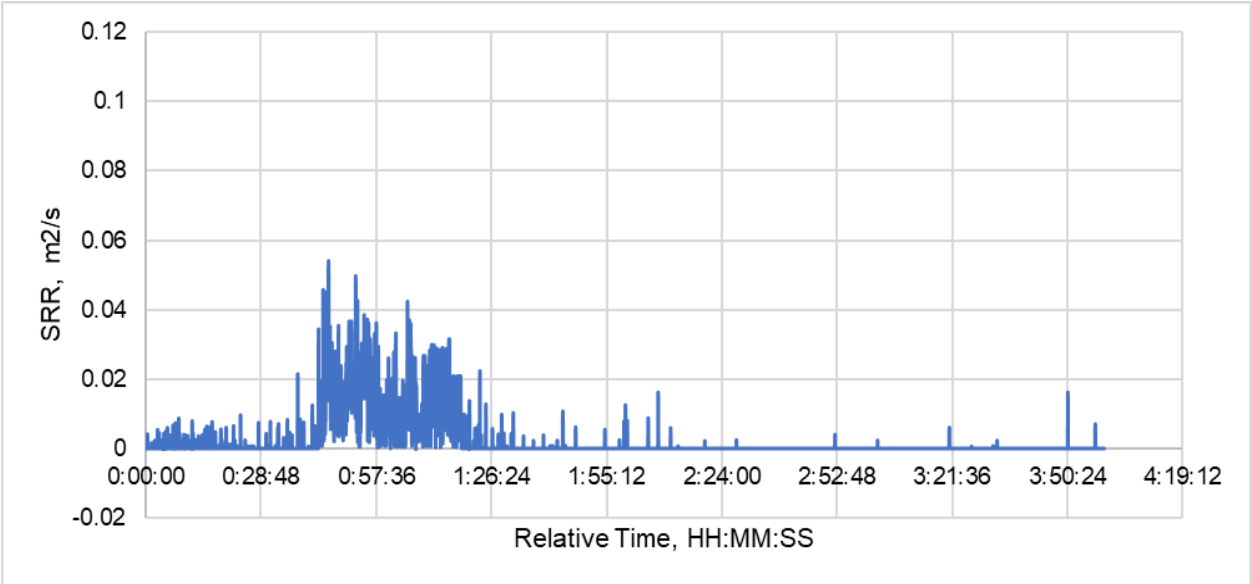


Figure 15. Smoke release rate versus time

Flammable gas generation and composition
Flammable gas generation: ☒ YES ☐ NO
Flammable gas content ⩾ 25% of LFL or not: N/A.
Description : Total gas generation during test: 698 L (25°C,101kPa) Recommend smallest room for installation: 61 m^3

