TEST REPORT

ANSI/CAN/UL 9540A:2019

TÜV SÜD Test Report for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems on Unit Level

Report No.:	5061924025706
Date of issue:	2024-06-21
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Address:	Building 3, No. 1065, Beihe Road, Jiading District, Shanghai
Testing location:	as above
Client:	Shanghai PYTES Energy Co., Ltd.
Client number:	003364
Address:	No. 3492 Jinqian Road, Qingcun Town, Fengxian District, Shanghai, China
Contact person:	Yang, Lijuan
Standard:	ANSI/CAN/UL 9540A:2019 Fourth Edition (4Ed)
TRF number and revision:	TRF ANSI/CAN/UL 9540A:2019 Rev 0
TRF originated by:	TÜV SÜD Product Service
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Scheme:	☐ TUV Mark ☐ cTUV Mark (SCC) ☐ TUVus Mark (NRTL) ☐ GS Mark ☒ without certification ☒ other:TÜV SÜD Test Report from witness test ☐ AoC/CoC for EU-Directive / EU-Regulation:
Non-standard test method:	☒ No ☐ Yes, see details under *Summary of testing*
National deviations:	N/A
Number of pages *(Report)*:	65
Number of pages *(Attachments)*:	10

Compiled by: (Project Handler)	You, Duo You Duo 2024-06-21	Approved by: (Designated Reviewer)	Frank M... 2024-06-21

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Test sample:	Rechargeable Li-ion Battery System
Type of test object:	Protype Sample
Trademark:	Pytes
Model and/ or type reference:	HV48100 BMU-8
Rating(s):	409.6Vd.c., 100Ah

Manufacturer:	Shanghai PYTES Energy Co., Ltd.
Manufacturer number:	003364
Address:	No. 3492 Jinqian Road, Qingcun Town, Fengxian District, Shanghai, China
Name and address of factory(ies)	
Shanghai PYTES Energy Co., Ltd. No. 3492 Jinqian Road, Qingcun Town, Fengxian District, Shanghai, China	

Sub-contractors / tests (clause):	N/A
Name:	N/A
Order description:	☐ Complete test according to TRF
	☐ Partial test according to manufacturer's specifications
	☐ Preliminary test
	☐ Spot check
	☒ Others: witness test
Date of order:	2024-01-10
Date of receipt of test item:	2024-01-26
Date(s) of performance of test:	2024-04-26 to 2024-04-30

Test item particulars:

According to Unit Level of ANSI/CAN/UL 9540A:2019 Fourth Edition.

Purpose of the product (description of intended use):

Rechargeable Li-ion Battery System HV48100 BMU-8 uses in Battery Energy Storage Systems.

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Characteristic data (not shown on the marking plate):	
Product name	HV48100 BMU-8
Type/model	Unit
Nominal voltage	409.6 V
Rated capacity	100 Ah
Charging voltage specified by manufacturer	460.8 V
Upper limit charging voltage	460.8 V
Charging current specified by manufacturer	50 A
Maximum continuous charging current	50 A
Discharging current specified by manufacturer	50 A
Maximum continuous discharging current	50 A
End of discharge voltage	364 V
Standard temperature range for charging	0~57 °C
Standard temperature range for discharging	-18~57 °C
Standard charging method specified by manufacturer	Charge at constant current 50 A until the voltage reaches 456 V
Standard discharging method specified by manufacturer	Discharge at constant current 50 A until the voltage reaches 364 V
Dimension	600*640*1555mm (one module:484*530*140mm)
Weight	446.9 kg
Configuration	(1P16S)8S

Attachments:
Attachment 1: Product description
Attachment 2: Exploding drawing of module & Identification/location of cells within the module
Attachment 3: Pre-conditioning profile
Attachment 4: Photo for sample before test and test setup with thermocouple location
Attachment 5: Photo for sample after test
Attachment 6: Monitored temperature chart
Attachment 7: Flammable gas generation and composition data chart
Attachment 8: Heat release rate versus time data chart
Attachment 9: Peak smoke release rate and total smoke release data chart
Attachment 10: Summary of Heat release rate & Peak smoke release rate and total smoke release data

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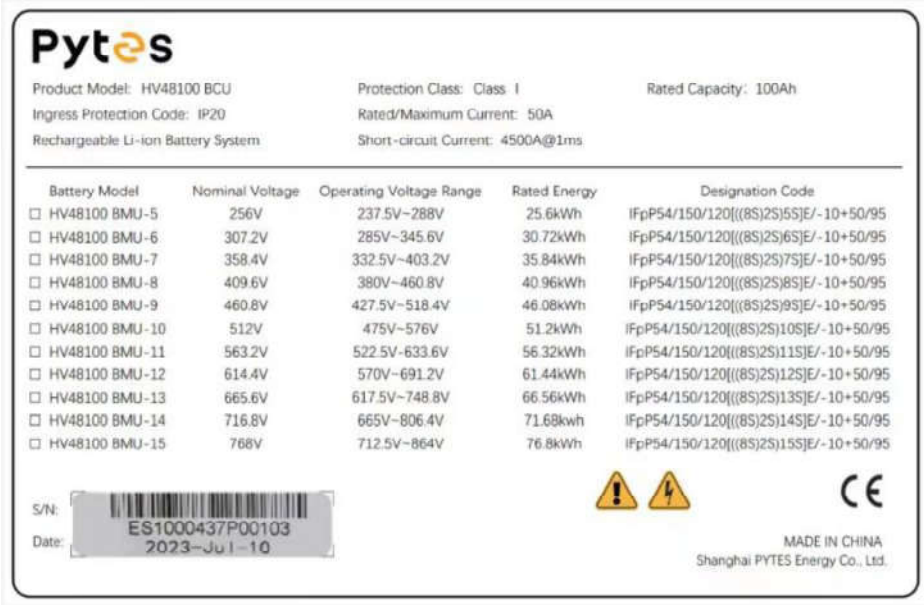
If additional information is necessary, please provide

N/A

Copy of marking plate:



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Pictures of the product:

Rechargeable Li-ion Battery System HV48100 BMU-8, which ratings is 409.6 Vd.c., 100 Ah, is used in energy storage systems.

Front and internal view of model:

Summary of unit level testing:	
Unit model name	HV48100 BMU-8
Ratings	409.6 Vd.c., 100 Ah
Whether UL 1973 compliant	Complied with UL 1973: TÜV SÜD Report No.: 64.280.23.60384.01
Number of modules in the initiating BESS unit	8
The construction of the initiating BESS unit per 5.3	See Attachment 1
Fire protection features/detection/suppression systems within unit	No fire protection features/detection/suppression systems within unit
Module voltage(s) corresponding to the tested SOC	See Table 1

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The thermal runaway initiation method used	Heating the cell with externally applied 2 pieces flexible film heaters that cover each large surface of the cell. Film heater specifications: 110 mm × 155 mm (375 W/pcs)
Location of the initiating module within the BESS unit	See Attachment 4
Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits	See Attachment 4
Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension	No flaming outside the initiating BESS enclosure
Chemical and convective heat release rate versus time data	See Attachment 8, 10
Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1)	See Attachment 4
Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	See Attachment 4
The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple	See Table 3 and Attachment 4 and 6
The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple	N/A
The maximum incident heat flux on target wall surfaces and target BESS units	Target wall surfaces: 0.17 kW/m^2 Target BESS unit: 0.38 kW/m^2
The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test	N/A
Gas generation and composition data	See Table 2 and Attachment 7
Peak smoke release rate and total smoke release data	See Attachment 9, 10
Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred	No integral fire protection systems within unit
Observation of flying debris or explosive discharge of gases	No observation of flying debris or explosive discharge of gases
Observation of re-ignition(s) from thermal runaway events	N/A (no fire during test)
Observation(s) of sparks, electrical arcs, or other electrical events	No observation of sparks, electrical arcs, or other electrical events
Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits;	1) Thermal runaway was observed on 8 cells on the same row with the initiating cell. Thermal runway was not observed on 8 cells on the opposite row;

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	2) No propagation to other modules of initiating unit; 3) No propagation to target units and no damage to target units; 4) No damage to adjacent walls, ceilings, or soffits; see Attachment 5
Performance at unit level testing:	
☒ Non-Residential Installations: ☒ Residential Installations: ☒ Indoor Floor Mounted ☒ Outdoor Ground Mounted ☐ Indoor Wall Mounted ☐ Outdoor Wall Mounted ☐ Rooftop and Open Garages	
a) Flaming outside the initiating BESS unit is not observed; (for Indoor Floor Mounted & Indoor Wall Mounted & Outdoor Wall Mounted)	No flaming outside the initiating BESS unit during test
a) If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test. (for Outdoor Ground Mounted & Rooftop and Open Garages)	No flaming outside the initiating BESS unit during test
b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	The maximum temperature of target modules within the target BESS units adjacent to the initiating BESS unit is 29.6 °C
c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15; (for Indoor Floor Mounted & Indoor Wall Mounted & Rooftop and Open Garages)	The maximum temperature of wall surface is 34.9 °C
c) For BESS units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15; (for Outdoor Ground Mounted)	The maximum temperature of wall surface is 34.9 °C
d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	No explosion hazards was observed
e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	0.02 kW/m^2
e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size. (for Indoor Floor Mounted)	Volume of flammable gas measured during this test: 638 L.

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	LFL from cell level report (external report with project number 4790342745): 5.95% at venting temperature. Resulting minimum room size: 10.73 m^3 to not exceed 25% LFL in air.
Performance - module level test:	
a) Thermal runaway is contained by module design; and	Thermal runaway was contained by module design.
b) Cell vent gas is nonflammable as determined by the cell level test.	Cell vent gas is flammable according to cell level test report (TÜV SÜD Report No. 5061924025705).
Performance - cell level test:	
a) Thermal runaway cannot be induced in the cell; and	Thermal runaway occurred according to cell level test report (external report with project number 4790342745).
b) The cell vent gas does not present a flammability hazard when mixed with any volume of air, as determined in accordance with ASTM E918 at both ambient and vent temperatures.	Cell vent gas present flammability hazard according to cell level test report (external report with project number 4790342745).

Additional information on non-standard test method(s)	
Sub clause:	N/A
Page:	N/A
Rational:	N/A

Possible test case verdicts:	
test case does not apply to the test object:	N/A (not applicable / not included in the order)
test object does meet the requirement:	P (Pass)
test object does not meet the requirement:	F (Fail)

General remarks:

"(see remark #)" refers to a remark appended to the report.

"(see appended table)" refers to a table appended to the report.

Throughout this report ***a*** ☐ ***Comma*** */* ☐ ***Point*** *is used as the decimal separator.*

The test results presented in this report relate only to the object tested.

