Test Report

For

ANSI/CAN/UL9540A

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

[Unit Level]

Report Number:	**CQES240300015201**
Date of issue:	**2024-03-25**
Total number of pages:	**44**
Test object / Model:	**Lithium-ion Rechargeable Battery System L3 HV-X (X=15, 20, 25, 30, 35, 40, 45, 50, 55, 60)**
Applicant's name:	**Portable Solar LLC d/b/a Sol-Ark**
Address:	**805 Central Expwy S Allen, Texas, 75013, United States of America**

SGS-CEC (Chongqing) Energy Technology Co., Ltd. | Building 13 & 14, No.1839, Ranjun Road, Shuangfu Street, Jiangjin District, Chongqing, China 402260 t (86-023) 863676001 www.sgsgroup.com.cn
中国·重庆市江津区双福街道冉钧路1839号附13号、14号 邮编：402260 t (86-023) 863676001 sgs.china@sgs.com
Member of the SGS Group (SGS SA)

Report Number:	CQES240300015201
Manufacturer:	
Address:	
Factory：	
Address:	
Test object / Model:	Lithium-ion Rechargeable Battery System L3 HV-X (X=15, 20, 25, 30, 35, 40, 45, 50, 55, 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:	2023-02-15
Sample No.:	M1 to M4
Test Period:	Original test date: 2023-03-18 to 2023-04-15
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. Building 13 & 14, No. 1839, Ranjun Road, Shuangfu Street, Jiangjin District, Chongqing, China
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:
[redacted]
Project No: 4790509108

Cell Design:	[redacted]
Thermal Runaway Methodology:	External heating
Cell Surface Temperature at Gas venting:	181°C
Cell Surface Temperature at the onset Thermal Runaway:	230°C
Gas Composition:	Hydrocarbon, H_2, CO_2, CO
Lower Flammability Limit:	8.25 Vol% at ambient temperature 6.73 Vol% at 181°C
Burning Velocity:	97.8 cm/s
Pmax:	102.3 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:
L3 HV-5.1kWh
Report No:
CQES230900045801

Module Design:	L3 HV-5.1kWh
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
Peak Heat Release Rate:	No flaming combustion observed outside test module
Gas Generation and Composition:	Hydrocarbon, Hydrogen, CO_2, CO
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
Model: L3 HV-X (X=15, 20, 25, 30, 35, 40, 45, 50, 55, 60)
Report No:
CQES240300015201

Unit Design:	L3 HV-X (X=15, 20, 25, 30, 35, 40, 45, 50, 55, 60)
Thermal Runaway Methodology:	External heating
External Flaming:	No external flaming observed
Locations of Flame Extension:	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:	23.3°C
Max. Temperature Rise on Wall Surfaces:	2.0°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:
1. This report only evaluated unit level test which is listed inside the dotted box.
2. This report is issued based on previous SGS report CQES230900045901, dated 2023-09-28, with following changes and/or additions:
   - Changed fire suppression system information to optional. See page 9, 13 & 14 for detail.

After comparison, no further tests were considered necessary. All test data were cited from original test report CQES230200005401.

Report Revision History

Report No.	Date	Description of Change
CQES230200005401	2023-06-12	Initial issued.
CQES230900045901	2023-09-28	1. Changed Model No. to new models “L3 HV-X (X=15, 20, 25, 30, 35, 40, 45, 50, 55, 60)” .
CQES240300015201	2024-03-22	1. Changed fire suppression system information to optional.

[Test object Description]

Table 1: Description of component cell

Model:		
Manufacturer:		
Nominal capacity:	100 Ah	
Nominal voltage:	3.2 V	
Chemistry:	Lithium ion, LiFePO4	
Charge current:	100 A	
Discharge current:	250 A	
Maximum charge voltage:	3.9 V	
Cut-off Voltage:	1.9 V	
External dimensions:	49.9(±1.0mm_ *160.0mm(±1.0mm) * 118.5mm(±1.0mm)	
UL 1973 compliant:	☒ Yes / ☐ No	Reference: UL (MH63503)
UL 9540A report provided:	☒ Yes / ☐ No	Reference: UL report No.: 4790509108

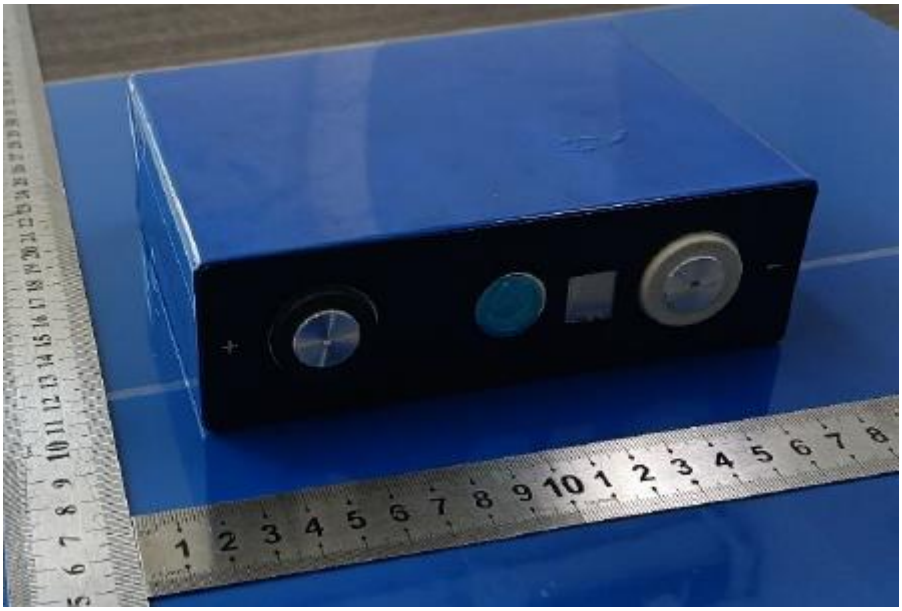


Figure 1. View of component cell

Table 2: Description of battery module

Model:	L3 HV-5.1kWh	
Manufacturer:		
Nominal capacity:	100 Ah	
Nominal voltage:	51.2 V	
Module designation:	1P16S	
Maximum charge current:	100 A	
Maximum discharge current:	100 A	
Maximum charge voltage:	57.6 V	
Cut-off Voltage:	45 V	
Charge temperature range:	0°C to 55°C	
Discharge temperature range:	-20°C to 55°C	
Module configuration:	16 Lithium ion cells in 16S cased by metal enclosure	
Enclosure material:	Painted metal	
Weight:	Appr. 44 kg	
UL 1973 compliant:	☒ Yes / ☐ No	Reference: Contract No: 802329, issued by SGS
UL 9540A report provided:	☒ Yes / ☐ No	Reference: SGS report No. CQES230900045801

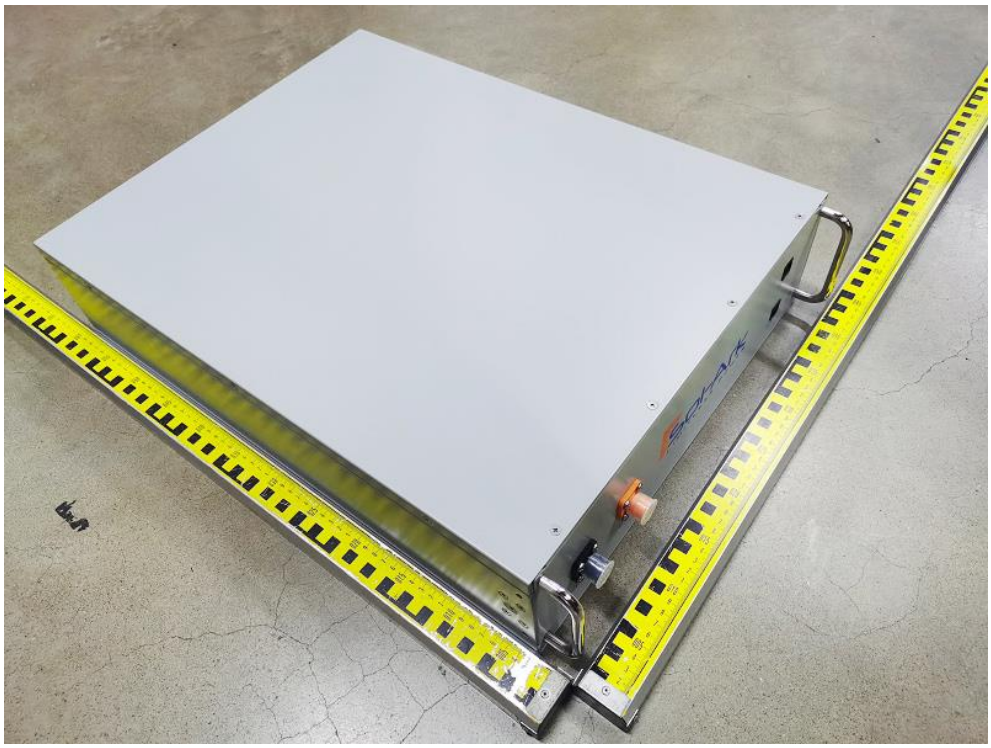


Figure 2a: View 01 of battery module.

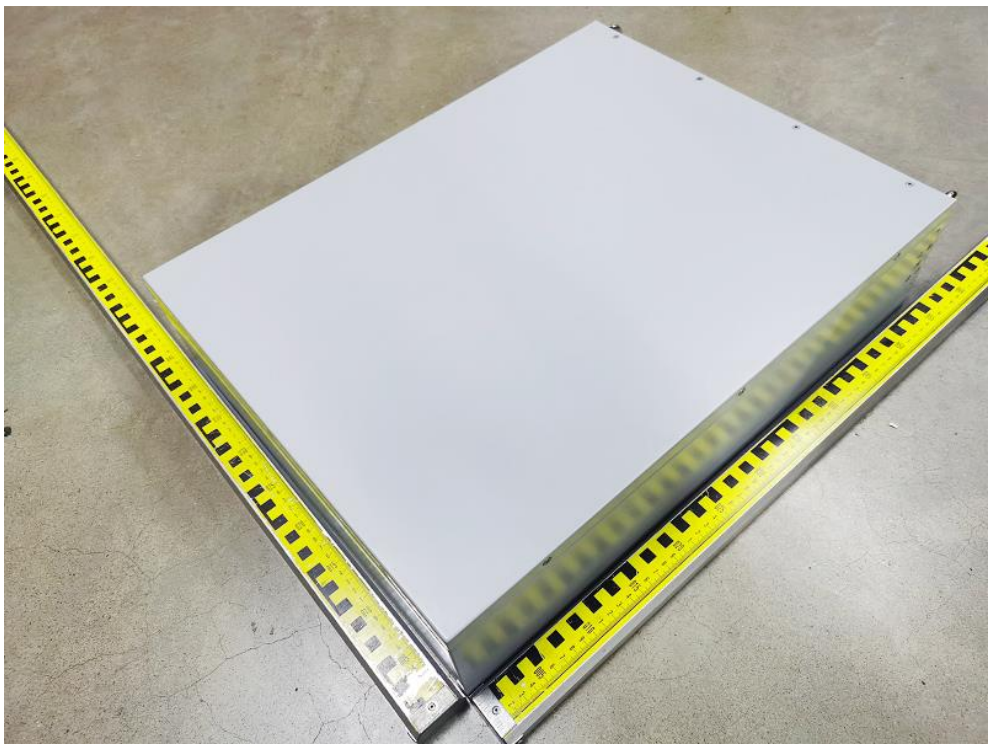


Figure 2b: View 02 of battery module.