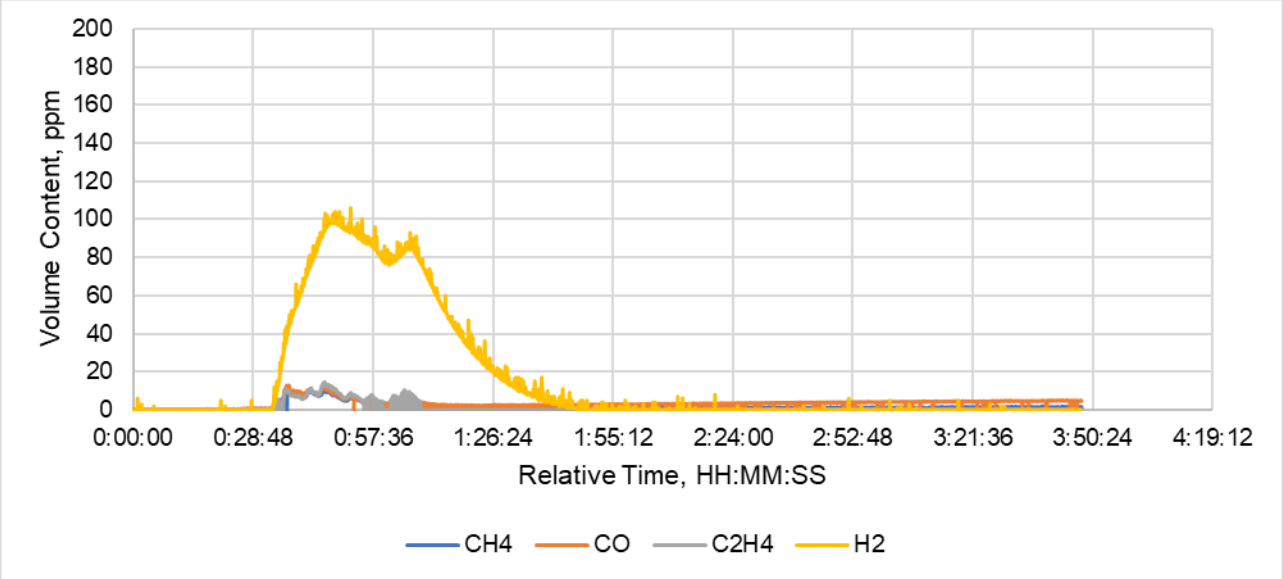


Figure 16. Online flammable gas content measurements during test. (Remark: The content of other hydrocarbons is below the detection limit of the test equipment.)

Locations and visual estimations of flame extension and duration from the unit
Flame extension : ☐ YES ☒ NO
Description : No external flaming observed.
N/A

Table 7: Data during test

Sample ID	OCV of Battery Module Before Test (V dc)	OCV of Battery Module After Test (V dc)	Observation Results
Initiating Battery System_lower	267.56	223.14	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	CH2003(WB38)		
Measurements (°C)	73.1 (temperature rise 54.3°C)		
Location	Surface of instrumented wall B, facing the rear surface of sub-module 1 within initiating battery system		
Limits: △T ≤ 97 °C			
Measured Maximum Surface Temperature of Modules within the Target BESS Units			
Thermocouple ID	CH2403		
Measurements (°C)	65.7		
Location	Left side surface of target unit D_2#		
Limits: 174.1 °C			
Cheesecloth indicator used or not ☒ Yes ☐ No Description of cheesecloth indicator after test : No flaming or carbonizing of the cheesecloth indicator.			
Supplementary information: N/A			

Figure 17. Photo of E1 (event 1) during test.

Figure 18. Photo of E3 during test.

Figure 19. Photo of E4 during test.

Figure 20. Photo of E5 during test.

Figure 21. Photo of E6 during test.

Figure 22. Photo of E7 during test.

Figure 23. Photo of E8 during test.

Figure 24. Photo of E9 during test.

Figure 25. Photo of E10 during test.

Figure 26. Photo of E11 during test.

Figure 27. Photo of E12 during test.

Figure 28. Photo of E13 during test.

Figure 29. Photo of E14 during test.