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	INTRODUCTION		
1.	**Scope**		—
2	**Units of Measurement**		—
3	**Normative References**		—
4	**Glossary**		—
	CONSTRUCTION		
5.	**General**		
5.1	**Cell**		
5.1.1	The cells associated with the BESS that were tested shall be documented in the test report, including cell chemistry (e.g. NMC, LFP), the physical format of the cell (i.e. prismatic, cylindrical, pouch), cell electrical rating in capacity and nominal voltage, the overall dimensions of the cell, and weight.		P
5.1.2	The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973.	Note: Cell complied with UL 1973; Certificate Number: UL-CA-2236692-0	P
5.1.3	Refer to 7.6.1 for further details to be included in the cell level test report		P
5.2	**Module**		
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report, including the generic (e. g., metallic or nonmetallic) enclosure material, the general layout of the module contents and the electrical configuration of the cells in the modules and the modules in the BESS.	Module consists of a metallic enclosure material. Further details of the layout and module contents see Attachement 2.	P
5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973.	Module is not compliant with UL 1973.	N/A
5.2.3	Refer to 8.3 for further details to be included in the module level test report.		P
5.3	**Battery energy storage system unit**		
5.3.1	The BESS unit documentation included in the test report shall indicate the units that comply with UL		P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	9540 and include the manufacturer, model, electrical ratings, and energy capacity of all BESS.		
5.3.2	For BESS units for which UL 9540 compliance cannot be determined, the documentation included in the test report shall include the number of modules in the BESS, electrical configuration of the module, and physical layout of the modules in the BESS, battery management system (BMS) and other major components of the BESS. The BESS enclosure overall dimensions and generic (e. g., metallic or nonmetallic) material used for the enclosure shall be documented. Depending upon the configuration of the BESS (e.g. the power conditioning system is external to the BESS enclosure), a battery system(s) can be tested as representative of the BESS. It shall be documented as to whether the battery system complies with UL 1973 in addition to the overall BESS compliance to UL 9540.	Battery system complies with UL 1973. TÜV SÜD Report No.: 64.280.23.60384.01	N/A
5.3.3	If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report.	No fire detection and suppression systems are within unit	N/A
5.3.4	Refer to 9.7, 10.4 and 10.7 for further details to be included in the unit level and if applicable, installation level test reports.		N/A
5.4	**Flow Batteries**		
5.4.1	For flow batteries, the report will cover the chemistry (e.g. vanadium redox, zinc bromine, etc.), a generic description of the electrolyte (s), the overall dimensions of the individual stack as well as the electrical rating in capacity and nominal voltage of the cell stack. The report will also include information on the complete flow battery system including the manufacturer's name and model number of the system, the electrical rating in volts and rated storage capacity in Ah or Wh, the number of cells and stacks in the system, and the maximum volume of electrolyte(s) for the system.		N/A
5.4.2	The flow battery documentation included in the test report shall indicate if the flow battery system complies with UL 1973.		N/A
5.4.3	See 7.6.2 for further details to be included in the flow battery thermal runaway determination level test report.		N/A

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	PERFORMANCE		
6	**General**		
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires, explosions, smoke, off gassing of flammable and toxic materials, exposure to toxic and corrosive liquids, and potential exposure to hazardous voltages and electrical energy. See Annex B for recommended testing practices.		P
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications. All samples shall be disposed of in accordance with local regulations.		P
7	**Cell Level**		—
8	**Module Level**		—
9	**Unit Level**		
9.1	**Sample and test configuration**		
9.1.1	The unit level test shall be conducted with BESS units installed as described in the manufacturer's instructions and this section. Test configurations include the following:		P
	a) Indoor floor mounted non-residential use BESS;		P
	b) Indoor floor mounted residential use BESS;		P
	c) Outdoor ground mounted non-residential use BESS;		P
	d) Outdoor ground mounted residential use BESS;		P
	e) Indoor wall mounted non-residential use BESS;		N/A
	f) Indoor wall mounted residential use BESS;		N/A
	g) Outdoor wall mounted non-residential use BESS;		N/A
	h) Outdoor wall mounted residential use BESS; and		N/A
	i) Rooftop and open garage non-residential use BESS installations.		N/A
9.1.2	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		P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	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. Examples of potential test configurations are shown in Figure 9.1, Figure 9.2, Figure 9.3, and Figure 9.4.		
	Exception: *Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place:* *a) Wind screens are utilized with a maximum wind speed maintained at ≤ 12 mph;* *b) The temperature range is within 10°C to 40°C (50°F to 104°F);* *c) The humidity is < 90% RH;* *d) There is sufficient light to observe the testing;* *e) There is no precipitation during the testing;* *f) There is control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; and* *g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing.*		N/A
9.1.3	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.		N/A
9.1.4	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.		P
9.1.5	Target BESS units shall include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components. The target		P

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MODULE LEVEL			
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	BESS unit module enclosures do not need to contain cells.		
9.1.6	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.	See Attachment 3: Pre-conditioning profile. Charging method: Charge at constant current 50A until the voltage reaches 456V. Discharge method: Discharge at constant current 50A until the voltage reaches 364V.	P
9.1.7	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.	No fire detection and suppression systems are within unit	N/A
9.1.8	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 per 9.1.7.		N/A
9.2	**Test method – Indoor floor mounted BESS units**		
9.2.1	Samples and test configurations are in accordance with 9.1. 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).		P
9.2.2	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.		P
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections.		P
9.2.4	Instrumented wall sections shall extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.		P
9.2.5	Instrumented wall sections shall be at least 0.61-m (2-ft) taller than the BESS unit height, but not less than 3.66 m (12 ft) in height above the bottom surface of the unit.		P

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9.2.6	The surface of the instrumented wall sections shall be covered with 16-mm (5/8-in) gypsum wall board and painted flat black.		P
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.		P
9.2.8	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 as described in 8.2.15.		P
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, using the methodologies specified in 8.2.11 and 9.2.12, respectively.		P
9.2.10	With reference to 9.2.9, 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.		P
9.2.11	With reference to 9.2.9, 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. See 9.2.12.		P
9.2.12	With reference to 9.2.9, the convective heat release rate shall be calculated using the following equation: $HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$		P
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation as noted in 9.1.	See Attachment 4	P
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		P
	a) The BESS units and the instrumented wall sections; and		P
	b) Adjacent BESS units.		P
9.2.15	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		P

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	installation, then the report should note that the installation shall contain no combustible construction and that surface temperature rises can be deemed not applicable.		
9.2.16	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.		P
9.2.17	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.		P
9.2.18	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.		P
9.2.19	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.		P
9.2.20	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.		P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
9.2.21	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.		P
9.2.22	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 in2) area.		P
9.2.23	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 (Section 8).		P
9.2.24	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.		P
9.2.25	The hydrocarbon content of the vent gas shall be measured using flame ionization detection.		P
9.2.26	The test shall be terminated if:		P
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;		P
	b) The fire propagates to adjacent units or to adjacent walls; or		N/A

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	c) A condition hazardous to test staff or the test facility requires mitigation.		N/A
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.	Volume of flammable gas measured during this test: 638 L. LFL from cell level report (external report with project number 4790342745): 5.95% at venting temperature. Resulting minimum room size: 10.73 m^3 to not exceed 25% LFL in air.	N/A
9.3	**Test method – Outdoor ground mounted units**		
9.3.1	Outdoor ground mounted non-residential use BESS being evaluated for installation in close proximity to buildings and structures shall use the test method described in Section 9.2. If intended for outdoor use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		P
9.3.2	Outdoor ground mounted residential use BESS being evaluated for installation in close proximity to buildings and structures shall use the test method described in Section 9.2 except as noted in 9.3.3 and 9.3.4. Heat flux measurements for the accessible means of egress shall be measured in accordance with 9.2.20. If intended for outdoor use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		N/A
9.3.3	Test samples shall be installed as shown in Figure 9.2 in proximity to an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (undersurface of the eave shown in Figure 9.2). The sample shall be mounted on a support substrate and spaced from the wall in accordance with the minimum separation distances specified by the manufacturer. The wall and soffit shall be constructed with 19.05-mm (3/4-in) plywood installed on wood studs and painted flat black. The instrumented wall shall extend not less than 0.49-m (1.6-ft) horizontally beyond the exterior of the target BESS units. The No. 24-gauge or smaller, Type-K exposed junction thermocouple array on the walls as noted in 9.2.16 shall extend to the surface of the soffit as shown in Figure 9.2.		P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	Exception: *If the manufacturer requires installation against non-flammable material, the test setup may include manufacturer recommended backing material between the unit and plywood wall.*		N/A
9.3.4	Target BESS shall be installed on each side of the initiating BESS in accordance with the manufacturer's installation specifications. The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		P
9.4	**Test Method – Indoor wall mounted units**		
9.4.1	Testing of indoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.3.		N/A
9.4.2	The test shall be conducted in a standard NFPA 286 fire test room, 3.66 × 2.44 × 2.44-m (12 × 8 × 8-ft) high, with a 0.76 × 2.13-m (2-1/2 × 7-ft) high opening. The room shall be constructed with 16-mm (5/8-in) gypsum wall board installed on wood studs and painted flat black.		N/A
9.4.3	The initiating BESS unit shall be positioned on the wall opposite of the door opening, with the center located 1.22-m (4-ft) above the floor, and halfway between adjacent walls.		N/A
9.4.4	Target BESS shall be installed on the wall on each side of the initiating BESS, at the same height above the floor as the initiating BESS. The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		N/A
9.4.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		N/A
9.4.6	The gas collection methods shall be in accordance with 9.2. For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.		N/A
9.4.7	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 in2) area.		N/A
9.5	**Test Method – Outdoor wall mounted units**		

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
9.5.1	Testing of outdoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.4. If intended for outdoor use only wall mount installations, the smoke release rate, the convective and chemical heat release rate; and the content, velocity and temperature of the released vent gases need not be measured.		N/A
9.5.2	Test samples shall be mounted on an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (undersurface of the eave shown in Figure 9.4). The wall and soffit shall be constructed with 19.05-mm (3/4-in) plywood installed on wood studs and painted flat black. The instrumented wall shall extend not less than 0.49-m (1.6-ft) horizontally beyond the exterior of the target BESS units. The No. 24-gauge or smaller, Type-K exposed junction thermocouple array on the walls as noted in 9.2.16 shall extend to the surface of the soffit as shown in Figure 9.4.		N/A
9.5.3	The initiating BESS unit shall be positioned on the instrumented wall, with its center located 1.22-m (4-ft) above the floor, and halfway between wall edges.		N/A
9.5.4	Target BESS shall be installed on the wall on each side of the initiating BESS, at the same height above the floor as the initiating BESS. The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		N/A
9.5.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		N/A
9.5.6	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 in2) area .		N/A
9.6	**Rooftop and open garage installations**		
9.6.1	Testing of BESS intended for non-residential use rooftop or open garage installations shall be in accordance with 9.2.		N/A
9.6.2	If intended for rooftop and open garage use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		N/A
9.7	**Unit level test report**		