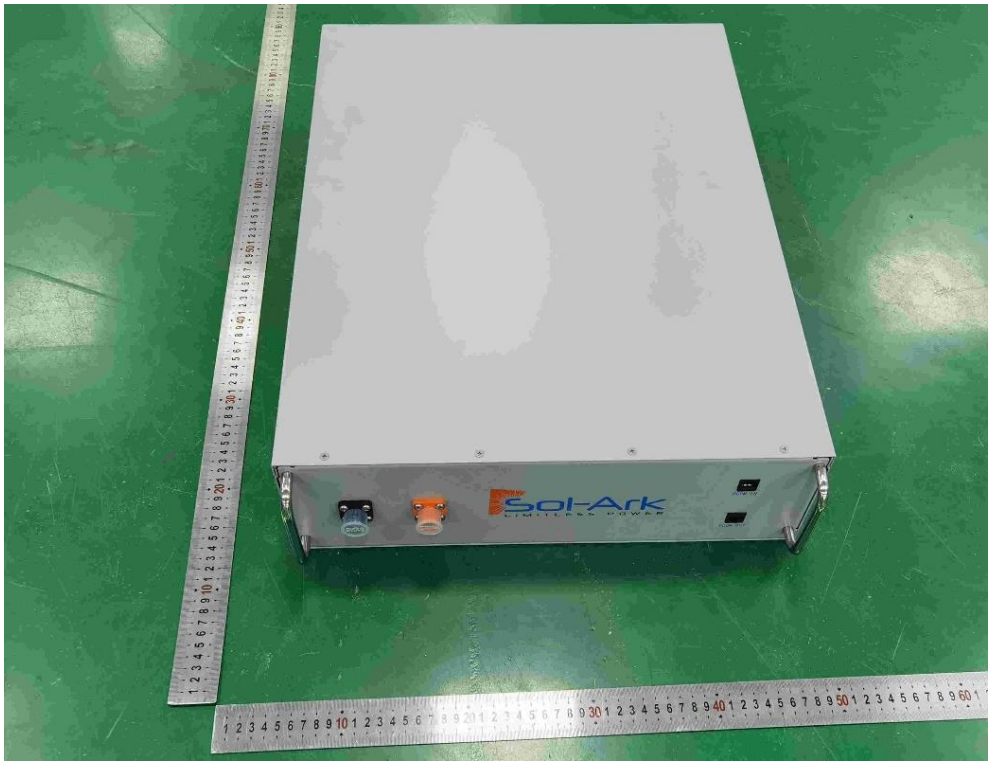


Figure 2c: View 03 of battery module.

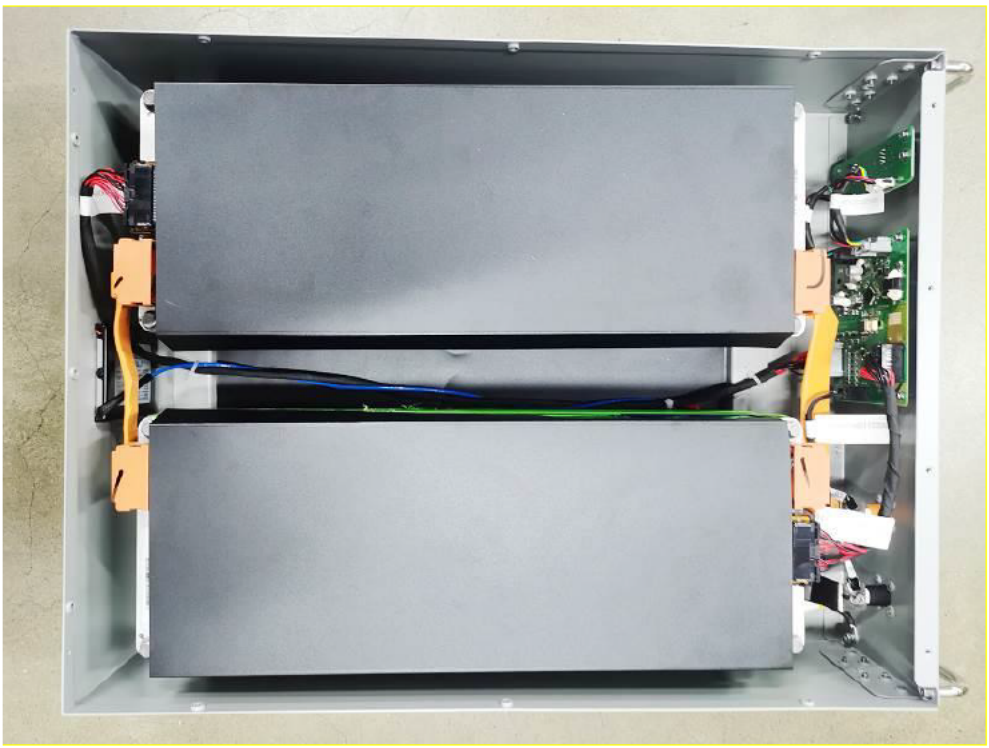


Figure 2d: View 04 of battery module.

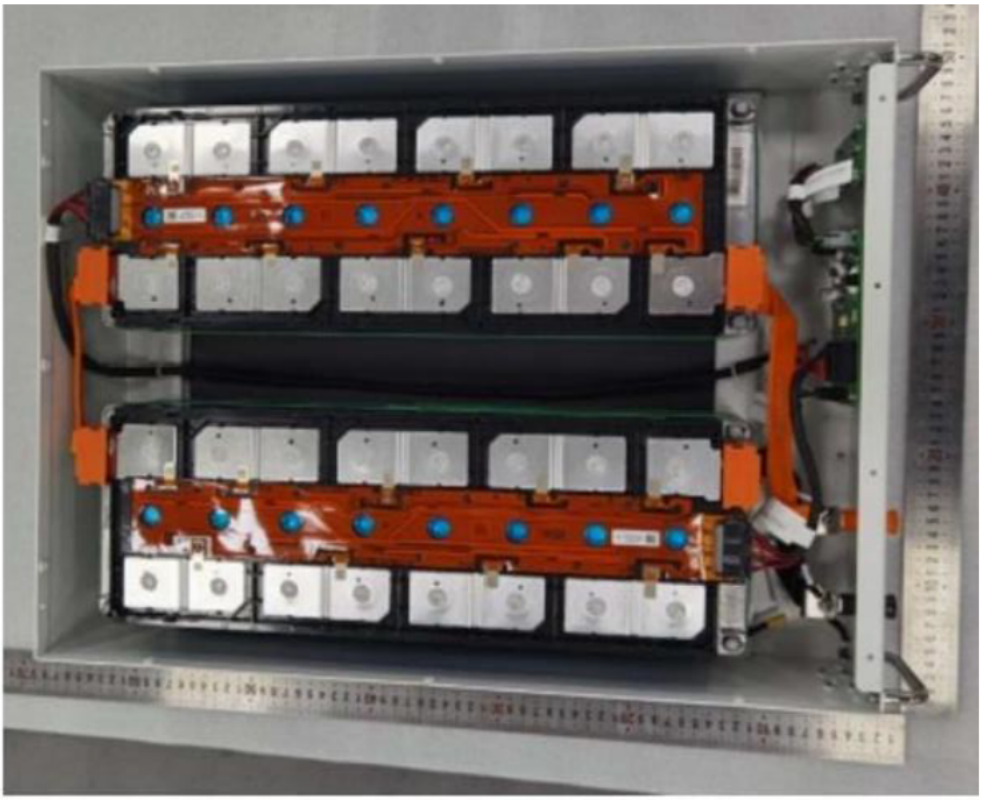


Figure 2e: View 05 of battery module.

Table 3: Description of battery unit (system)

<table>
<tr><td>Model:</td><td colspan="2">L3 HV-X (X=15, 20, 25, 30, 35, 40, 45, 50, 55, 60)</td></tr>
<tr><td>Manufacturer:</td><td colspan="2"></td></tr>
<tr><td>Nominal capacity:</td><td colspan="2">100 Ah</td></tr>
<tr><td>Nominal voltage:</td><td colspan="2">51.2 V x N</td></tr>
<tr><td>Module designation:</td><td colspan="2">Lithium ion, $LiFePO_4$</td></tr>
<tr><td>Maximum charge current:</td><td colspan="2">100 Ah</td></tr>
<tr><td>Maximum discharge current:</td><td colspan="2">100 Ah</td></tr>
<tr><td>Maximum charge voltage:</td><td colspan="2">57.6 V x N</td></tr>
<tr><td>Cut-off Voltage:</td><td colspan="2">45 V x N</td></tr>
<tr><td>Charge temperature range:</td><td colspan="2">0°C to 55°C</td></tr>
<tr><td>Discharge temperature range:</td><td colspan="2">-20°C to 55°C</td></tr>
<tr><td>Unit configuration:</td><td colspan="2">Each unit consists of N pcs of battery modules and 1 battery management system controller (model: L3 BMS-750V), housed by metal rack (N may be 3 to 12 in this model series, which represents the number of battery modules included in the rack, connected in series). Each module consists of 16 Lithium-ion cells in 16S cased by metal enclosure.
<table>
<tr><th>Model of battery system</th><th>Rated voltage</th></tr>
<tr><td>L3 HV-15</td><td>51.2Vd.c. x 3</td></tr>
<tr><td>L3 HV-20</td><td>51.2Vd.c. x 4</td></tr>
<tr><td>L3 HV-25</td><td>51.2Vd.c. x 5</td></tr>
<tr><td>L3 HV-30</td><td>51.2Vd.c. x 6</td></tr>
<tr><td>L3 HV-35</td><td>51.2Vd.c. x 7</td></tr>
<tr><td>L3 HV-40</td><td>51.2Vd.c. x 8</td></tr>
<tr><td>L3 HV-45</td><td>51.2Vd.c. x 9</td></tr>
<tr><td>L3 HV-50</td><td>51.2Vd.c. x 10</td></tr>
<tr><td>L3 HV-55</td><td>51.2Vd.c. x 11</td></tr>
<tr><td>L3 HV-60</td><td>51.2Vd.c. x 12</td></tr>
</table></td></tr>
<tr><td>External dimensions:</td><td colspan="2">580mm*590mm*2200mm</td></tr>
<tr><td>Enclosure material:</td><td colspan="2">Iron</td></tr>
<tr><td>Weight:</td><td colspan="2">Appr. 628 kg</td></tr>
<tr><td>Fire suppression system contain</td><td>☒ Yes / ☐ No</td><td>Reference: Aerosol unit (Optional)
Manufacturer: Hubei Jiandun Fire Protection Technology Co., Ltd.
Model: QRR0.012G/S</td></tr>
<tr><td>UL 1973 compliant:</td><td>☒ Yes / ☐ No</td><td>Reference: SGS Contract No.: 802329</td></tr>
</table>

UL 9540 compliant:	☒ Yes / ☐ No	Reference: Reference: SGS report No.: SHES230801533032
Supplementary information: Test is conducted on L3 HV-60, and no further testing is considered as necessary for other models.		