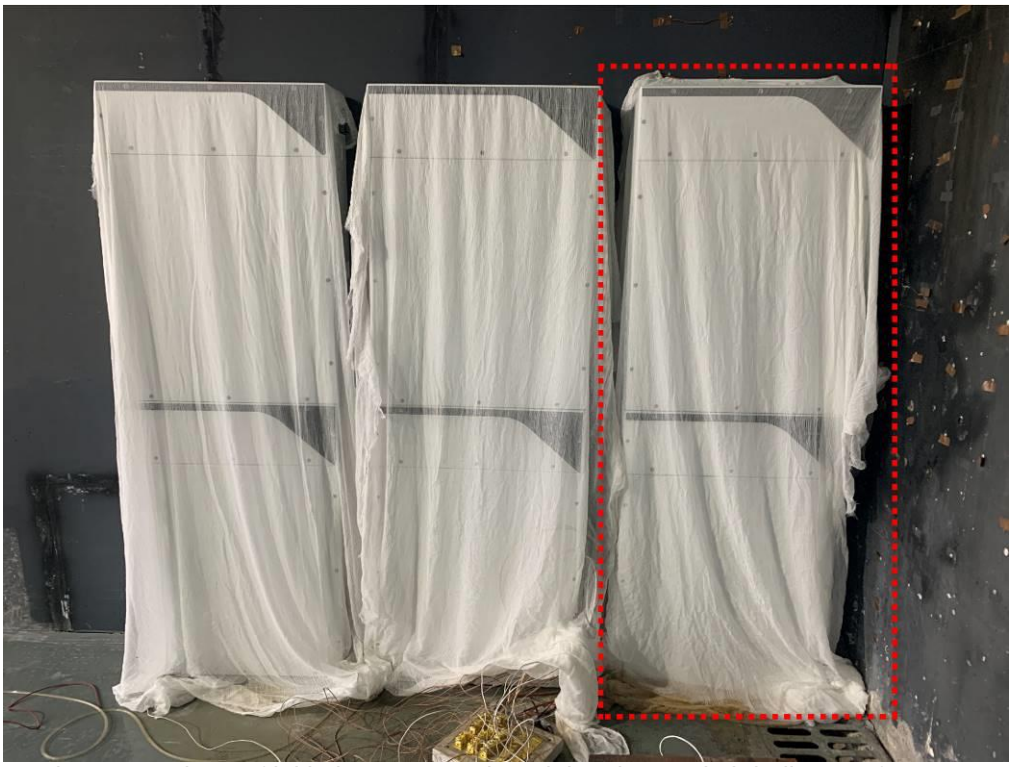


Figure 30: Photo of initiating BESS unit and the cheesecloth indicator after test.

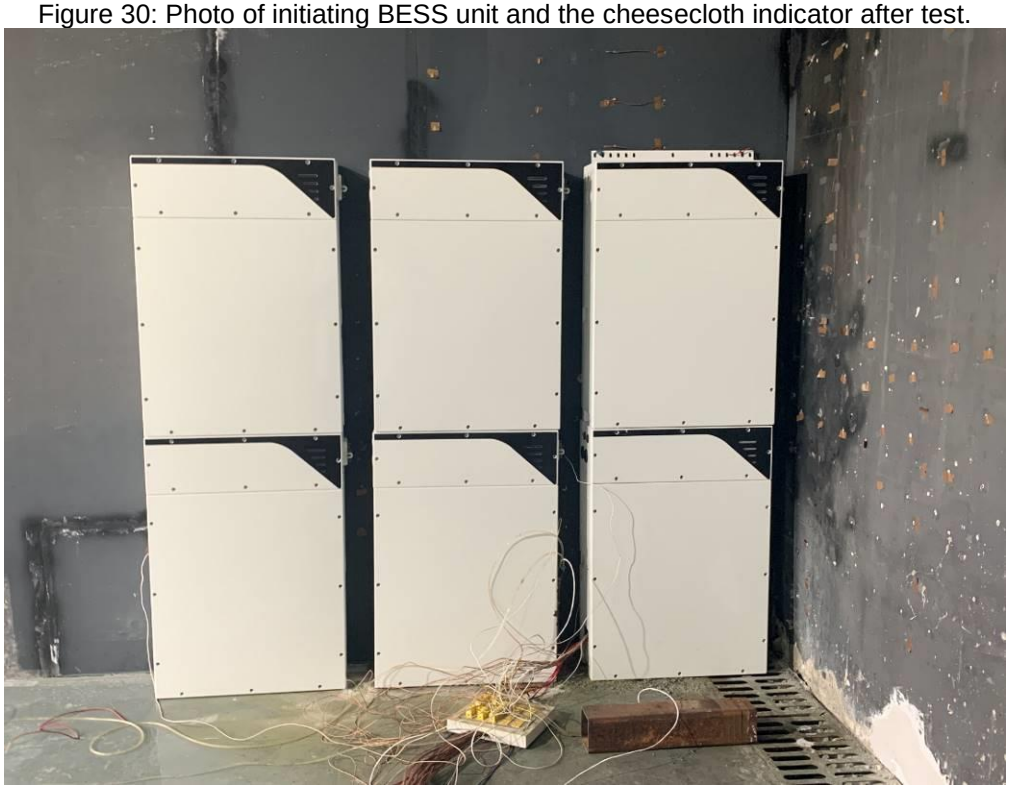


Figure 31. Photo of initiating and target BESS units after test.