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
9.7.1	The report on the unit level testing shall identify the type of installation being tested, as follows:		P
	a) Indoor floor mounted non-residential use BESS;		P
	b) Indoor floor mounted residential use BESS;		P
	c) Outdoor ground mounted non-residential use BESS;		P
	d) Outdoor ground mounted residential use BESS;		P
	e) Indoor wall mounted non-residential use BESS;		N/A
	f) Indoor wall mounted residential use BESS;		N/A
	g) Outdoor wall mounted non-residential use BESS;		N/A
	h) Outdoor wall mounted residential use BESS;		N/A
	i) Rooftop installed non-residential use BESS; or		N/A
	j) Open garage installed non-residential use BESS.		N/A
9.7.2	With reference to 9.7.1, if testing is intended to represent more than one installation type, this shall be noted in the report.	Testing is intended to represent Indoor floor mounted non-residential use BESS and Indoor floor mounted residential use BESS and Outdoor ground mounted non-residential use BESS and Outdoor ground mounted residential use BESS	P
9.7.3	The report shall include the following, as applicable:		P
	a) Unit manufacturer name and model number (and whether UL 9540 compliant);	Unit manufacturer name: Shanghai PYTES Energy Co., Ltd. Model no.: HV48100 BMU-8 Unit is not compliant with UL 9540.	P
	b) Number of modules in the initiating BESS unit;	8 modules	P
	c) The construction of the initiating BESS unit per 5.3;	See Attachment 1	P
	d) Fire protection features / detection / suppression systems within unit;		P
	e) Module voltage(s) corresponding to the tested SOC;	See Table 1	P
	f) The thermal runaway initiation method used;	See Table 1	P
	g) Location of the initiating module within the BESS unit;	See Attachment 4	P
	h) Diagram and dimensions of the test setup including mounting location of the initiating and target	See Attachment 4	P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	BESS units, and the locations of walls, ceilings, and soffits;		
	i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	No flaming during the test	P
	j) Chemical and convective heat release rate versus time data;	See Attachment 8, 10	P
	k) Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1);	See Attachment 4	P
	l) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	See Attachment 4	P
	m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	See Table 3 and Attachment 4 and 6	P
	n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;		N/A
	o) The maximum incident heat flux on target wall surfaces and target BESS units;	Target wall surfaces: 0.17 kW/m^2 Target BESS unit: 0.38 kW/m^2	P
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;		N/A
	q) Gas generation and composition data;	See Table 2 and Attachment 7	P
	r) Peak smoke release rate and total smoke release data;	See Attachment 9, 10	P
	s) Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	No fire detection and suppression systems are within unit	N/A
	t) Observation of flying debris or explosive discharge of gases;	No observation of flying debris or explosive discharge of gases	P
	u) Observation of re-ignition(s) from thermal runaway events;	No fire during test	N/A
	v) Observation(s) of sparks, electrical arcs, or other electrical events;	No observation(s) of sparks, electrical arcs, or other electrical events	P
	w) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units;	see Attachment 5	P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	3) Adjacent walls, ceilings, or soffits; and		
	x) Photos and video of the test.		P
9.8	**Performance at unit level testing**		
9.8.1	Installation level testing in Section 10 is not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.		P
Table 9.1	**Unit Level Performance Criteria**		
	Non-Residential Installations: **Indoor Floor Mounted**		P
	a) Flaming outside the initiating BESS unit is not observed;	No flaming outside the initiating BESS unit during test	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	The maximum temperature of target modules within the target BESS units adjacent to the initiating BESS unit is 29.6 °C	P
	c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	The maximum temperature of wall surface is 34.9 °C	P
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	Explosion hazards are not observed	P
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	0.02kW/m^2	P
	Non-Residential Installations: **Outdoor Ground Mounted**		
	a) If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.	No flaming outside the initiating BESS unit during test	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	The maximum temperature of target modules within the target BESS units adjacent to the initiating BESS unit is 29.6 °C	P
	c) For BESS units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	The maximum temperature of wall surface is 34.9 °C	P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	Explosion hazards are not observed	P
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	0.02 kW/m^2	P
	Non-Residential Installations: **Indoor Wall Mounted**		
	a) Flaming outside the initiating BESS unit is not observed;		N/A
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		N/A
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;		N/A
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		N/A
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.		N/A
	Non-Residential Installations: **Outdoor Wall Mounted**		
	a) Flaming outside the initiating BESS unit is not observed;		N/A
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		N/A
	c) For BESS units intended for installation on walls with combustible construction, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;		N/A
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.		N/A
	Non-Residential Installations: **Rooftop and Open Garages**		
	a) If flaming outside the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test;		N/A
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		N/A
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;		N/A
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		N/A
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.		N/A
	Residential Installations: **Indoor Floor Mounted**		
	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;	No flaming outside the initiating BESS unit during test	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	The maximum temperature of target modules within the target BESS units adjacent to the initiating BESS unit is 29.6 °C	P
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	The maximum temperature of wall surface is 34.9 °C	P
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	Explosion hazards are not observed	P
	e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size.	Volume of flammable gas measured during this test: 638 L.	N/A

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Clause	Requirement + Test	Result – Remark	Verdict
		LFL from cell level report (external report with project number 4790342745): 5.95% at venting temperature. Resulting minimum room size: 10.73 m^3 to not exceed 25% LFL in air.	
	Residential Installations: **Outdoor Ground Mounted**		
	a) If flaming outside the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.	No flaming outside the initiating BESS unit during test	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	The maximum temperature of target modules within the target BESS units adjacent to the initiating BESS unit is 29.6 °C	P
	c) For BESS units intended for near exposures, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	The maximum temperature of wall surface is 34.9 °C	P
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	Explosion hazards are not observed	P
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	0.02 kW/m^2	P
	Residential Installations: **Indoor Wall Mounted**		
	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;		N/A
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		N/A
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;		N/A
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		
	e) The concentration of flammable gas does not exceed 25% LFL for the smallest intended room installation size.		N/A
	Residential Installations: **Outdoor Wall Mounted**		
	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;		N/A
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;		N/A
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15; and		N/A
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases.		N/A
10	**Instalaton Level**		—
ANNEX A	**Test Concepts And Application Of Test Results To Installations** (informative)		—
A1	Introduction		N/A
A2	Test Methodology and Purpose		N/A
A3	Evaluating the Results		N/A
ANNEX B	**Safety Recommendations for Testing** (informative)		—
B1	General		P

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	TABLE: Critical components information				
Object/part no.	**Manufacturer/ trademark**	**Type/model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Rechargeable Lithium-ion Cell			3.2Vd.c., 100Ah	ANSI/CAN/UL 1973: 2022	UL MH64238
Rechargeable Lithium-ion Cell			3.2Vd.c., 100Ah	ANSI/CAN/UL 9540A: 2019	External report with project number 4790342745
Rechargeable Li-ion Battery Module	Shanghai PYTES Energy Co., Ltd.	HV48100 BMU	51.2Vd.c., 100Ah	ANSI/CAN/UL 9540A: 2019	TÜV SÜD Report No. 5061924025705
Rechargeable Li-ion Battery System	Shanghai PYTES Energy Co., Ltd.	HV48100 BMU-8	409.6Vd.c., 100Ah	ANSI/CAN/UL 1973: 2022	TÜV SÜD Report No.: 64.280.23.60384.01
Supplementary information: N/A					

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UNIT LEVEL

MODULE LEVEL TEST RESULT:

Table 1: Thermal runaway test result	
Summary of initiating module	
Initial ambient temperature:	25.4 °C
Initial relative humidity:	74% RH
Pre-conditioning time	From 2024-04-26 10:24:05 to 2024-04-29 08:27:05
Thermal runwaway test start time	2024-04-28 17:54:28
Module voltage before test:	53.67 V
Methods used to initiate thermal runaway	Heating the cell with externally applied flexible film heater
Average heating rate:	T13: 4.73 K/min (T12 is not working properly before the test)
Surface temperature at which gases were first vented:	T13: 188.1 °C, T5: 130.8 °C
Time when gases were first vented:	Cell 5: 2024-04-28 18:28:34
Surface temperature prior to thermal runaway:	T13: 170.5 °C, T5: 193.3 °C
Time when thermal runaway:	Cell 5: 2024-04-28 18:39:52
Module voltage after test:	26.61 V
Location of cell(s) for intiating thermal runaway	Cell 5 (see Attachment 2)
Thermal runaway of other cells within module:	Thermal runaway was observed on 8 cells on the same row with the initiating cell. Thermal runway was not observed on 8 cells on the opposite row.
Observation(s) of flying debris:	No
Observation(s) of explosive discharge of gas:	No
Observation(s) of sparks, electrical arcs or other electrical events:	No
Locations and visual estimations of flame	N/A, no flames observed.
Module weight before test:	43.4 kg
Module weight after test:	40.2 kg
Module weight loss:	3.2 kg
Summary of other modules	
Status of other modules	No thermal runaway observed
Supplementary information:	N/A

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UNIT LEVEL

Timeline of thermal runaway		
Time (hh:mm:ss)	Event	Description
2024-04-28 17:54:28	Start testing (one film heater got damaged, and only one film heater worked).	
2024-04-28 18:28:34	The initiating cell 5 first vented at 18:28:34.	
2024-04-28 18:39:45	The temperature of initiating cell 5 started to rise sharply, thermal runaway occurred.	

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UNIT LEVEL		
2024-04-28 18:40:16	Smoke generated continuously.	
2024-04-28 18:39:31	The cell 6 vented at 18:39:31.	
2024-04-28 18:40:52	The cell 4 vented at 18:40:52.	

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UNIT LEVEL		
2024-04-28 18:45:07	The cell 7 vented at 18:45:07.	
2024-04-28 18:45:10	The cell 3 vented at 18:45:10.	
2024-04-28 18:50:21	The cell 2 vented at 18:50:21.	

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UNIT LEVEL		
2024-04-28 18:50:50	The cell 8 vented at 18:50:50.	
2024-04-28 19:02:00	The cell 1 vented at 19:02:00.	
2024-04-28 20:42:31	No smoke was observed	
Remark: Refer to attachment 4 for details of sample before test and test setup with thermocouple location.		