Figure 3a. External view 01 of battery system

Figure 3b. External view 02 of battery system

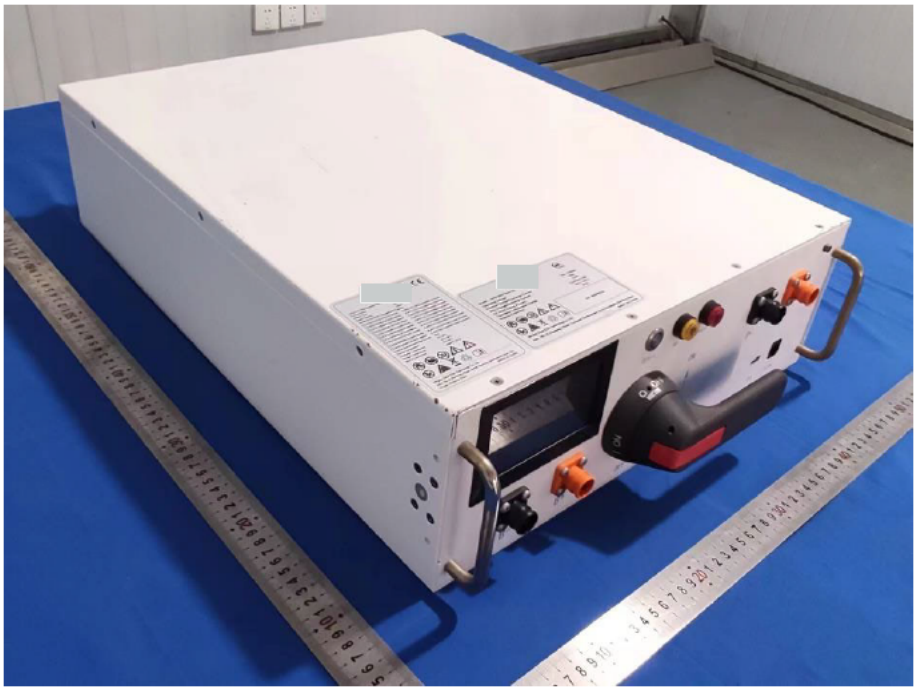


Figure 3c. External view of battery management system controller

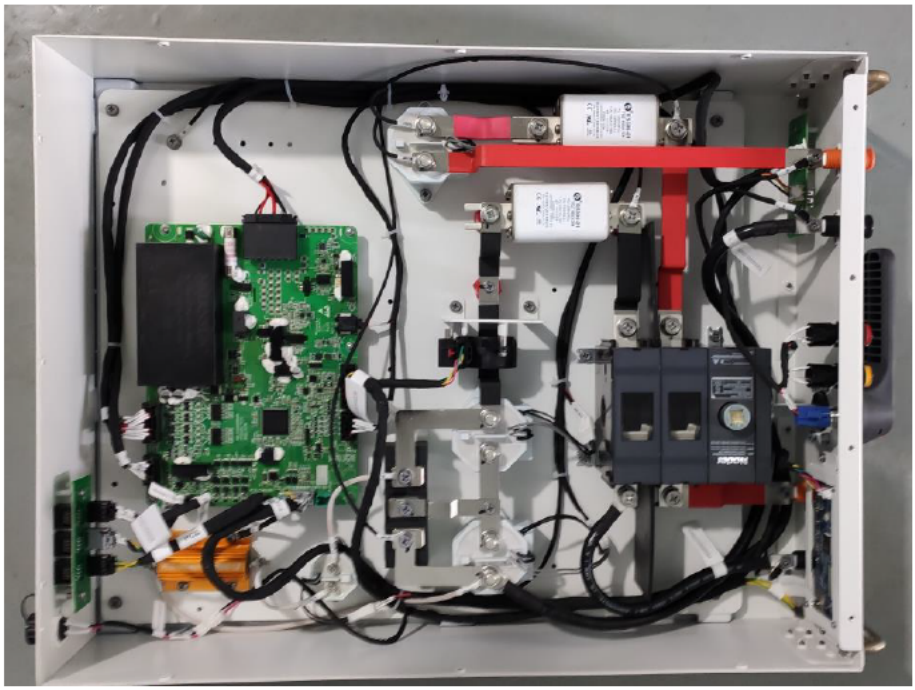


Figure 3d. Internal view of battery management system controller

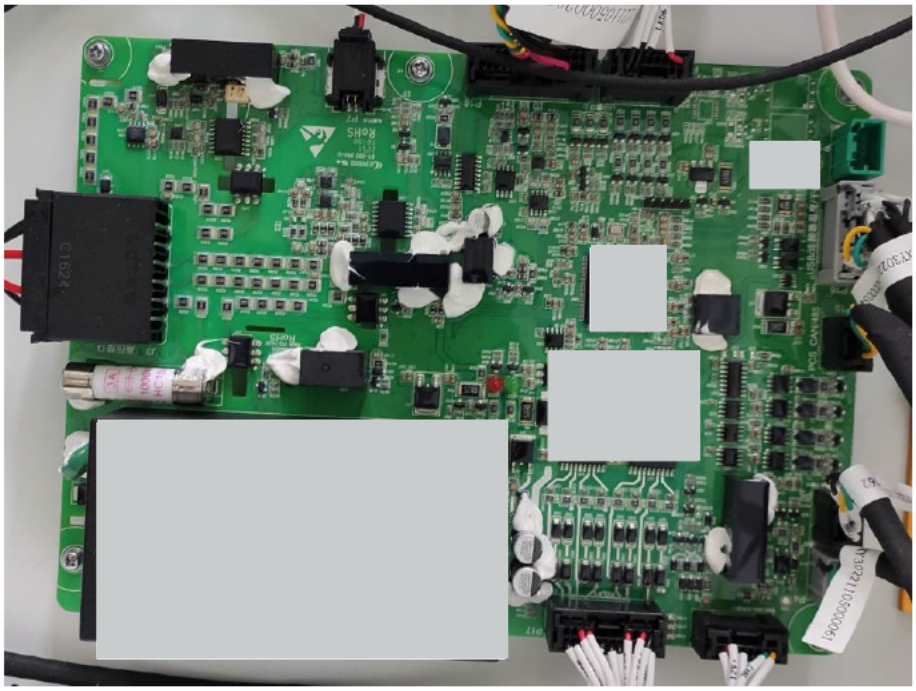


Figure 3e. View of BMS

Figure 3f View of Aerosol unit (Internal side of battery pack)

[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.

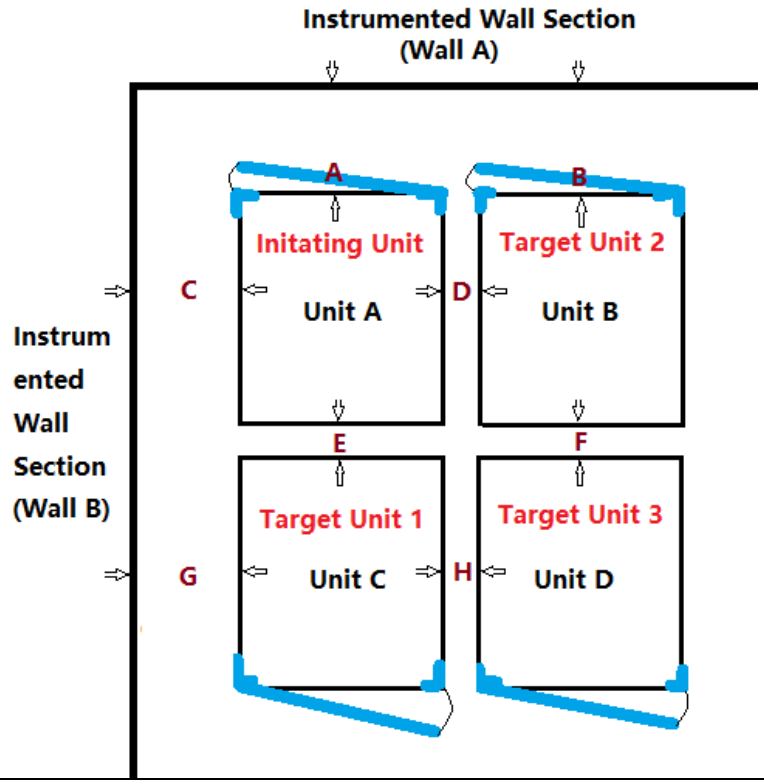
If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT. If the BESS unit is provided with an optional integral fire suppression system, the system shall not be provided on the DUT.

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 (Manufacturer: Hubei Jiandun Fire Protection Technology Co., Ltd. Model: QRR0.012G/S)
Standard or optional	☐ Standard / ☒ Optional / ☐ N/A
Test with fire suppression or not	☐ Yes / ☒ No

Table 5: 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	600 mm
	B	600 mm
	C	600 mm
	D	100 mm
	E	100 mm
	F	100 mm
	G	600 mm
	H	100 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 unit level test:
The propensity of the cell to exhibit thermal runaway be demonstrated by heating the cell with externally applied heaters. With a surface heating rate of 4ºC (7.2ºF) to 7ºC (12.6ºF) per minute until cell thermal runaway occurs within the test unit.

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.

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Test configuration description

Illustration of the initiating BESS unit
Description: N/A

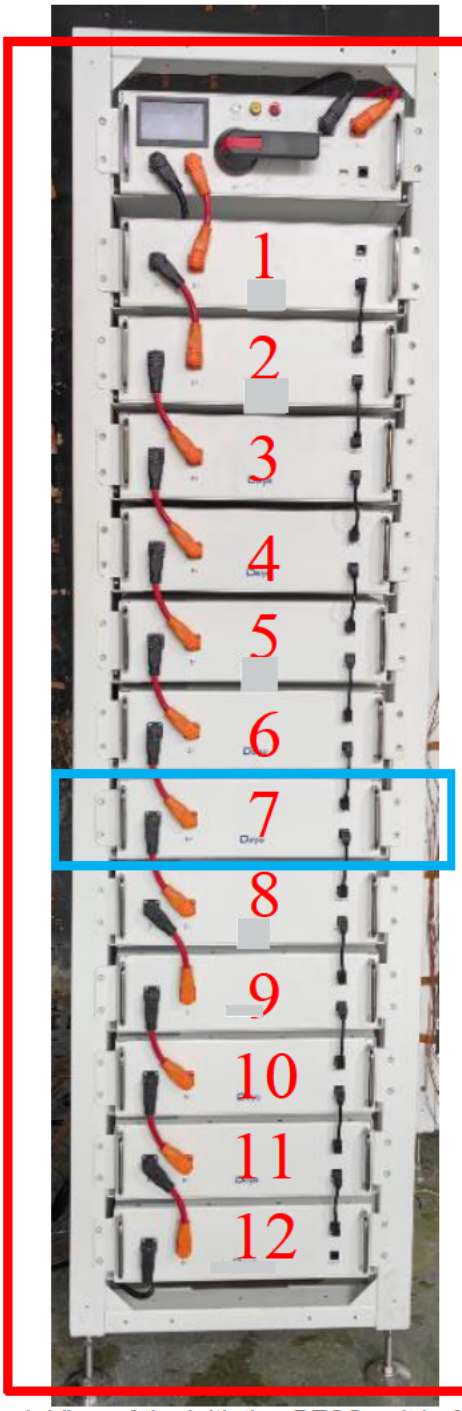

Figure 4. View of the initiating BESS unit before test.

Thermal runaway initiation method used (including number and locations of cells for initiating thermal runaway)
Initiation method: External heating method was used to initiate thermal runaway. 2 film heaters were used to initiate thermal runaway. Each heater was connected to one voltage regulator. Heater 1 and Heater 2 were energized at the same time. The working currents of Heater 1 and Heater 2 were continuously adjusted to make sure that the initiating cell was heated at a ramp of 4-7 °C/min.
Number of cells for initiating thermal runaway: ☒ Single cell 102 Ah (total capacity) ☐ Multiple cell Ah (total capacity)
Locations of cells for initiating thermal runaway: This Battery system is constructed with 12 battery modules, 1 control box a metal rack without enclosure. Module 7 in initiating unit (marked as Unit A) was selected as initiating module. Each battery module consists of 2 submodules. Each submodule consists of 8 cells with a connection mode of 8S. Two submodules are connected in series. One 8S submodule (as shown in Figure 5b) is selected as the initiating submodule. Heater 1 was placed between the large surfaces of Cell 13 and Cell 14. Heater 2 was placed between the large surfaces of Cell 13 and Cell 12. Cell 13 was selected as initiating cell.
Other description: N/A

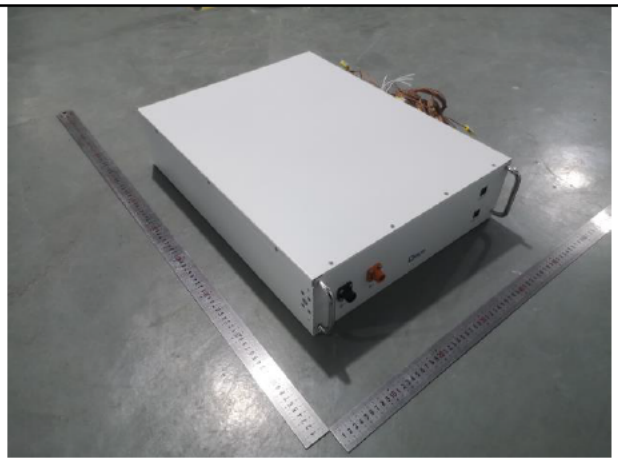

Figure 5a. External view of battery module.

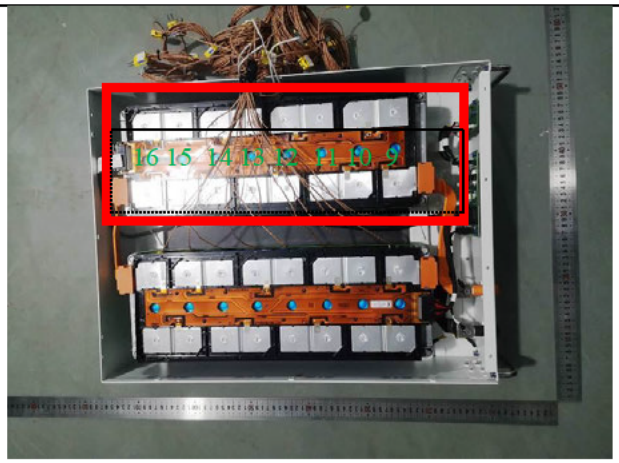

Figure 5b. Internal view 01 of battery module.