Figure 32a. Photo of initiating battery system after test.

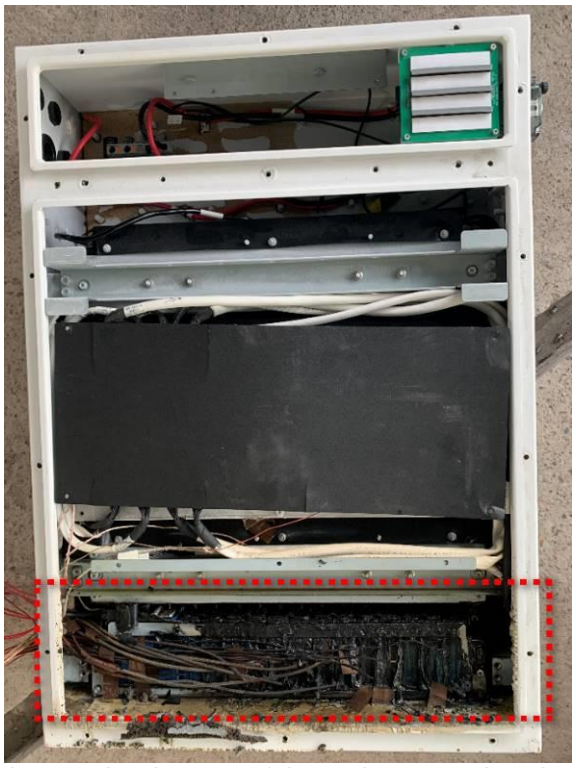


Figure 32b. Photo 01 of thermal runaway location.

Figure 32c. Photo 02 of thermal runaway location.

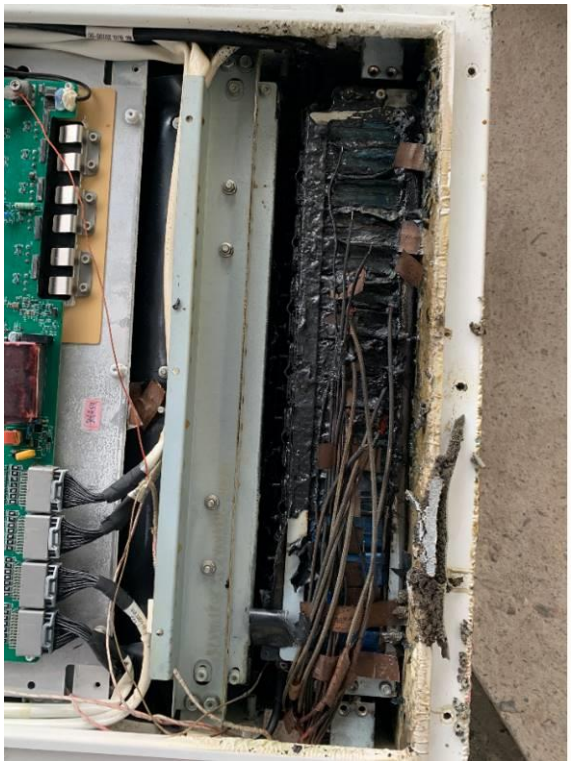


Figure 32d. Photo 03 of thermal runaway location.