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UNIT LEVEL

Table 2: Vent gas composition			
Composition	Chemical formula	Measurement peak (L/s)	Analysis Method
Carbon monoxide	CO	0.06	FTIR
Carbon dioxide	CO2	0.81	FTIR
Methane	CH4	0.022	FTIR
Acetylene	C2H2	0.0015	FTIR
Ethene	C2H4	0.012	FTIR
Ethane	C2H6	0.0026	FTIR
Propane	C3H8	0.0059	FTIR
Butane	C4H10	/	FTIR
Pentane	C5H12	/	FTIR
Benzene	C6H6	/	FTIR
Hexane	C6H14	/	FTIR
Hydrofluoric acid	HF	0.00077	FTIR
Hydrogen chloride	HCl	/	FTIR
Hydrogen	H2	0	Hydrogen sensor
Total Hydrocarbons	(Methane Equivalent)	0.214	FID
Flow rate in exhaust duct (m^3/s)		1.5	

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UNIT LEVEL

Table 3: Monitored temperature result			
Number	Thermocouple location	Measured maximum temperature, °C	Limit, °C
T1	Center of side surface of cell 1, near module housing	421	-
T2	Center of side surface of cell 2, near module housing	449.9	-
T3	Center of side surface of cell 3, near module housing	420.2	-
T4	Center of side surface of cell 4, near module housing	481.6	-
T5	Center of side surface of cell 5, near module housing	1299.1	-
T6	Center of side surface of cell 6, near module housing	461.7	-
T7	Center of side surface of cell 7, near module housing	446.2	-
T8	Center of side surface of cell 8, near module housing	425.2	-
T9	Center of side surface of cell 12, near module housing	116.1	-
T10	Center of side surface of cell 13, near module housing	104.1	-
T11	Center of side surface of cell 11, near module housing	116.6	-
T12	Center of the film heater 1, near cell 4	/	-
T13	Center of the film heater 2, near cell 6	1295.6	-
T101	Center of top surface of module M01, Initiating Unit	33.7	-
T102	Center of top surface of module M02, Initiating Unit	187	-
T103	Center of top surface of module M03, Initiating Unit	213.2	-
T104	Center of top surface of module M04, Initiating Unit	41.6	-
T105	Center of top surface of module M05, Initiating Unit	39.7	-
T106	Center of top surface of module M06, Initiating Unit	31.8	-
T107	Center of top surface of module M07, Initiating Unit	51.8	-
T108	Center of left surface of module M09, Target Unit 1	27.8	130.8
T109	Center of left surface of module M10, Target Unit 1	25.7	130.8
T110	Center of left surface of module M11, Target Unit 1	25.4	130.8
T111	Center of left surface of module M12, Target Unit 1	27.3	130.8
T112	Center of left surface of module M13, Target Unit 1	24.4	130.8
T113	Center of left surface of module M14, Target Unit 1	27.1	130.8
T114	Center of left surface of module M15, Target Unit 1	29.6	130.8
T115	Center of left surface of module M16, Target Unit 1	25.7	130.8
T116	Center of back surface of module M17, Target Unit 2	23.8	130.8
T117	Center of back surface of module M18, Target Unit 2	24.1	130.8
T118	Center of back surface of module M19, Target Unit 2	24.5	130.8
T119	Center of back surface of module M20, Target Unit 2	26.1	130.8

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UNIT LEVEL			
T120	Center of back surface of module M21, Target Unit 2	22	130.8
T121	Center of back surface of module M22, Target Unit 2	24.7	130.8
T122	Center of back surface of module M23, Target Unit 2	25.3	130.8
T123	Center of back surface of module M24, Target Unit 2	26.6	130.8
T124	Bottom of inner corner of Target Unit 3	24.2	130.8
T125	Center of inner corner of Target Unit 3	24.1	130.8
T126	Top of inner corner of Target Unit 3	24.2	130.8
T201	Center of front surface of Initiating Unit	44	-
T202	Center of back surface of Initiating Unit	32.8	-
T203	Center of left surface of Initiating Unit	36	-
T204	Center of right surface of Initiating Unit	62.7	-
T205	Center of front surface of Target Unit 1	25	130.8
T206	Center of back surface of Target Unit 1	23.4	130.8
T207	Center of left surface of Target Unit 1	33.4	130.8
T208	Center of right surface of Target Unit 1	23.2	130.8
T209	Center of front surface of Target Unit 2	24.8	130.8
T210	Center of back surface of Target Unit 2	20.8	130.8
T211	Center of left surface of Target Unit 2	23	130.8
T212	Center of right surface of Target Unit 2	24.1	130.8
T213	Center of front surface of Target Unit 3	25.4	130.8
T214	Center of back surface of Target Unit 3	24.5	130.8
T215	Center of left surface of Target Unit 3	24	130.8
T216	Center of right surface of Target Unit 3	24.1	130.8
TA1	Wall A surface 1	26.4	121.3
TA2	Wall A surface 2	28.2	121.3
TA3	Wall A surface 3	30.6	121.3
TA4	Wall A surface 4	31.4	121.3
TA5	Wall A surface 5	25.3	121.3
TA6	Wall A surface 6	28.6	121.3
TA7	Wall A surface 7	29.2	121.3
TA8	Wall A surface 8	30.7	121.3
TA9	Wall A surface 9	29.5	121.3
TA10	Wall A surface 10	27.6	121.3
TA11	Wall A surface 11	26.1	121.3
TA12	Wall A surface 12	27.4	121.3
TA13	Wall A surface 13	22.3	121.3

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UNIT LEVEL			
TA14	Wall A surface 14	24.5	121.3
TA15	Wall A surface 15	25.4	121.3
TA16	Wall A surface 16	26.5	121.3
TA17	Wall A surface 17	24.3	121.3
TA18	Wall A surface 18	24.3	121.3
TA19	Wall A surface 19	24.2	121.3
TA20	Wall A surface 20	25.6	121.3
TA21	Wall A surface 21	21.3	121.3
TA22	Wall A surface 22	24.2	121.3
TA23	Wall A surface 23	24.7	121.3
TA24	Wall A surface 24	26.3	121.3
TA25	Wall A additional 1,the same height of initiating module	34.9	121.3
TA26	Wall A additional 2,the same height of initiating module	21.9	121.3
TA27	Wall A additional 3,the same height of initiating module	29.6	121.3
TB1	Wall B surface 1	26.9	121.3
TB2	Wall B surface 2	28.6	121.3
TB3	Wall B surface 3	29.4	121.3
TB4	Wall B surface 4	30	121.3
TB5	Wall B surface 5	24.6	121.3
TB6	Wall B surface 6	27.3	121.3
TB7	Wall B surface 7	28.1	121.3
TB8	Wall B surface 8	30	121.3
TB9	Wall B surface 9	27.6	121.3
TB10	Wall B surface 10	25.8	121.3
TB11	Wall B surface 11	24.6	121.3
TB12	Wall B surface 12	26	121.3
TB13	Wall B surface 13	23.2	121.3
TB14	Wall B surface 14	23.9	121.3
TB15	Wall B surface 15	24.3	121.3
TB16	Wall B surface 16	25.2	121.3
TB17	Wall B surface 17	24	121.3
TB18	Wall B surface 18	23.9	121.3
TB19	Wall B surface 19	23.7	121.3
TB20	Wall B surface 20	25.6	121.3
TB21	Wall B surface 21	19.9	121.3
TB22	Wall B surface 22	23.6	121.3

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UNIT LEVEL			
TB23	Wall B surface 23	24.5	121.3
TB24	Wall B surface 24	25.5	121.3
TB25	Wall B additional 1,the same height of initiating module	27	121.3
TB26	Wall B additional 2,the same height of initiating module	30.4	121.3
TB27	Wall B additional 3,the same height of initiating module	26.3	121.3
	Top case -Initiating Module	246.8	-
	Bottom case -Initiating Module	58	-
	Left case -Initiating Module	115.3	-
	Right case -Initiating Module	137.9	-
	Front case -Initiating Module	126.9	-
	Back case -Initiating Module	85.5	-
	Ambient	24.3	-
Remark: please see Attachment 4 for thermocouple locations and Attachment 6 for monitored temperature charts.			

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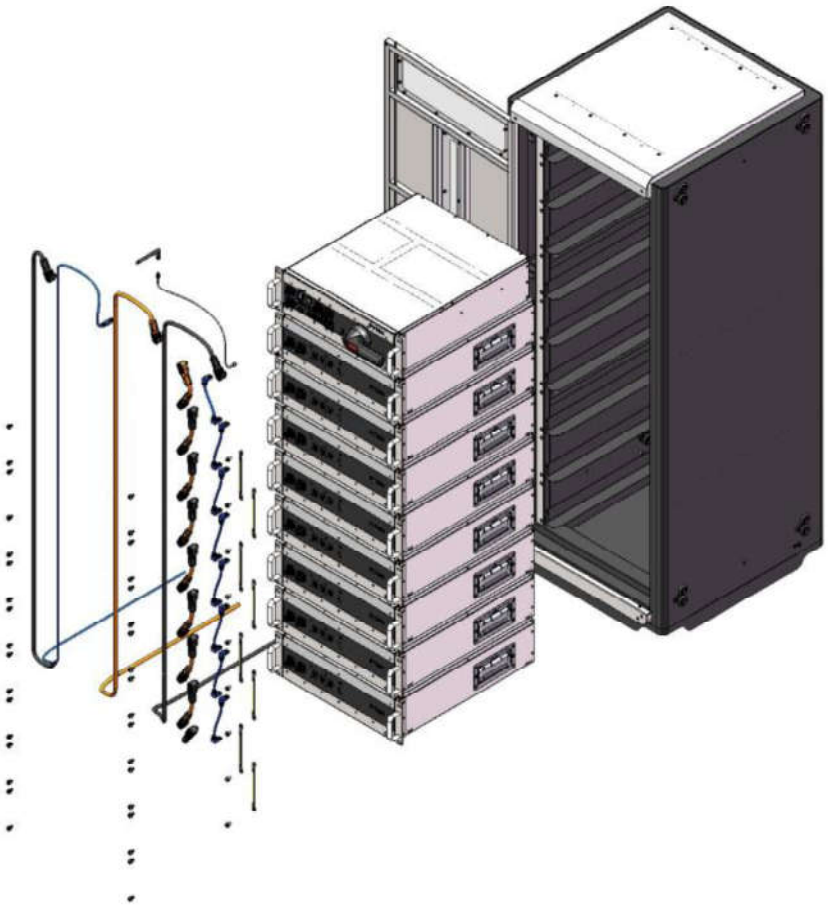
UNIT LEVEL