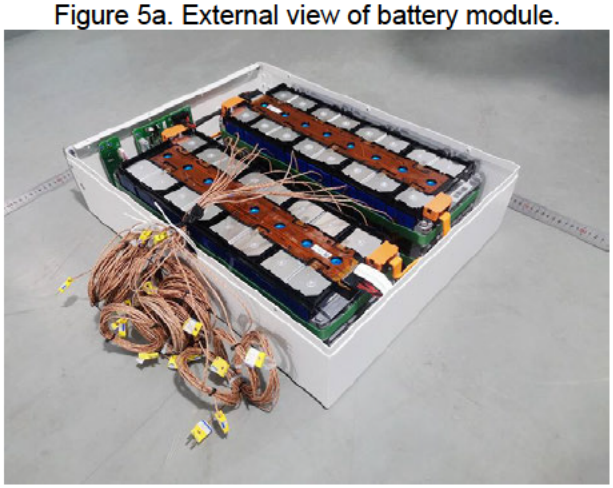

Figure 5c. Internal view 02 of battery module.

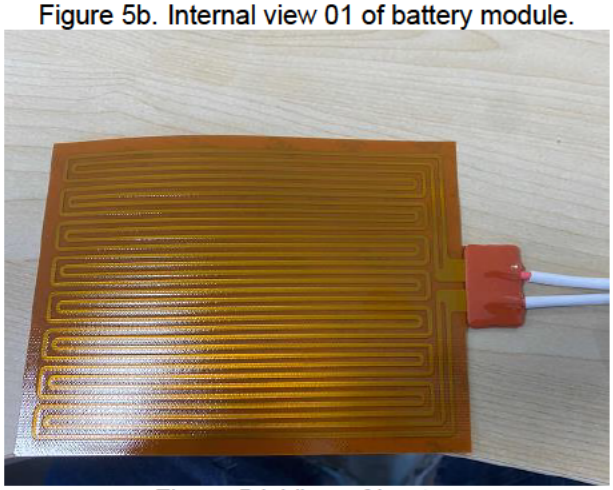

Figure 5d. View of heater.

Illustration of external heater and thermocouple locations
Description: N/A

Figure 6. Schematic diagram of external heater and thermocouple locations in the initiating module (View from top).

Positioning of units within testing room
Test Start Time: 2023-04-08 16:57:00
Initial Ambient Test Temperature: 19.1 °C
Initial Relative Humidity: 58%
Description: N/A

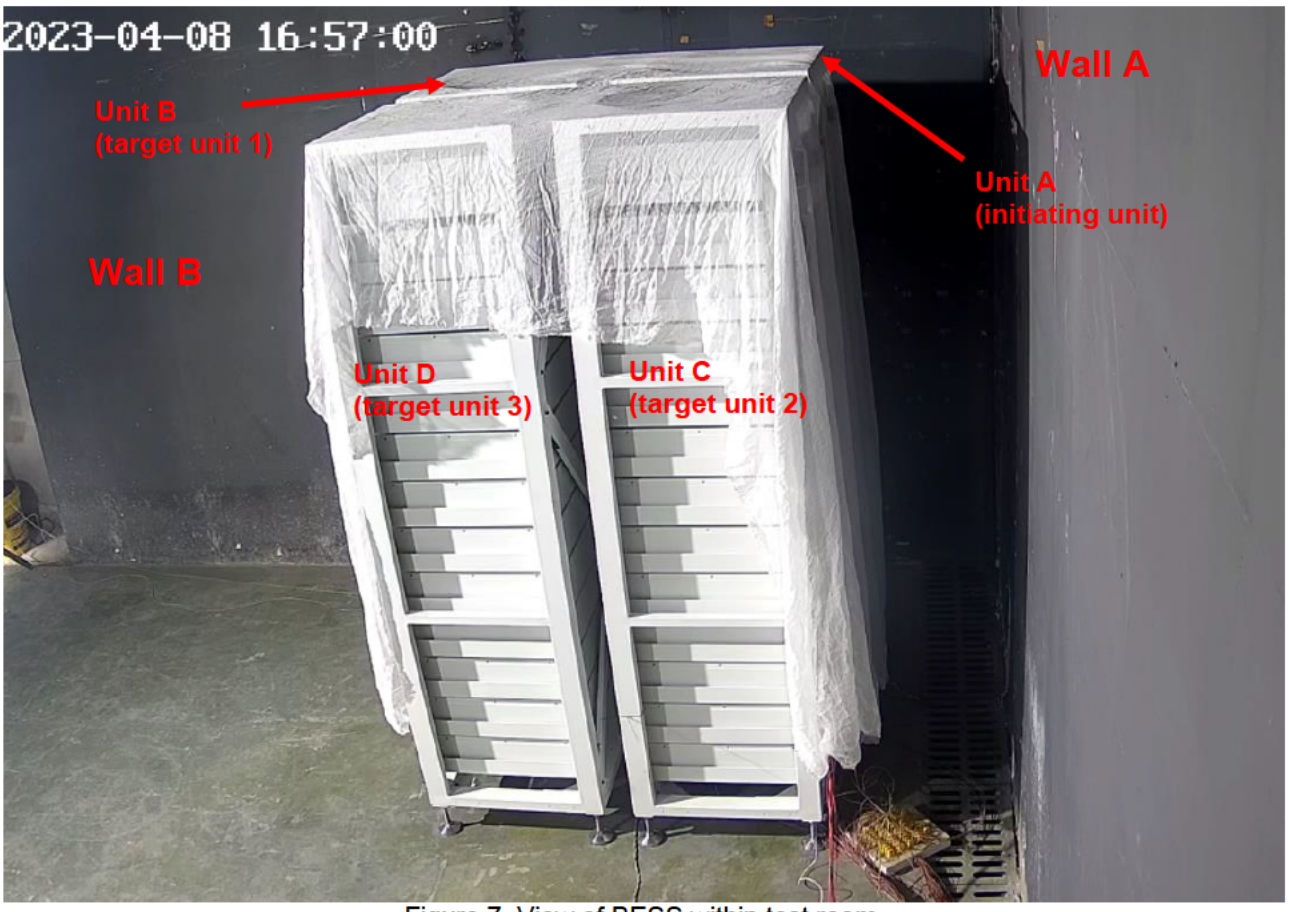

Figure 7. View of BESS within test room.

Table 6: Thermocouple placement

Thermocouple ID	Description of location	Remark
CH2106	Side surface B of Cell 1	T1, in initiating module
CH2107	Side surface B of Cell 2	T2, in initiating module
CH2108	Side surface B of Cell 3	T3, in initiating module
CH2109	Side surface B of Cell 4	T4, in initiating module
CH2110	Side surface B of Cell 5	T5, in initiating module
CH2201	Side surface B of Cell 6	T6, in initiating module
CH2202	Side surface B of Cell 7	T7, in initiating module
CH2203	Side surface B of Cell 8	T8, in initiating module
CH2204	Side surface A of Cell 9	T9, in initiating module
CH2205	Side surface A of Cell 10	T10, in initiating module
CH2206	Side surface A of Cell 11	T11, in initiating module
CH2207	Side surface A of Cell 12	T12, in initiating module
CH2208	Side surface A of Cell 13	T13, in initiating module
CH2209	Side surface A of Cell 14	T14, in initiating module
CH2301	Side surface A of Cell 15	T15, in initiating module
CH2303	Side surface A of Cell 16	T16, in initiating module
CH2302	Large surface of cell 13, between cell surface and Heater 1	T17, in initiating module
CH2210	Large surface of cell 13, between cell surface and Heater 2	T18, in initiating module
CH1206	No. 1 of wall B	WB-1
CH1207	No. 2 of wall B	WB-2
CH1208	No. 3 of wall B	WB-3
CH1209	No. 4 of wall B	WB-4
CH1210	No. 5 of wall B	WB-5
CH1301	No. 6 of wall B	WB-6
CH1302	No. 7 of wall B	WB-7
CH1303	No. 8 of wall B	WB-8
CH1304	No. 9 of wall B	WB-9
CH1305	No. 10 of wall B	WB-10
CH1306	No. 11 of wall B	WB-11
CH1307	No. 12 of wall B	WB-12
CH1308	No. 13 of wall B	WB-13

CH1309	No. 14 of wall B	WB-14
CH1310	No. 15 of wall B	WB-15
CH2001	No. 16 of wall B	WB-16
CH2002	No. 17 of wall B	WB-17
CH2003	No. 18 of wall B	WB-18
CH2004	No. 19 of wall B	WB-19
CH2005	No. 20 of wall B	WB-20
CH2006	No. 21 of wall B	WB-21
CH2007	No. 22 of wall B	WB-22
CH2008	No. 23 of wall B	WB-23
CH2009	No. 24 of wall B	WB-24
CH2010	No. 25 of wall B	WB-25
CH2102	No. 26 of wall B	WB-26
CH2103	No. 27 of wall B	WB-27
CH2104	No. 28 of wall B	WB-28
CH2105	No. 29 of wall B	WB-29
CH0206	No. 30 of wall B	WB-30
CH0207	No. 31 of wall B	WB-31
CH0208	No. 32 of wall B	WB-32
CH0209	No. 33 of wall B	WB-33
CH0210	No. 34 of wall B	WB-34
CH0301	No. 35 of wall B	WB-35
CH0302	No. 36 of wall B	WB-36
CH0303	No. 37 of wall B	WB-37
CH0304	No. 38 of wall B	WB-38
CH0305	No. 39 of wall B	WB-39
CH0306	No. 40 of wall B	WB-40
CH0307	No. 41 of wall B	WB-41
CH0308	No. 42 of wall B	WB-42
CH0309	No. 43 of wall B	WB-43
CH0310	No. 44 of wall B	WB-44
CH0402	No. 45 of wall B	WB-45

CH0403	No. 46 of wall B	WB-46
CH0404	No. 47 of wall B	WB-47
CH0405	No. 48 of wall B	WB-48
CH0406	No. 49 of wall B	WB-49
CH0407	No. 50 of wall B	WB-50
CH0408	No. 51 of wall B	WB-51
CH0409	No. 52 of wall B	WB-52
CH0410	No. 1 of wall A	WA-1
CH0501	No. 2 of wall A	WA-2
CH0502	No. 3 of wall A	WA-3
CH0503	No. 4 of wall A	WA-4
CH0504	No. 5 of wall A	WA-5
CH0505	No. 6 of wall A	WA-6
CH0506	No. 7 of wall A	WA-7
CH0507	No. 8 of wall A	WA-8
CH0508	No. 9 of wall A	WA-9
CH1002	No. 10 of wall A	WA-10
CH1003	No. 11 of wall A	WA-11
CH1004	No. 12 of wall A	WA-12
CH1005	No. 13 of wall A	WA-13
CH1006	No. 14 of wall A	WA-14
CH1007	No. 15 of wall A	WA-15
CH1008	No. 16 of wall A	WA-16
CH1009	No. 17 of wall A	WA-17
CH1010	No. 18 of wall A	WA-18
CH1101	No. 19 of wall A	WA-19
CH1102	No. 20 of wall A	WA-20
CH1103	No. 21 of wall A	WA-21
CH1104	No. 22 of wall A	WA-22
CH1105	No. 23 of wall A	WA-23
CH1106	No. 24 of wall A	WA-24
CH1107	No. 25 of wall A	WA-25