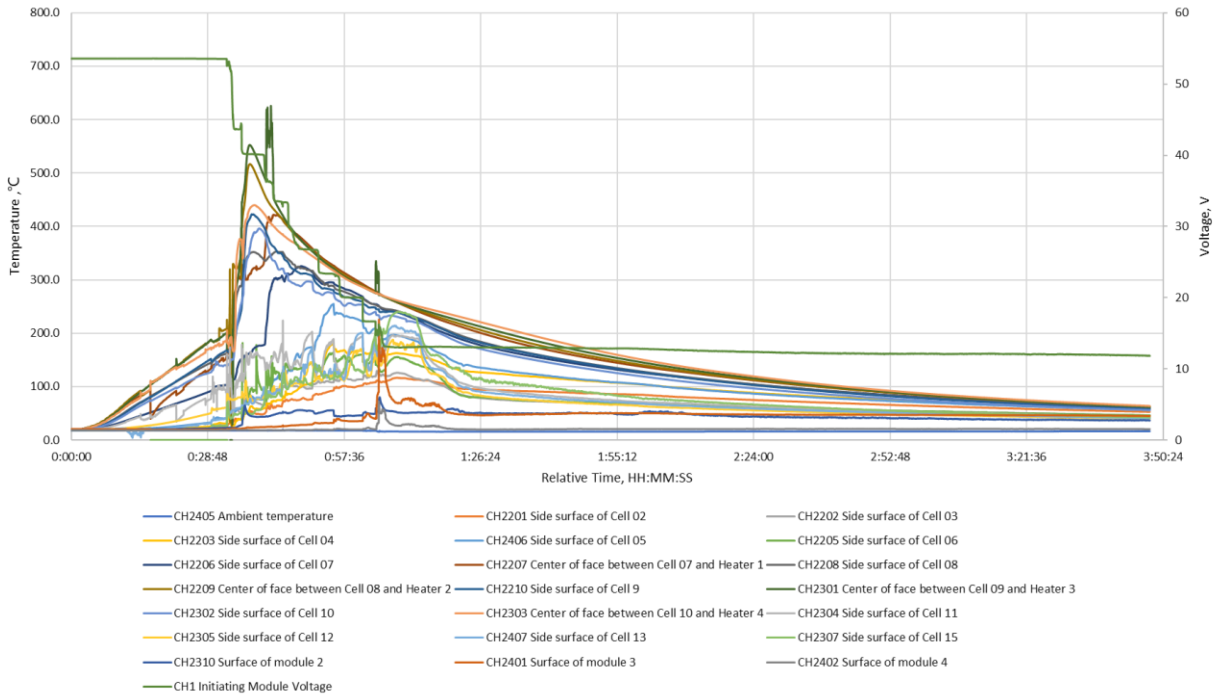


Figure 33. Temperature and voltage measurement results on the initiating module SM1.