Attachment 1: Product description



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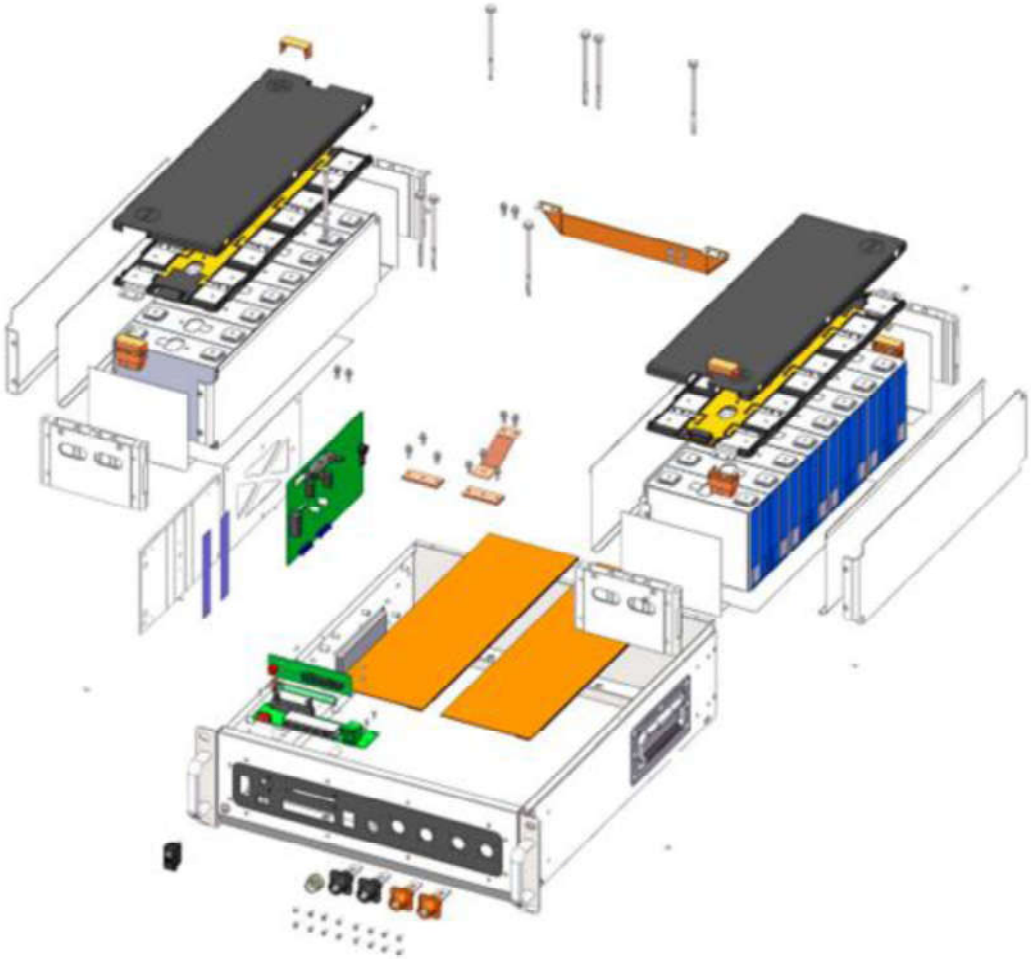
UNIT LEVEL

Attachment 2: Explosion drawing of module & Identification/location of cells within the module

Exploding drawing of module as below:



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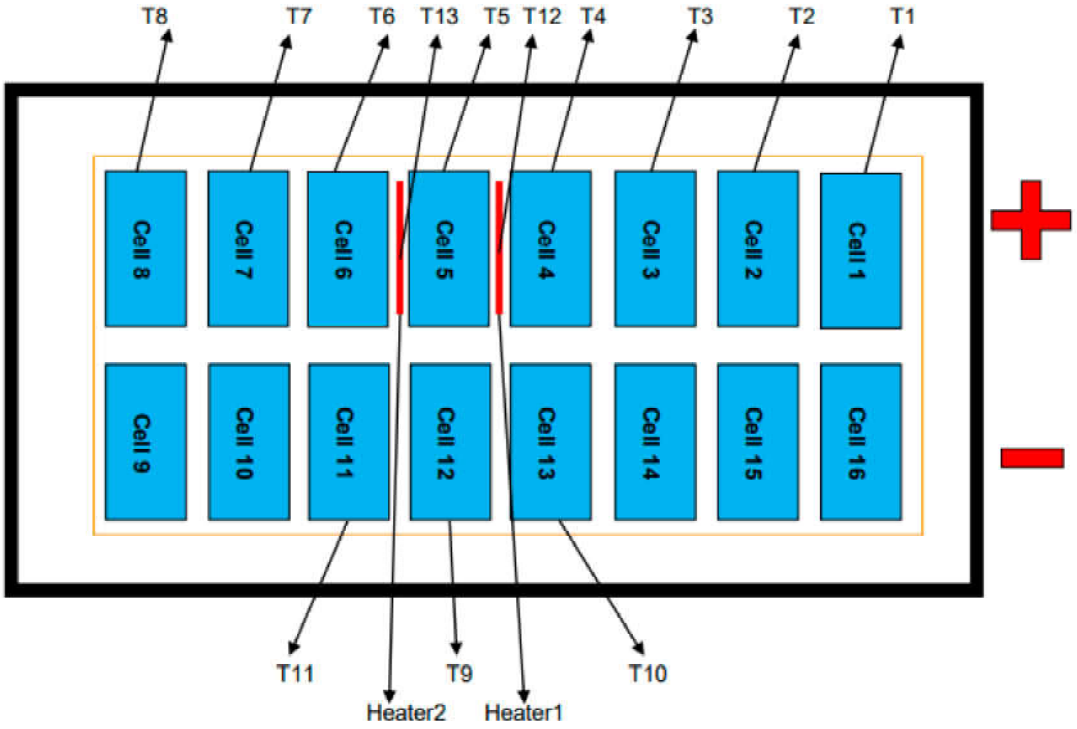
Identification/location of cells within the module as below (Cell 5 as inititating cell):



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UNIT LEVEL

Attachment 3: Pre-conditioning profile

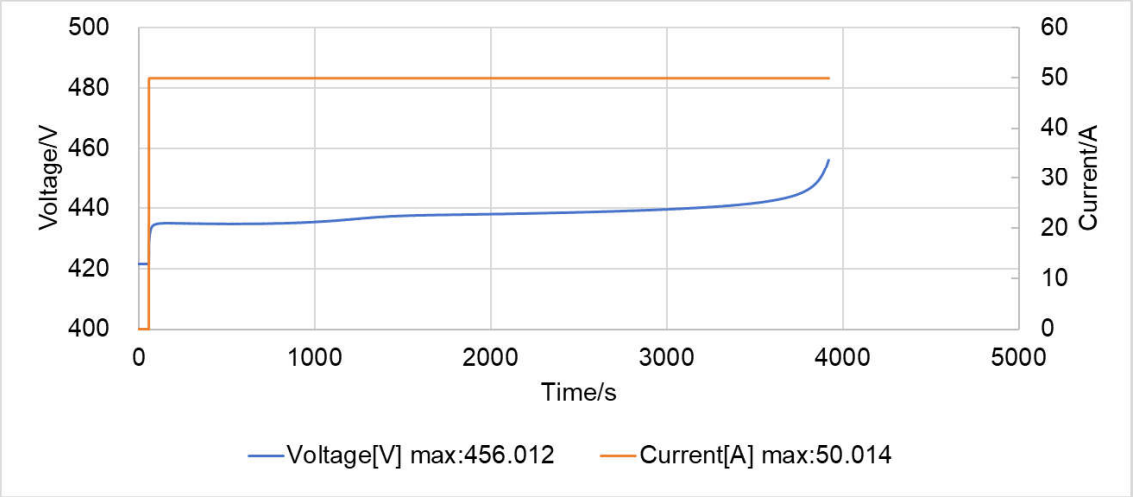

Figure 1 of Attachment 3: Charge cycle chart for six modules connected in series of initiating unit.

Figure 1 of Attachment 3: SOC of six modules connected in series of initiating unit after pre-conditioning.

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UNIT LEVEL

Attachment 4: Photo for sample before test and test setup with thermocouple location

Details of:	Figure 1 of Attachment 4 Overview of initiating module_before test
	Top case 

Details of:	Figure 2 of Attachment 4 Overview of initiating module_before test
	Front case 

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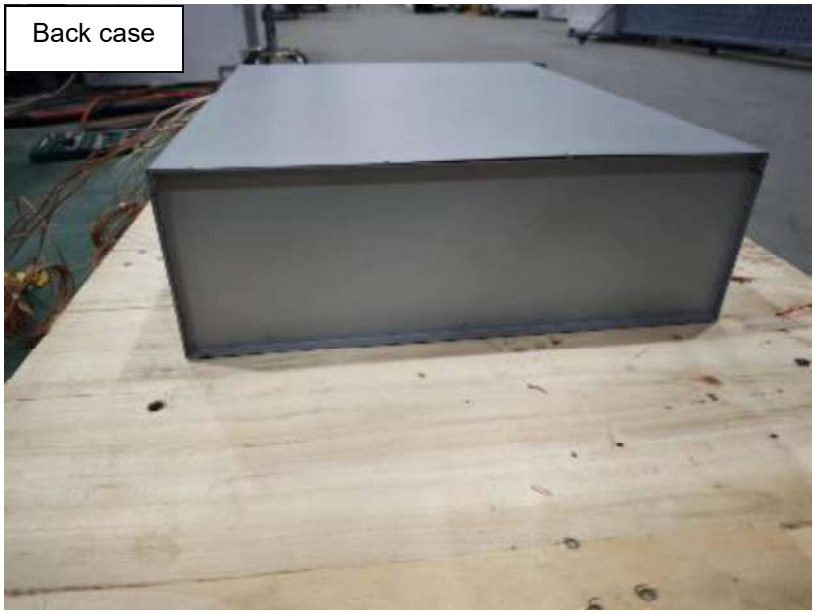
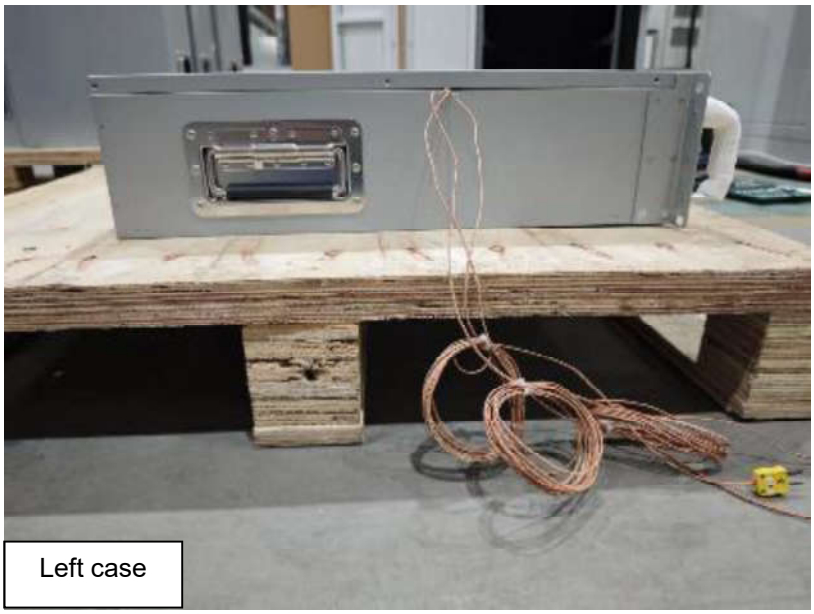
UNIT LEVEL