CH1108	No. 26 of wall A	WA-26
CH1109	No. 27 of wall A	WA-27
CH1110	No. 28 of wall A	WA-28
CH1201	No. 29 of wall A	WA-29
CH1202	No. 30 of wall A	WA-30
CH1203	No. 31 of wall A	WA-31
CH1204	No. 32 of wall A	WA-32
CH1205	No. 33 of wall A	WA-33
CH0002	No. 34 of wall A	WA-34
CH0004	No. 35 of wall A	WA-35
CH0005	No. 36 of wall A	WA-36
CH0006	No. 37 of wall A	WA-37
CH0007	No. 38 of wall A	WA-38
CH0008	No. 39 of wall A	WA-39
CH0009	No. 40 of wall A	WA-40
CH0010	No. 41 of wall A	WA-41
CH0101	No. 42 of wall A	WA-42
CH0102	No. 43 of wall A	WA-43
CH0103	No. 44 of wall A	WA-44
CH0104	No. 45 of wall A	WA-45
CH0105	No. 46 of wall A	WA-46
CH0106	No. 47 of wall A	WA-47
CH0107	No. 48 of wall A	WA-48
CH0108	No. 49 of wall A	WA-49
CH0109	No. 50 of wall A	WA-50
CH0110	No. 51 of wall A	WA-51
CH0201	No. 52 of wall A	WA-52
CH0202	No. 53 of wall A	WA-53
CH0203	No. 54 of wall A	WA-54
CH0204	No. 55 of wall A	WA-55
CH2304	Top surface of module 2 in unit A	TA1
CH2305	Top surface of module 3 in unit A	TA2

CH2306	Top surface of module 4 in unit A	TA3
CH2307	Top surface of module 5 in unit A	TA4
CH2308	Top surface of module 6 in unit A	TA5
CH2309	Left surface of module 7 in unit A	TA6
CH2310	Top surface of module 7 in unit A	TA7
CH2401	Front surface of module 7 in unit A	TA8
CH2402	Right surface of module 7 in unit A	TA8
CH2403	Top surface of module 8 in unit A	TA8
CH2404	Top surface of module 9 in unit A	TA8
CH2405	Top surface of module 10 in unit A	TA8
CH2406	Top surface of module 11 in unit A	TA8
CH2407	Top surface of module 12 in unit A	TA8
CH3201	Rear surface of module 3 in unit B	TB1
CH3202	Rear surface of module 4 in unit B	TB2
CH3203	Rear surface of module 5 in unit B	TB3
CH3204	Rear surface of module 6 in unit B	TB4
CH3205	Rear surface of module 7 in unit B	TB5
CH3206	Rear surface of module 8 in unit B	TB6
CH3207	Rear surface of module 9 in unit B	TB7
CH3208	Rear surface of module 10 in unit B	TB8
CH2408	Right surface of module 3 in unit C	TC1
CH2410	Right surface of module 4 in unit C	TC2
CH2501	Right surface of module 5 in unit C	TC3
CH2502	Right surface of module 6 in unit C	TC4
CH2503	Right surface of module 7 in unit C	TC5
CH2504	Right surface of module 8 in unit C	TC6
CH2505	Right surface of module 9 in unit C	TC7
CH2507	Right surface of module 10 in unit C	TC8
Thermocouple information: Type K, 24AWG.		

[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
16:57:00	0:00:00	E1	Test Start	--	Figure 12
16:58:00	0:01:00	E2	Heater 1 and Heater 2 Energized	--	--
17:57:45	1:00:45	E3	First Release	Smoke release observed from initiating battery system enclosure.	Figure 13
18:24:42	1:27:42	E4	Second Release	Smoke release observed from initiating battery system enclosure.	Figure 14
20:18:47	3:21:47	E5	Test Termination	--	--

Chemical heat release rate versus time
Description: No flaming extension observed outside the initiating unit.
N/A
Convective heat release rate (HRRc) versus time
Description: N/A

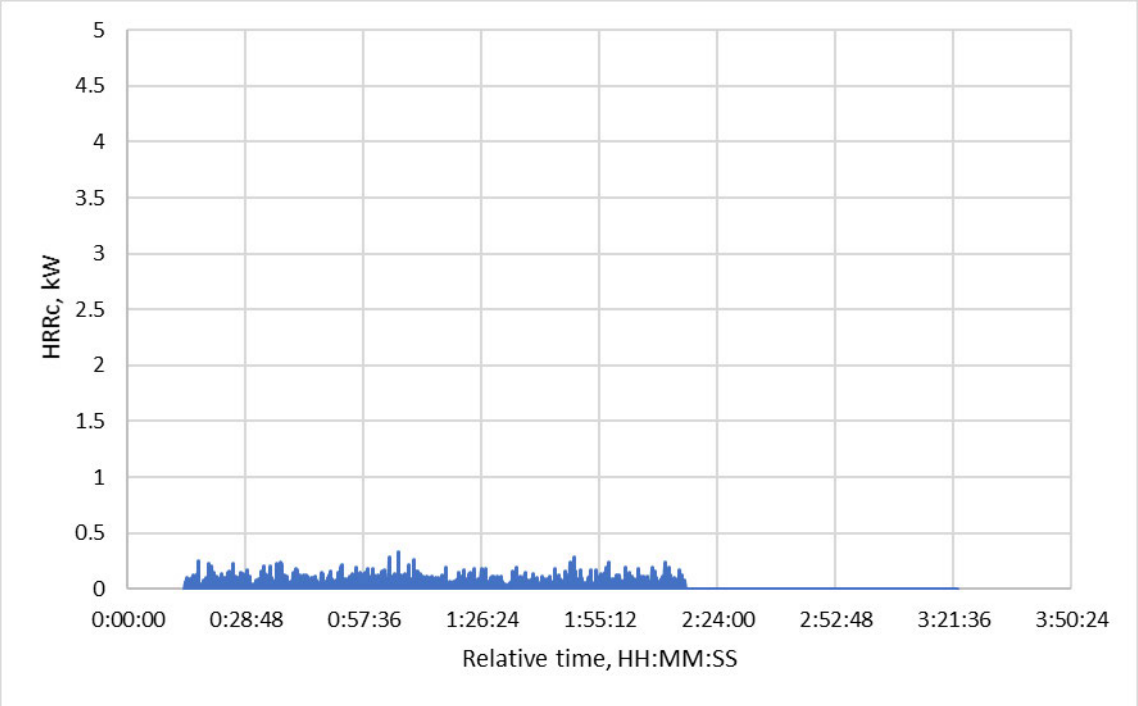

Figure 8. Convective heat release rate versus time

Maximum incident heat flux on target units and wall surfaces

Result:

Heat Flux Sensor ID	Description of location
CH1401	Surface of wall A, facing the center of front surface of module 6 in initiating unit
CH1402	Surface of wall A, facing the center of front surface of module 7 in initiating unit
CH1403	Surface of wall B, facing the center of right surface of module 6 in initiating unit
CH1404	Surface of wall B, facing the center of right surface of module 7 in initiating unit
CH1405	Center of right surface of module 7 in target unit 2(Unit C)
CH1406	Center of rear surface of module 7 in target unit 3(Unit B)

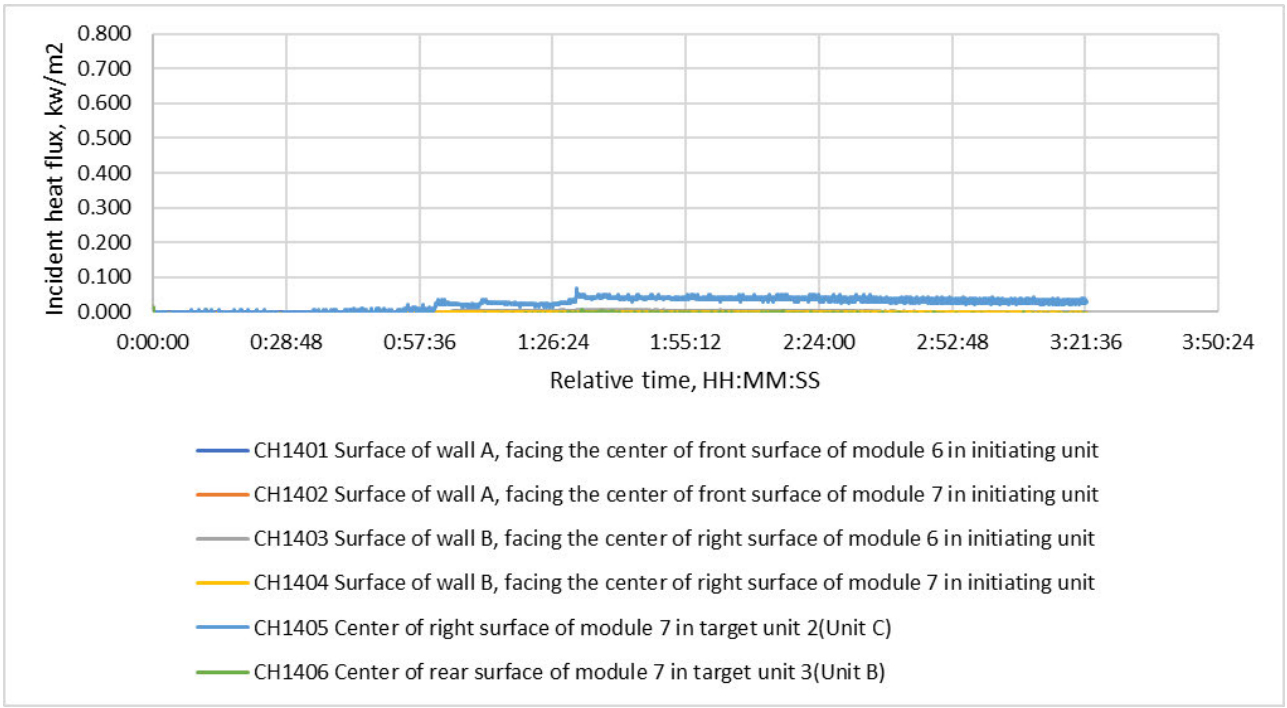

Figure 9. Incident heat flux on target wall surfaces and target BESS units.

Peak smoke release rate and total smoke release
Result: 1. Peak smoke release rate is 0.056 m^2/s during test. 2. Total smoke release is 60 m^2 during test.

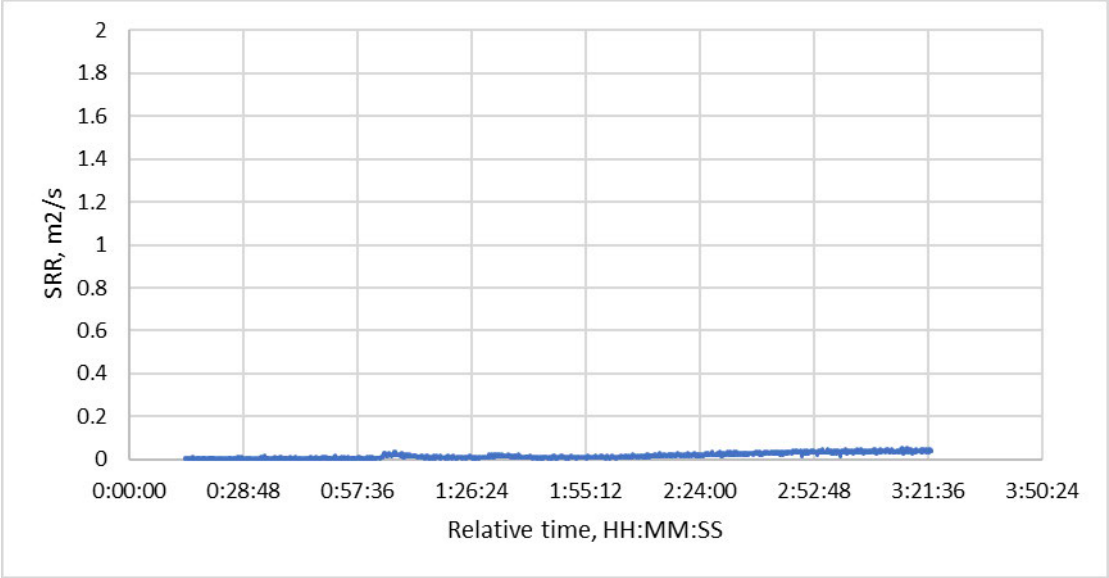

Figure 10. Smoke release rate versus time.