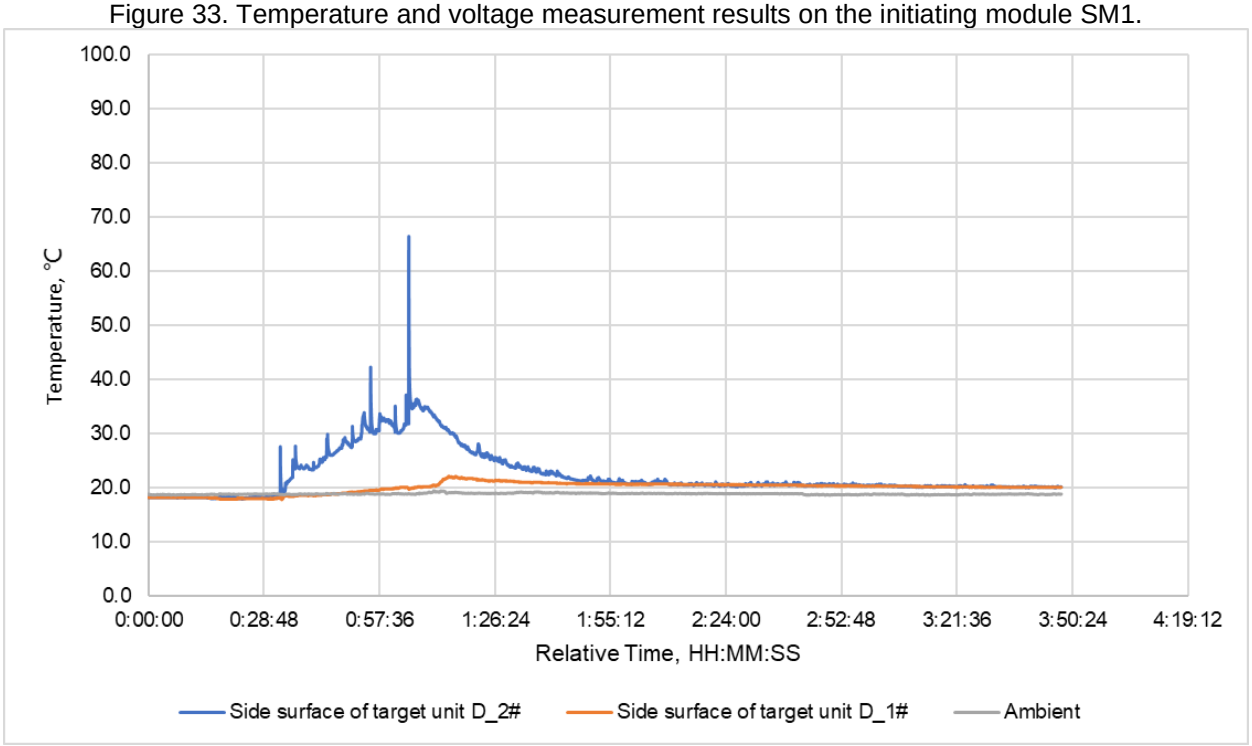


Figure 34. Temperature measurement results on target unit.