Details of:	Figure 3 of Attachment 4 Overview of initiating module_before test
	 Back case

Details of:	Figure 4 of Attachment 4 Overview of initiating module_before test
	 Left case

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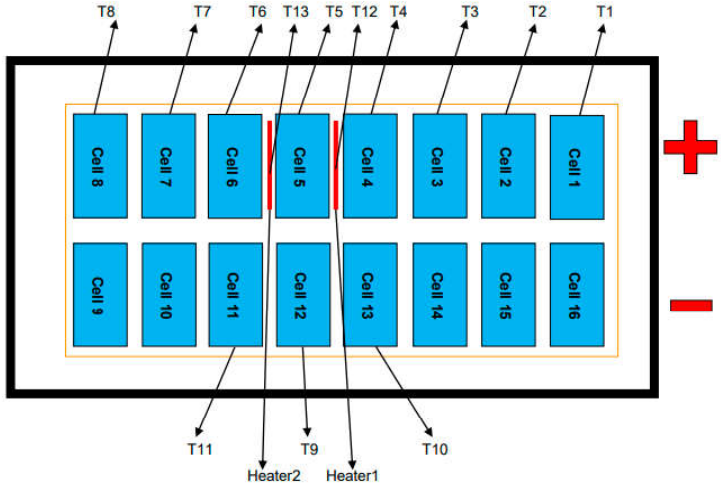
UNIT LEVEL

Details of:	Figure 5 of Attachment 4 Overview of initiating module_before test
	 Right case

Details of:	Figure 6 of Attachment 4 Overview of sample & thermocouple location of initiating module _before test
	 Schematic Illustration of film heaters and thermocouple locations in DUT. Cell 5 is the initiating cell, Heater1 and heater2 mean Film heater1 and film heater2. T1 to T13 means thermocouples T1 to T13. View from top.

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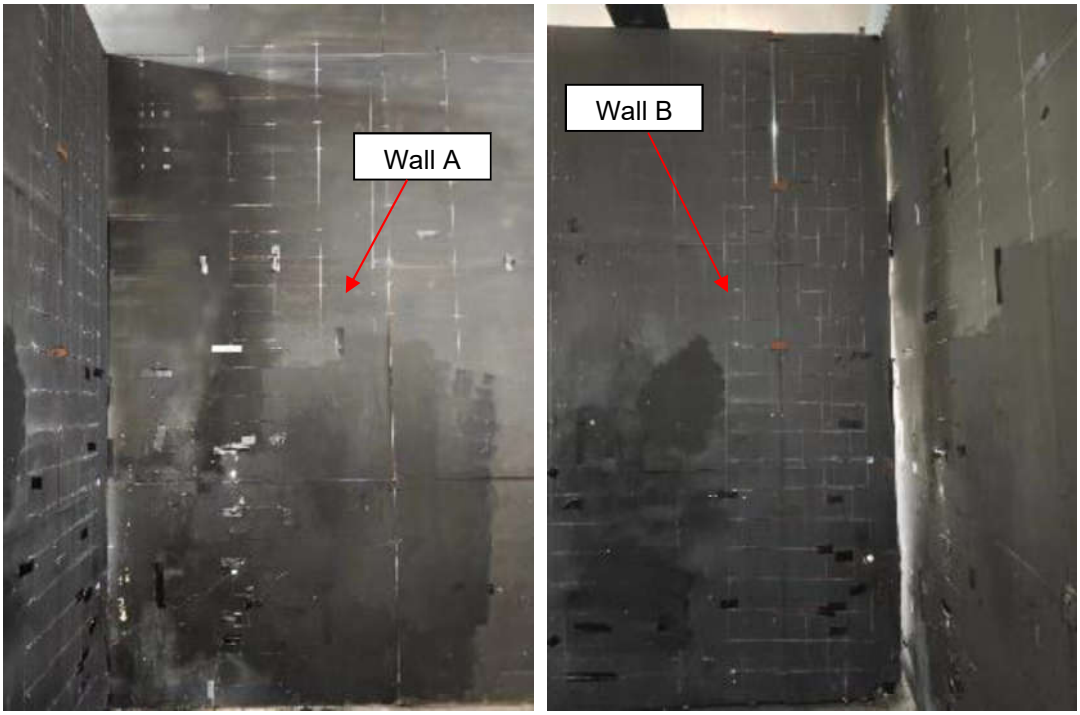
UNIT LEVEL

Details of:	Figure 7 of Attachment 4 Overview of instrumented walls_before test
	 Remark: thermocouple locations of wall surface (one vertical array at 152mm intervals for the full height)

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UNIT LEVEL

Details of:	Figure 8 of Attachment 4 Thermocouple location of initiating unit_before test
	

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UNIT LEVEL

Details of:	Figure 9 of Attachment 4 Overview of initiating unit covered with cheesecloth - before test

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UNIT LEVEL

Details of:	Figure 10 of Attachment 4 Overview of sample & test setup - before test

Front view

Side view

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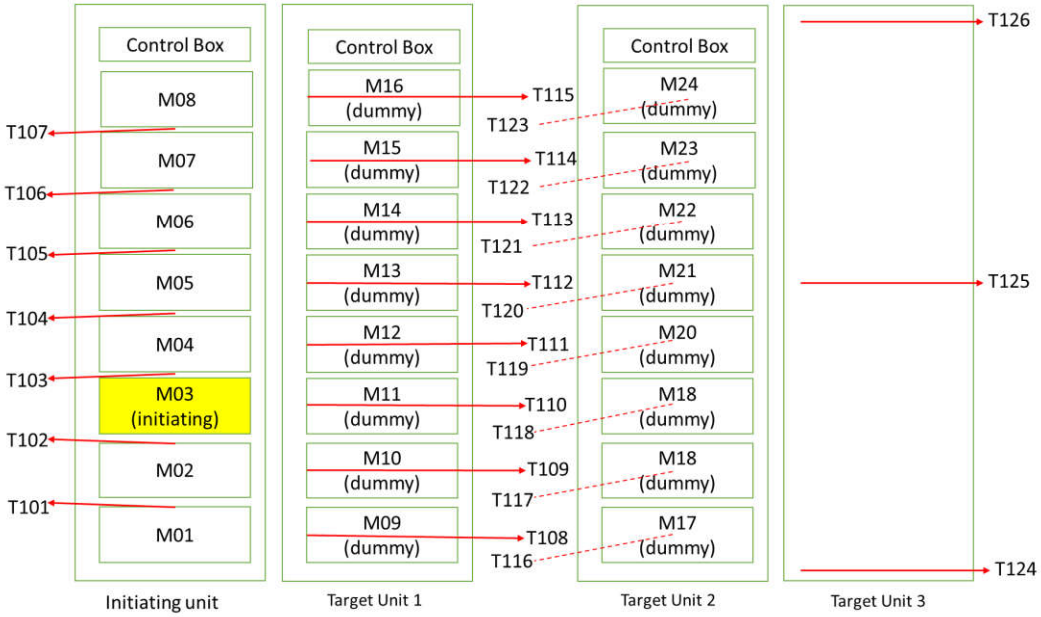
UNIT LEVEL

Details of:	Figure 11 of Attachment 4 Thermocouple location for neighbour modules and other locations for samples - before test



Remark:

T101 -T107: center of top surface of module M01 - M07

T108 -T115: center of left surface of module M09 - M16

T116 -T123: center of back surface of module M17 - M24

T124 -T126: Bottom, Center, and Top of inner corner of Target Unit 3

T201 -T216: Center of front, back, left, right surface of Unit 1 - Unit 4

View from front.

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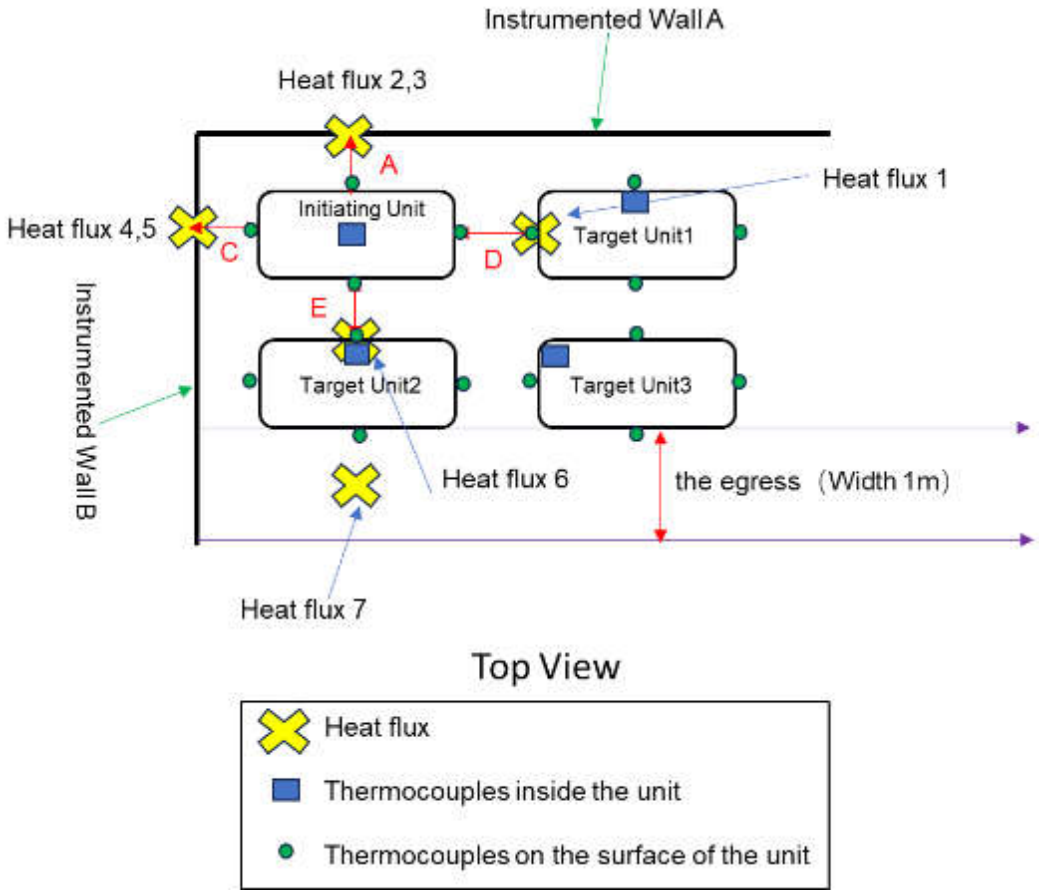
UNIT LEVEL