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: 195 L (25°C,101kPa) Recommend smallest room for installation: ≥ 10 m^3

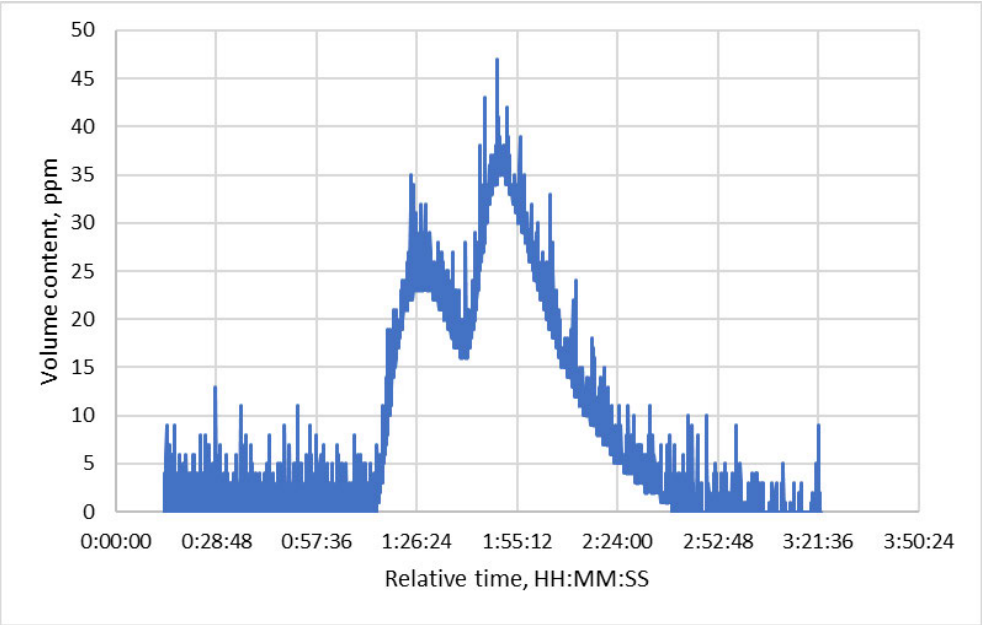

Figure 11a. Online Hydrogen content measurements during test.

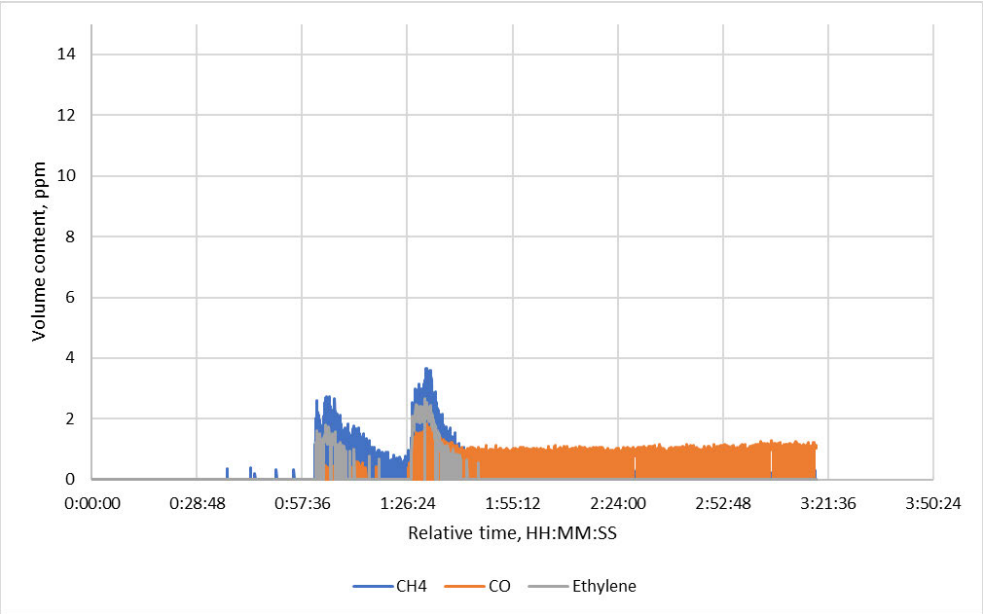

Figure 11b. Online flammable gas content measurements during test. (Remark: The content of other hydrocarbons is below the detection limit of the test equipment.)

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

Table 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 of initiatig unit	53.429	53.429	No gas venting observed. No external flaming observed.
Module 2 of initiatig unit	53.434	53.434	No gas venting observed. No external flaming observed.
Module 3 of initiatig unit	53.429	53.428	No gas venting observed. No external flaming observed.
Module 4 of initiatig unit	53.429	53.429	No gas venting observed. No external flaming observed.
Module 5 of initiatig unit	53.429	53.426	No gas venting observed. No external flaming observed.
Module 6 of initiatig unit	53.428	53.428	No gas venting observed. No external flaming observed.
Module 7 of initiatig unit	53.855	45.990	Gas and smoke venting observed. No external flaming observed. No flying debris observed. No explosion observed.
Module 8 of initiatig unit	53.441	53.440	No gas venting observed. No external flaming observed.
Module 9 of initiatig unit	53.437	53.435	No gas venting observed. No external flaming observed.
Module 10 of initiatig unit	53.436	53.436	No gas venting observed. No external flaming observed.
Module 11 of initiatig unit	53.450	53.450	No gas venting observed. No external flaming observed.
Module 12 of initiatig unit	53.446	53.446	No gas venting observed. No external flaming observed.
Measured Maximum Temperature Rise of Wall Surface			
Thermocouple ID	CH0402		
Measurements, (°C)	21.0 (temperature rise 2.0 °C)		
Location	Surface of wall B, facing the side enclosure of initiating module.		
Limits: △T ≤ 97 °C			
Measured Maximum Surface Temperature of Modules within the Target BESS Units			

Thermocouple ID	CH3205
Measurements, (°C)	23.3
Location	Rear surface of module 7 in unit B
Limits: Tmax. ≤181 °C (Cell surface temperature at gas venting)	
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 12. Photo of E1 (event 1) during test.

Figure 13. Photo of E3 during test.

Figure 14. Photo of E4 during test.

Figure 15. Photo 01 of initiating BESS unit and target BESS units after test.

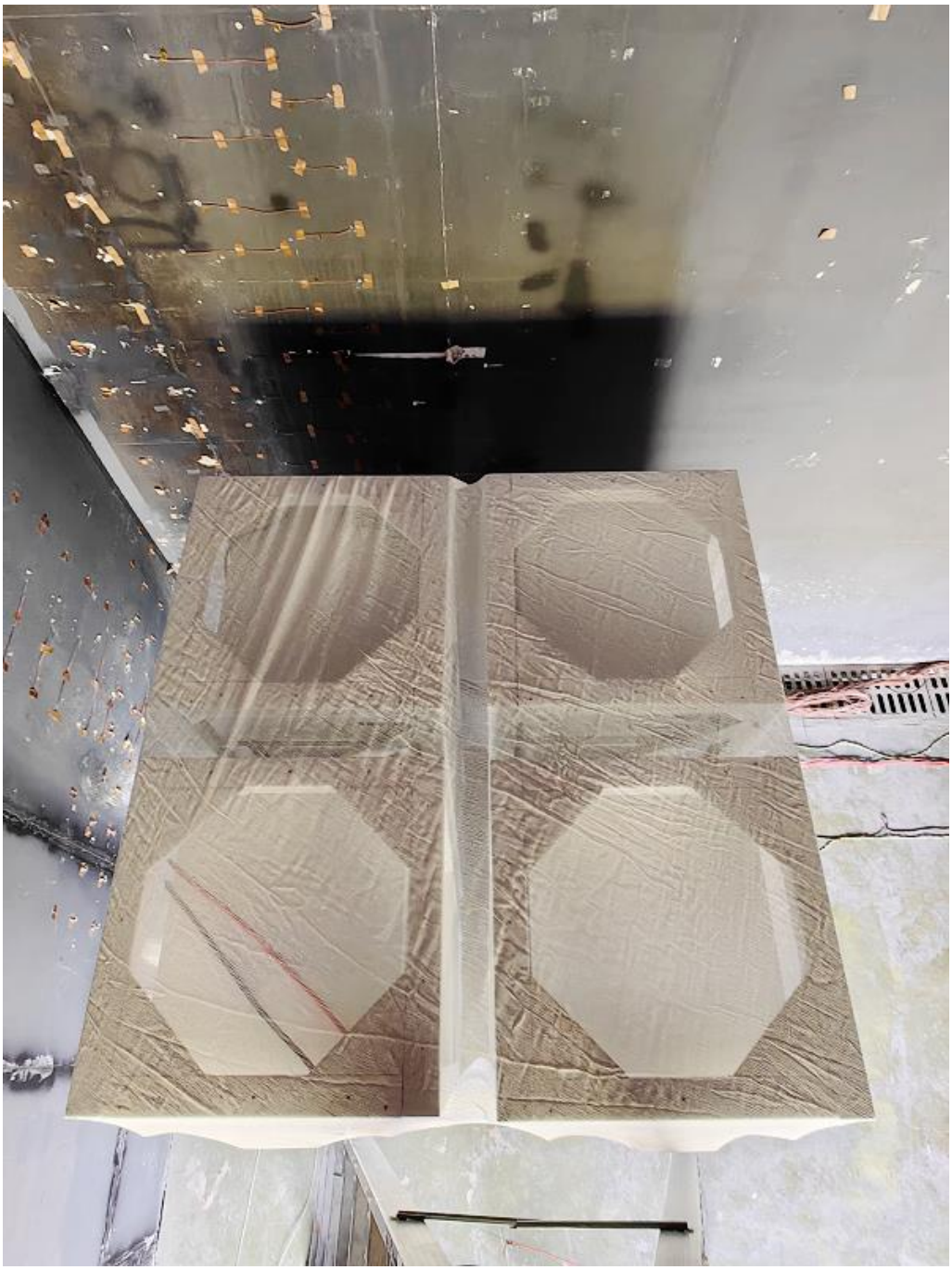

Figure 16. Photo 02 of initiating BESS unit and target BESS units after test.

Figure 17. Photo 01 of initiating BESS unit after test.

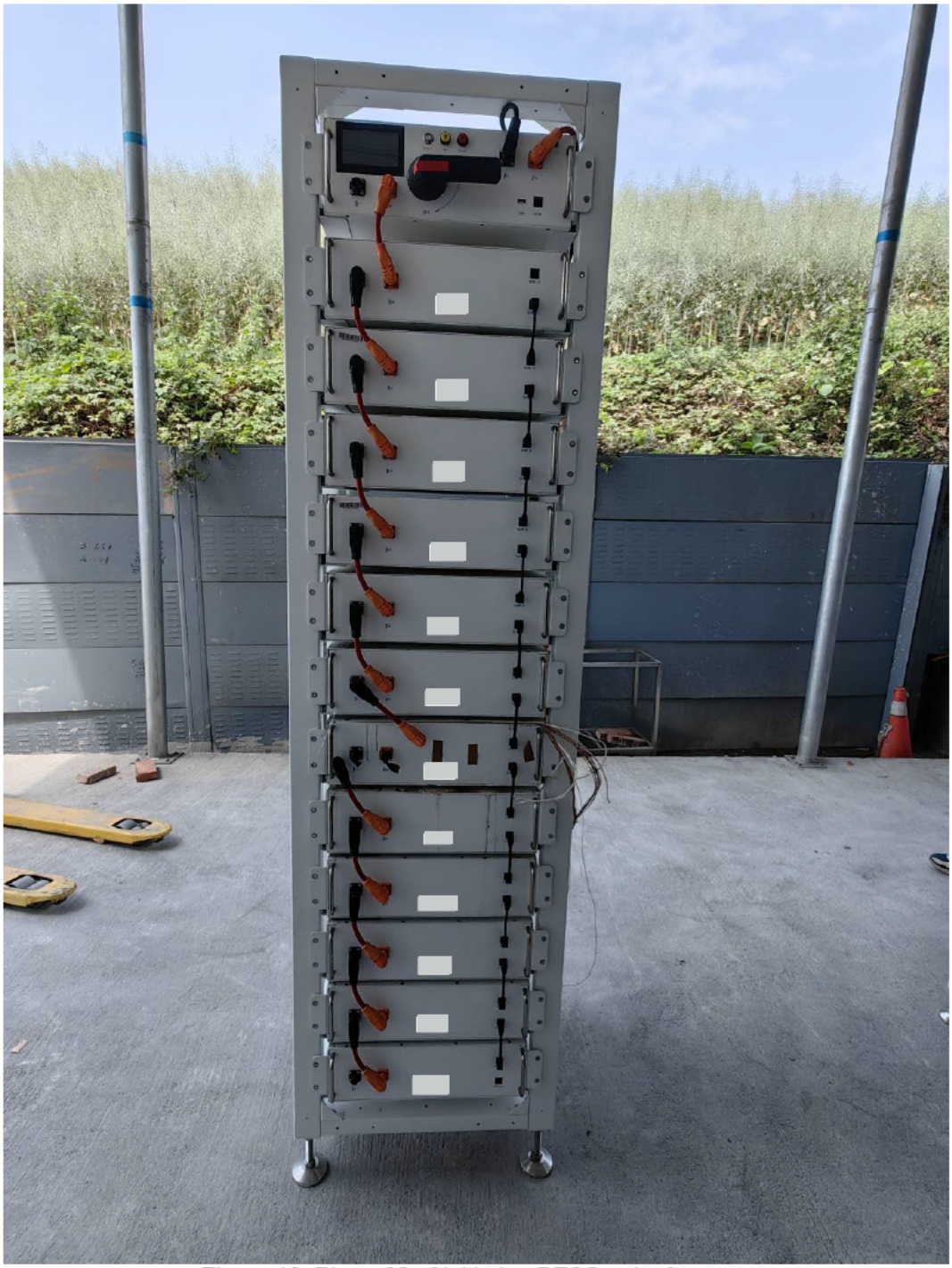

Figure 18. Photo 02 of initiating BESS unit after test.