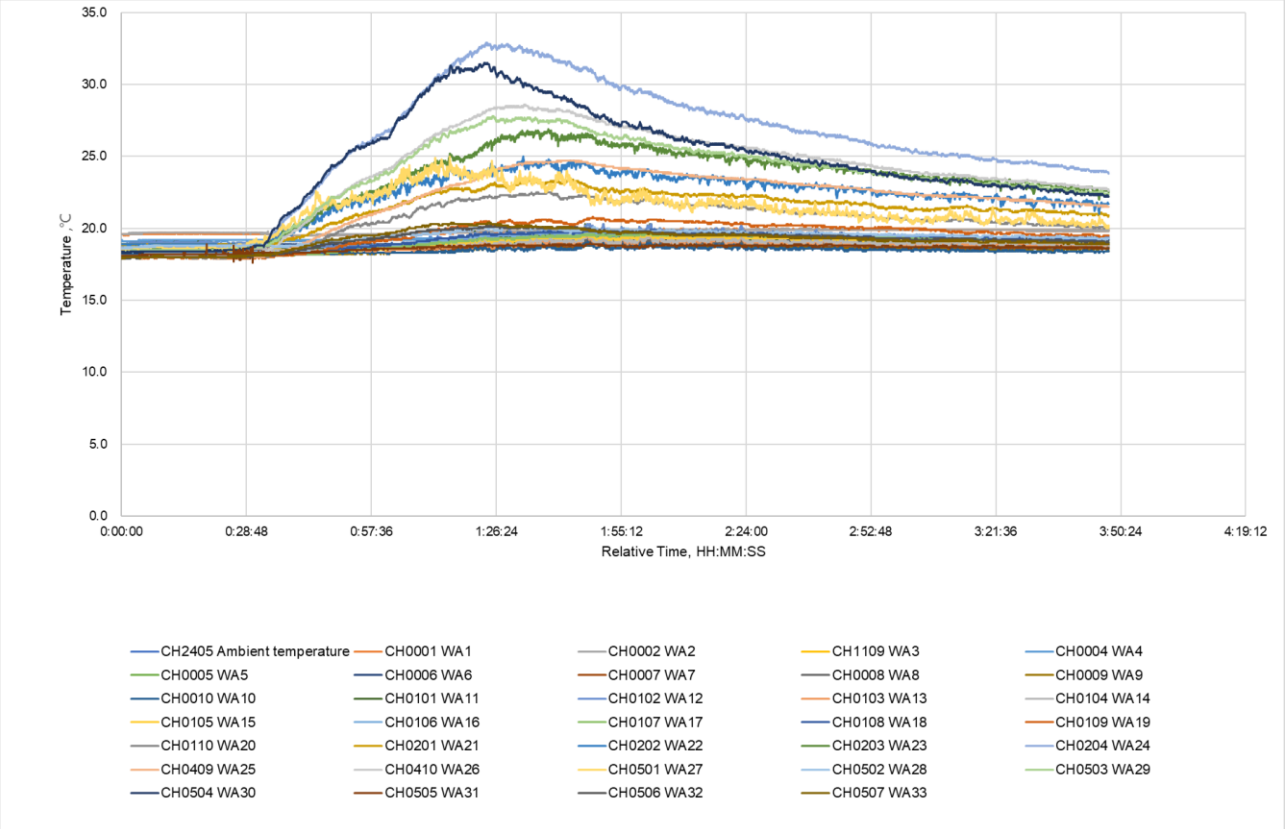


Figure 35. Temperature measurement results on instrumented wall A (WA1 to WA33).

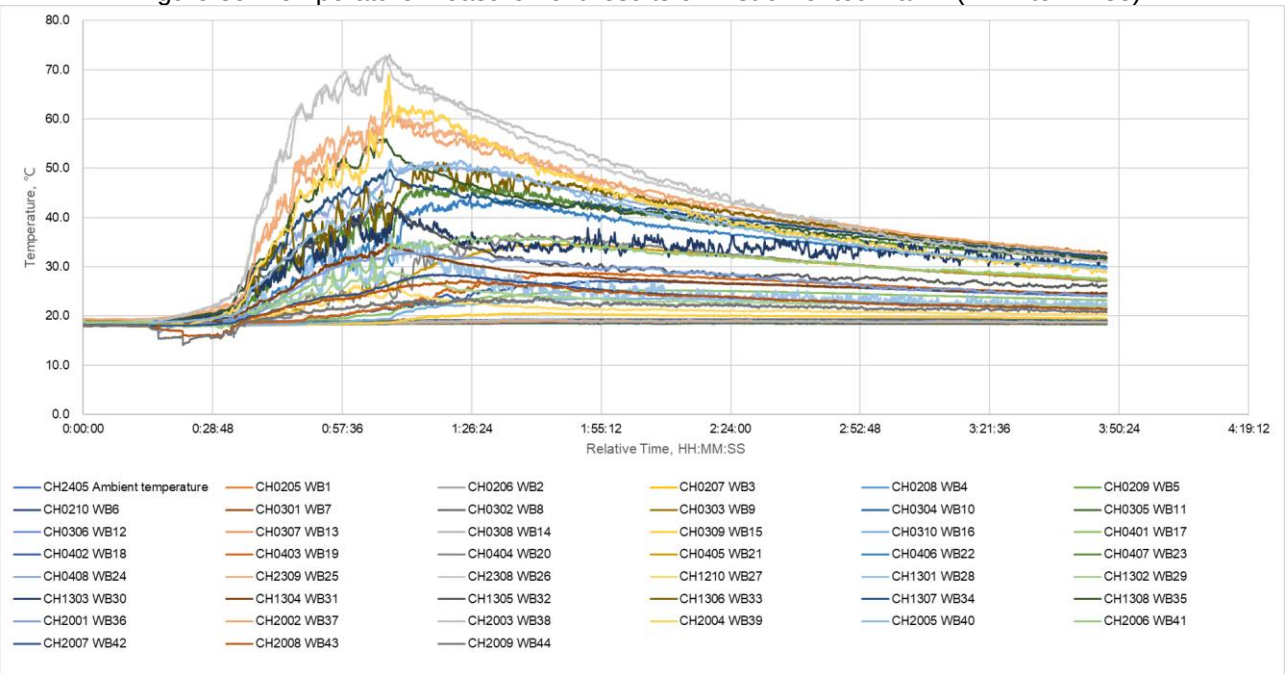


Figure 36. Temperature measurement results on instrumented wall B.

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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.

- - - End of Report - - -

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