Details of:	Figure 12 of Attachment 4 Location of heat flux sensors



Remarks:

Heat flux 1: Positioned at the target unit 1 faced to the initiating module of the initiating unit

Heat flux 2: Positioned at the wall A faced to the initiating module of the initiating unit

Heat flux 3: Positioned at the wall A faced to the initiating module, potential propagation of thermal runaway

Heat flux 4: Positioned at the wall B faced to the initiating module of the initiating unit

Heat flux 5: Positioned at the wall B faced to the initiating module, potential propagation of thermal runaway

Heat flux 6: Positioned at the target unit 2 faced to the initiating module of the initiating unit

Heat flux 7: Positioned at the middle of the egress

A=50.8 mm; C=101.6 mm; D=101.6mm; E=520 mm

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UNIT LEVEL

Item	Height, mm	Distance to Instrumented wall A, mm	Distance to Instrumented wall B, mm
Heat flux 1	479	370.8	627.2
Heat flux 2	479	0	401.6
Heat flux 3	759	0	401.6
Heat flux 4	479	370.8	0
Heat flux 5	759	370.8	0
Heat flux 6	479	1210.8	401.6
Heat flux 7	479	2350.8	401.6

Attachment 5: Photo for sample after test

Details of:	Figure 1 of Attachment 5 Overview of sample_after test

Front view

Side view

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Details of:	Figure 2 of Attachment 5 Overview of initiating unit_after test
	 

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Details of:	Figure 3 of Attachment 5 Internal view of initiating unit_after test

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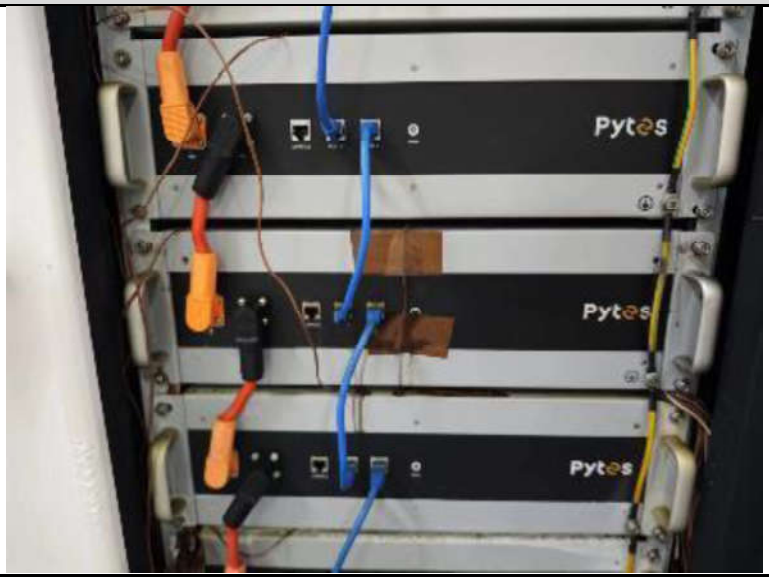
Details of:	Figure 4 of Attachment 5 Internal view of initiating unit_after test
	

Details of:	Figure 5 of Attachment 5 Top view of initiating module_after test
	

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Details of:	Figure 6 of Attachment 5 Bottom view of initiating module_after test
	

Details of:	Figure 7 of Attachment 5 Front view of initiating module_after test
	

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Details of:	Figure 8 of Attachment 5 Back view of initiating module_after test
	

Details of:	Figure 9 of Attachment 5 Left side view of initiating module_after test
	

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Details of:	Figure 10 of Attachment 5 Right side view of initiating module_after test
	

Details of:	Figure 11 of Attachment 5 Top view of initiating module_after test, without top cover.
	 Internal view of DUT.

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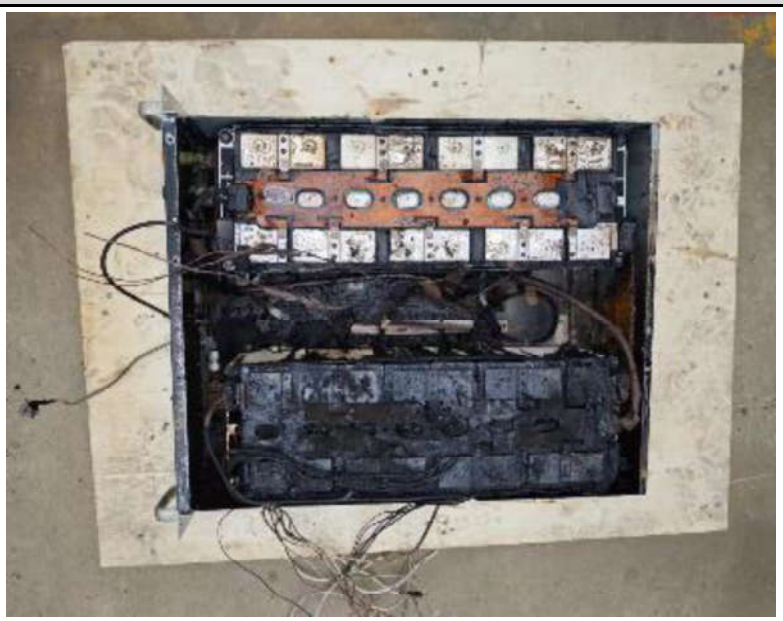
Details of:	Figure 12 of Attachment 5 View of initiating module top cover (inner side)_after test
	 Internal view of DUT.

Details of:	Figure 13 of Attachment 5 Top view of initiating module_after test, without top cover.
	 Internal view of DUT. After cleaning of cell row opposite initiating cell.

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Attachment 6: Monitored voltage and temperature chart

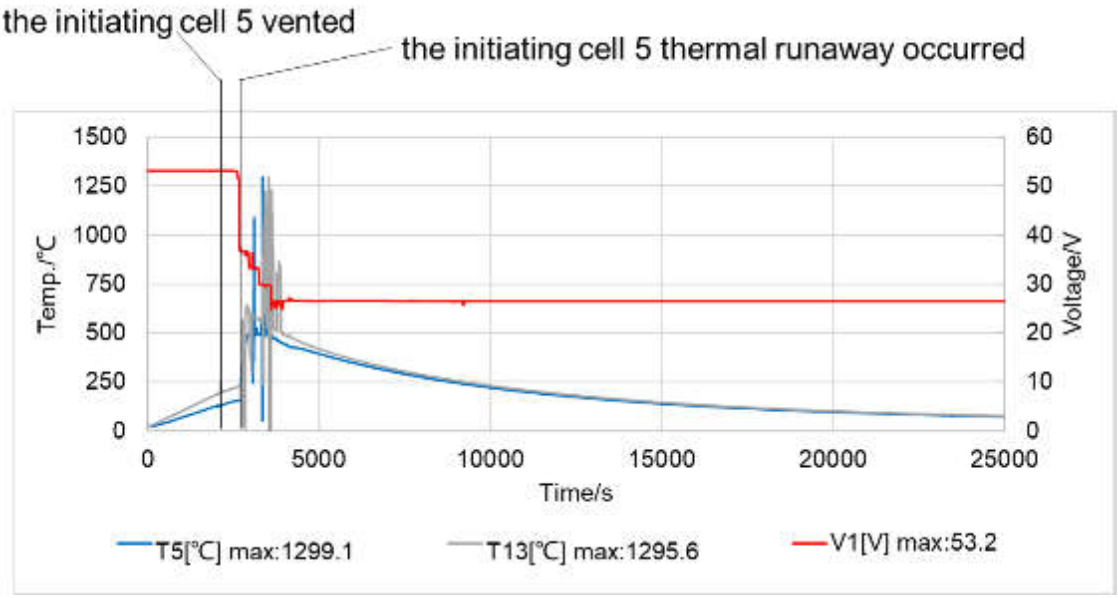

Figure 1 of Attachment 6: temperature of initiating cell in initiating module

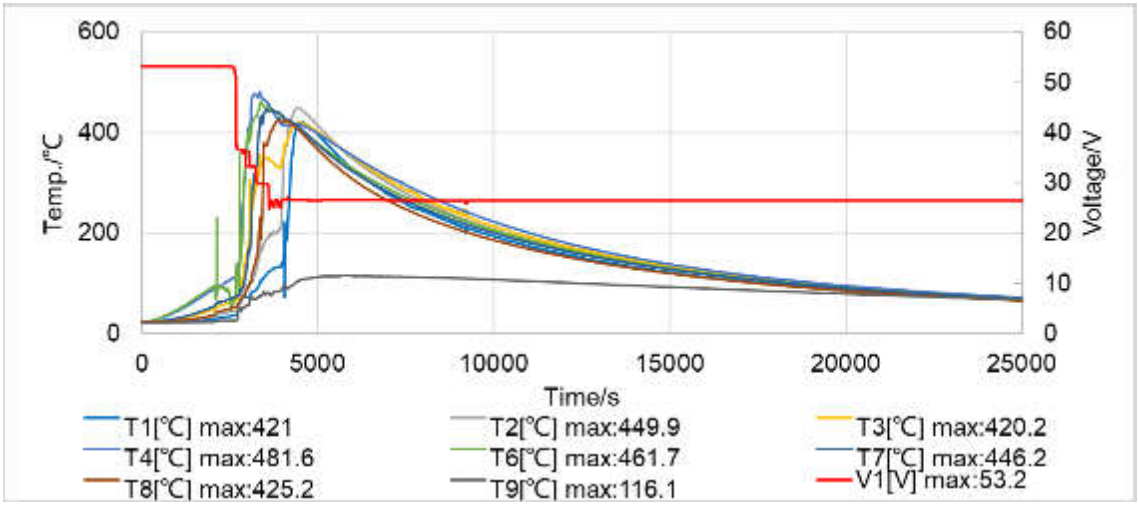

Figure 2 of Attachment 6: temperature of other cells in initiating module.