Figure 19. Photo 03 of initiating BESS unit after test

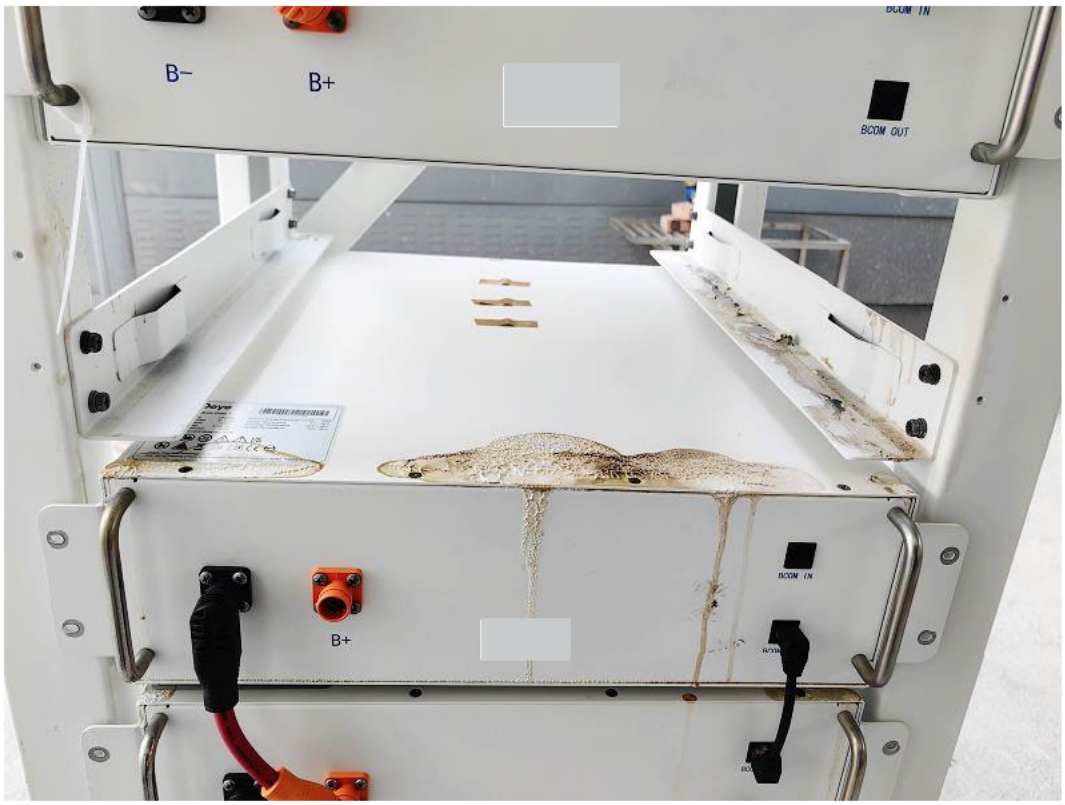

Figure 20. Photo 04 of initiating BESS unit after test.

Figure 21a. Photo 01 of initiating battery module after test.

Figure 21b. Photo 02 of initiating battery module after test.

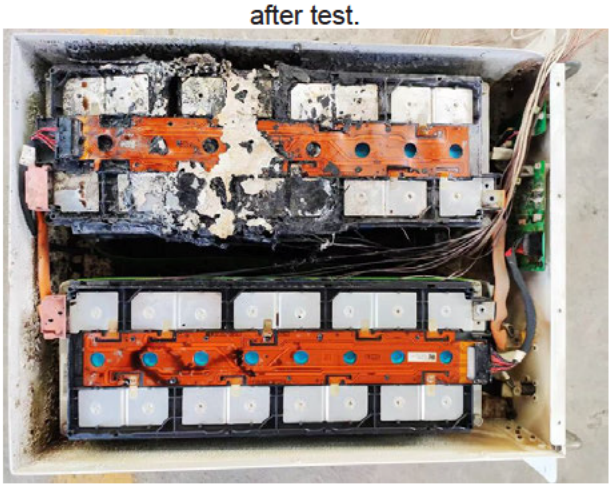

Figure 21c. Photo 01 of thermal runaway location.

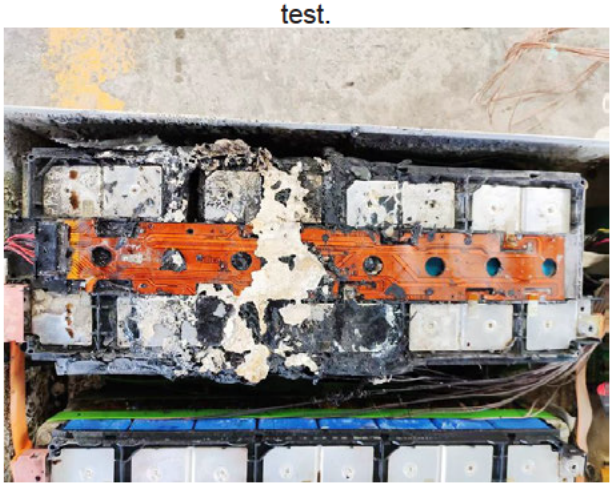

Figure 21d. Photo 02 of thermal runaway location.

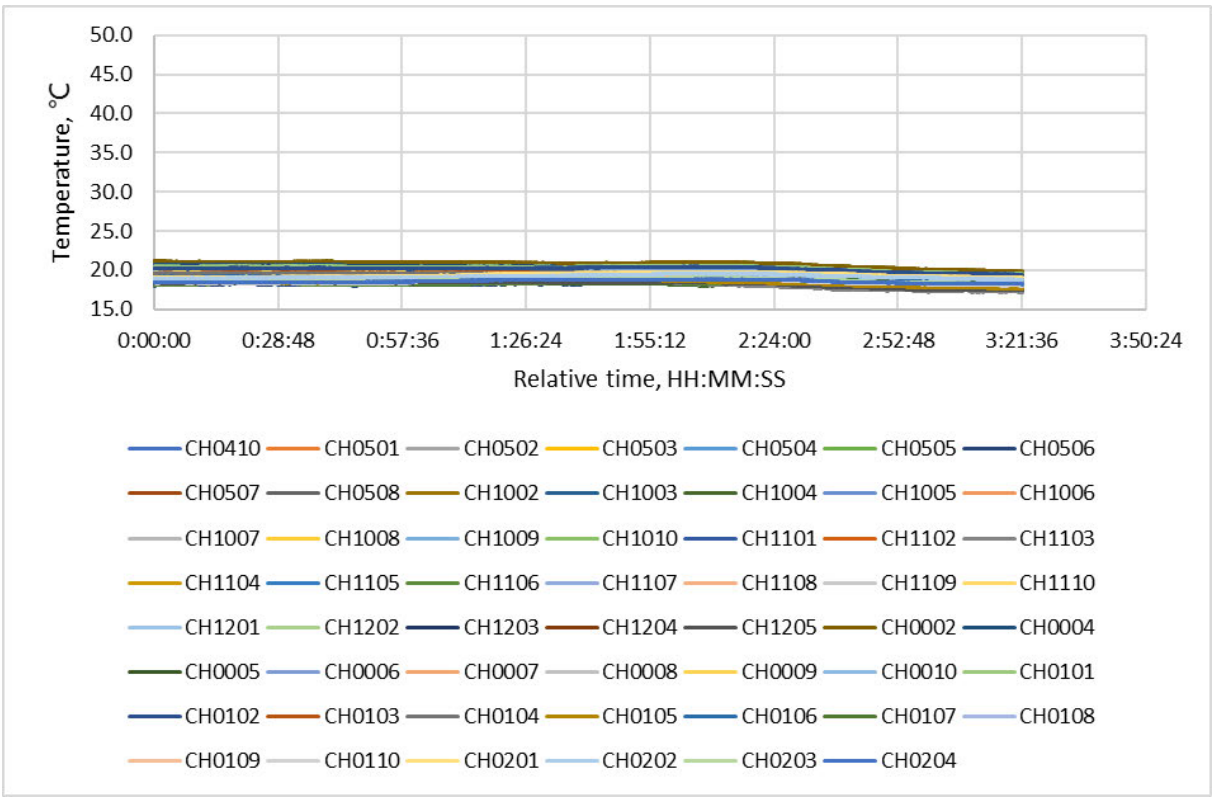

Figure 22. Temperature measurement results on wall A.

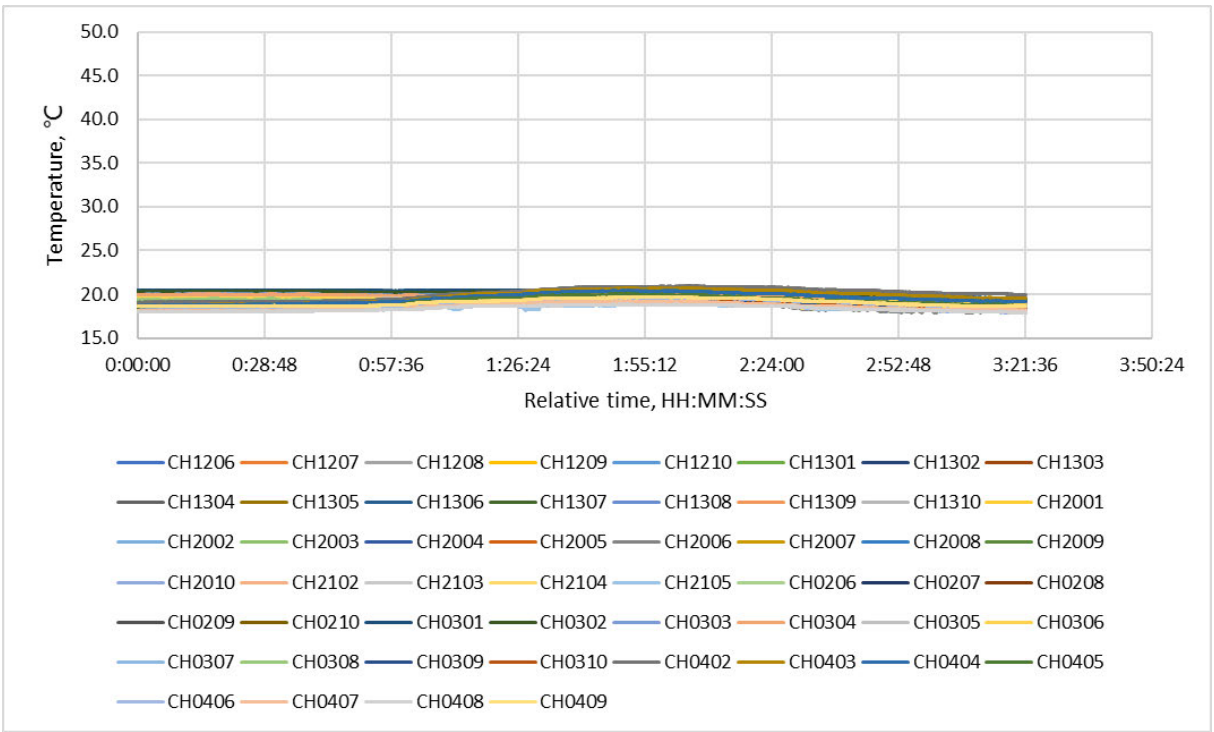

Figure 23. Temperature measurement results on wall B.

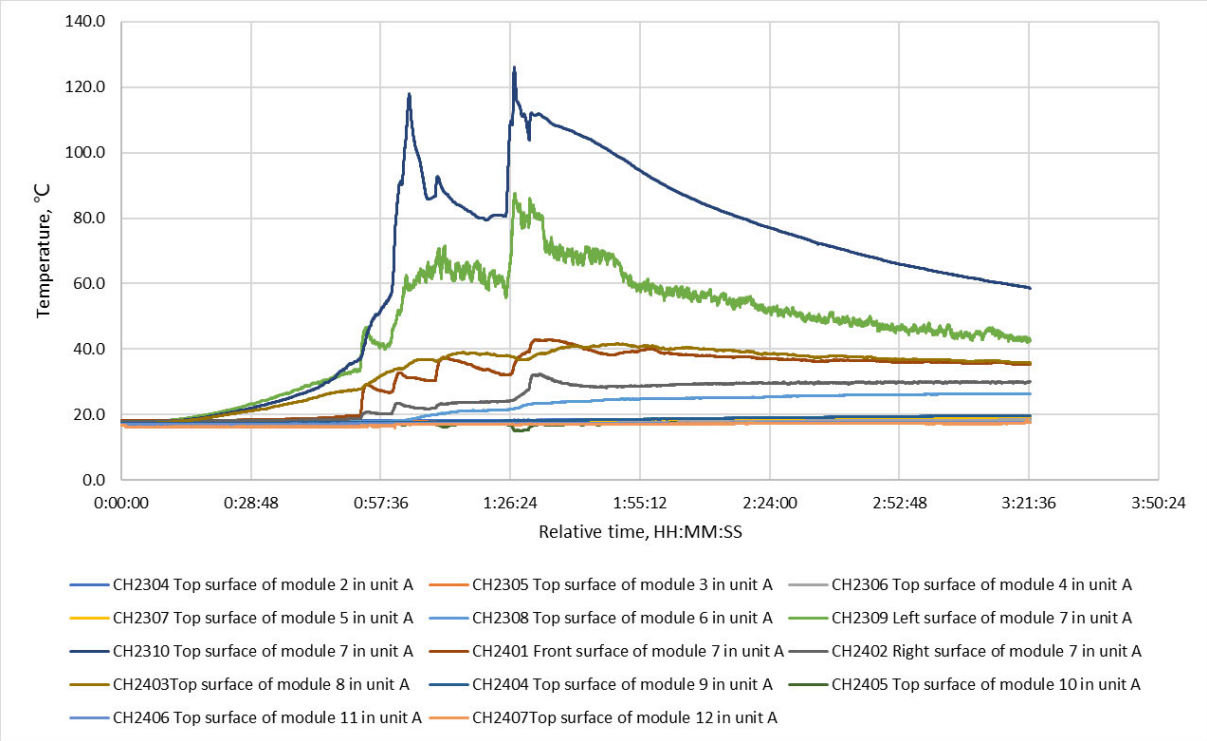

Figure 24. Temperature measurement results on the initiating unit (unit A).

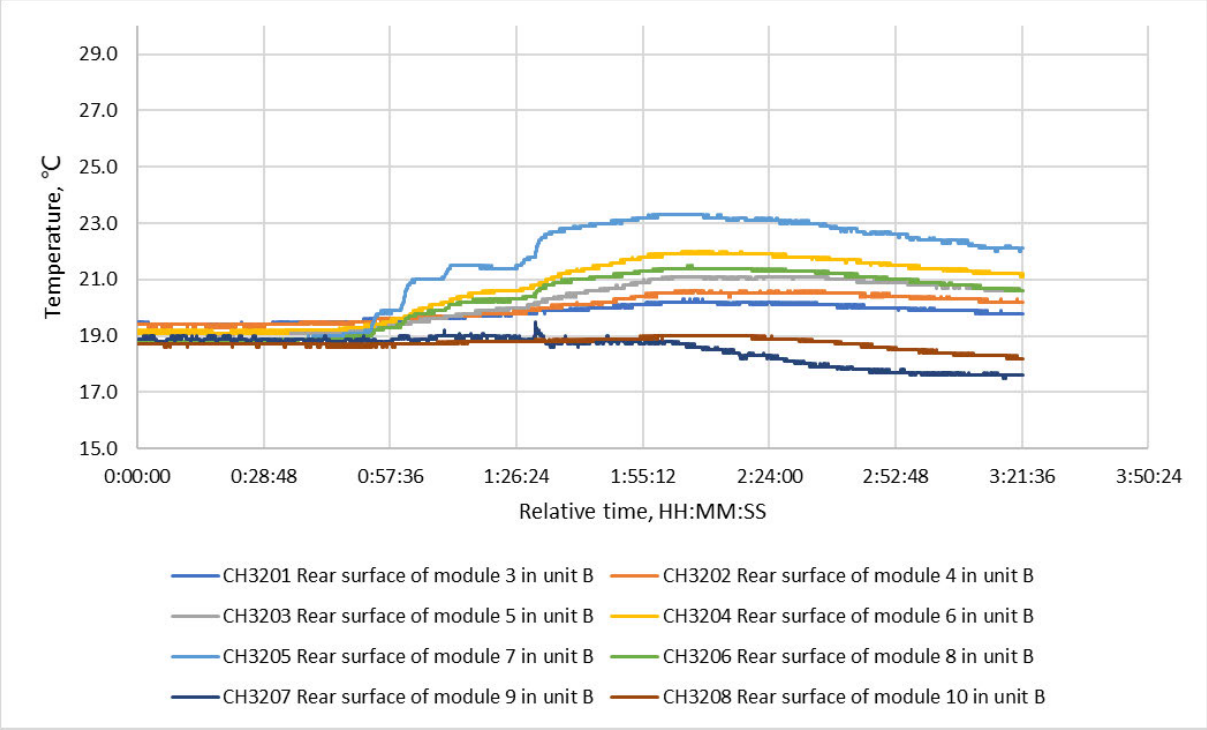

Figure 25. Temperature measurement results on target units (Unit B)

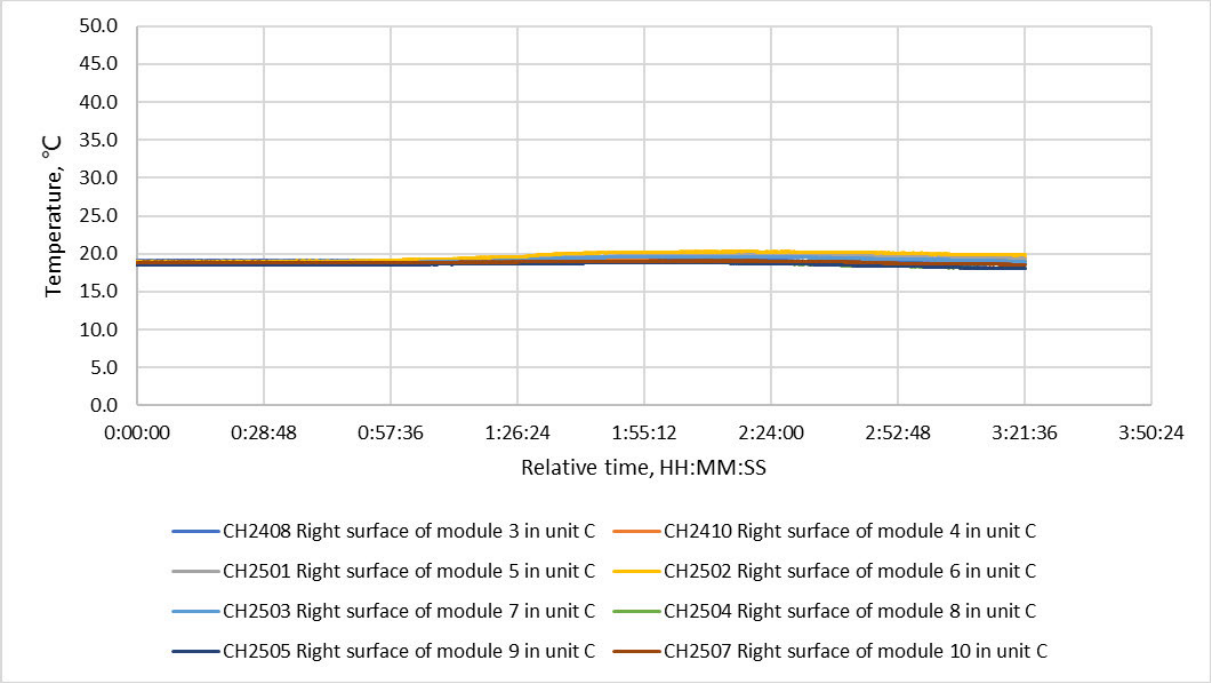

Figure 26. Temperature measurement results on target units (Unit C)

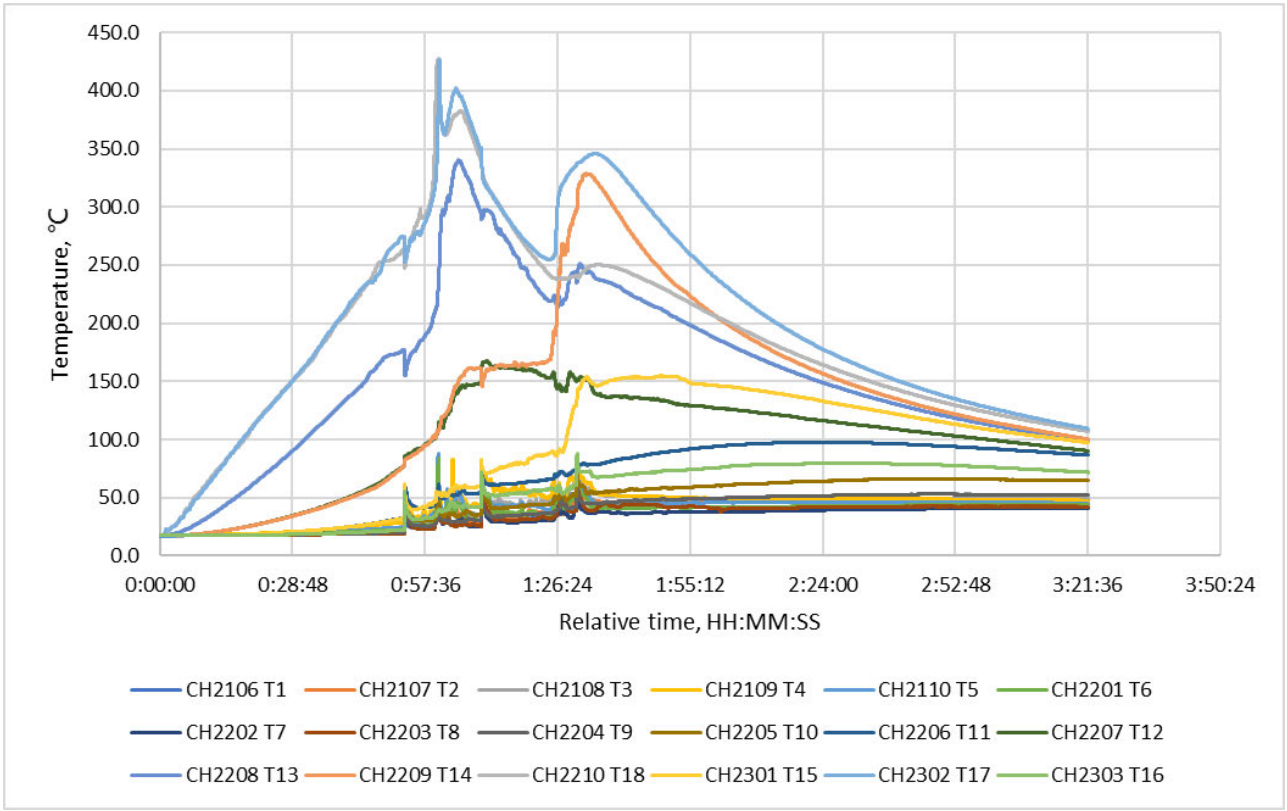

Figure 27. Temperature measurement results on the initiating module.

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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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