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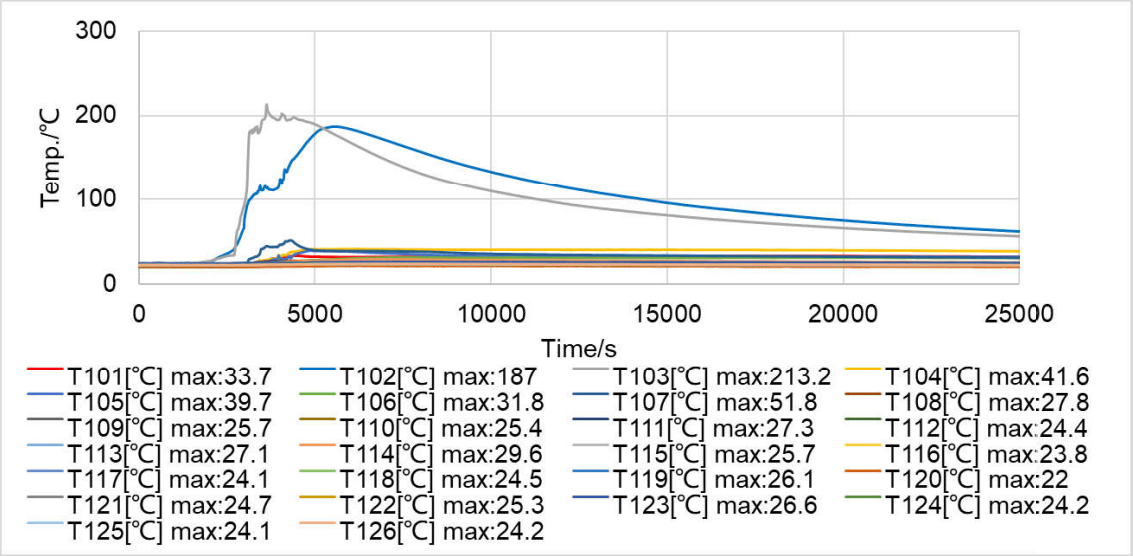

Figure 3 of Attachment 6: Temperature inside initiating unit and target unit.

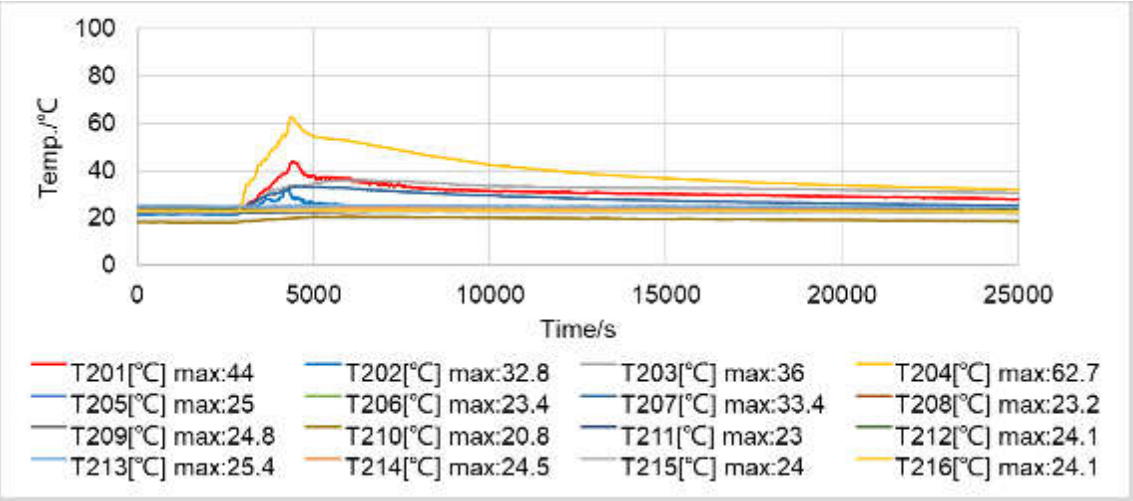

Figure 4 of Attachment 6: Temperature of external surface of initiating unit and target unit.

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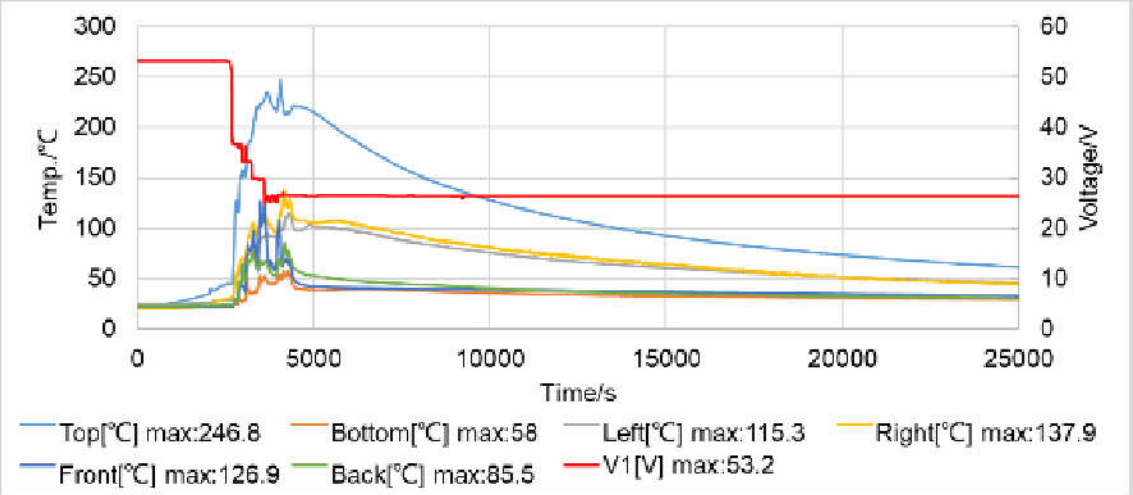

Figure 5 of Attachment 6: temperature of module case in initiating module.

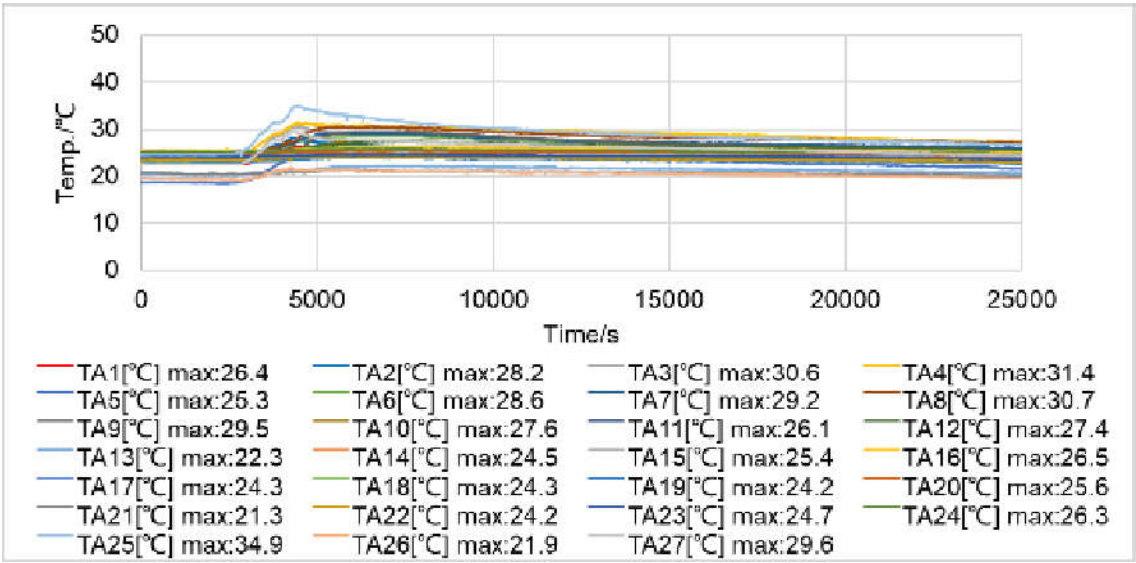

Figure 6 of Attachment 6: Temperature of wall A surface.

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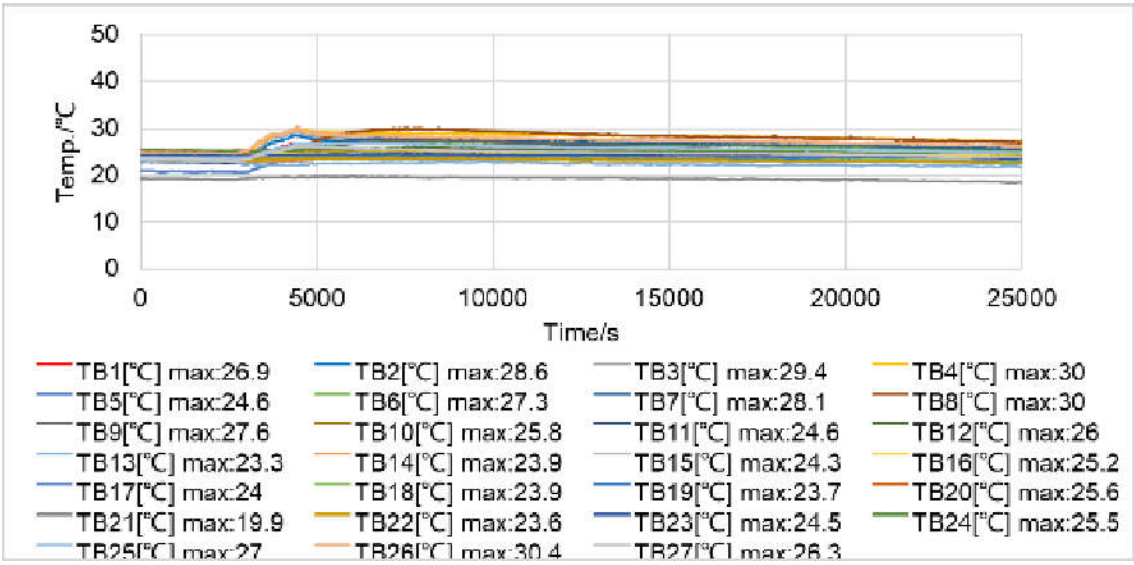

Figure 7 of Attachment 6: Temperature of wall B surface.

Attachment 7: Flammable gas generation and composition data charts

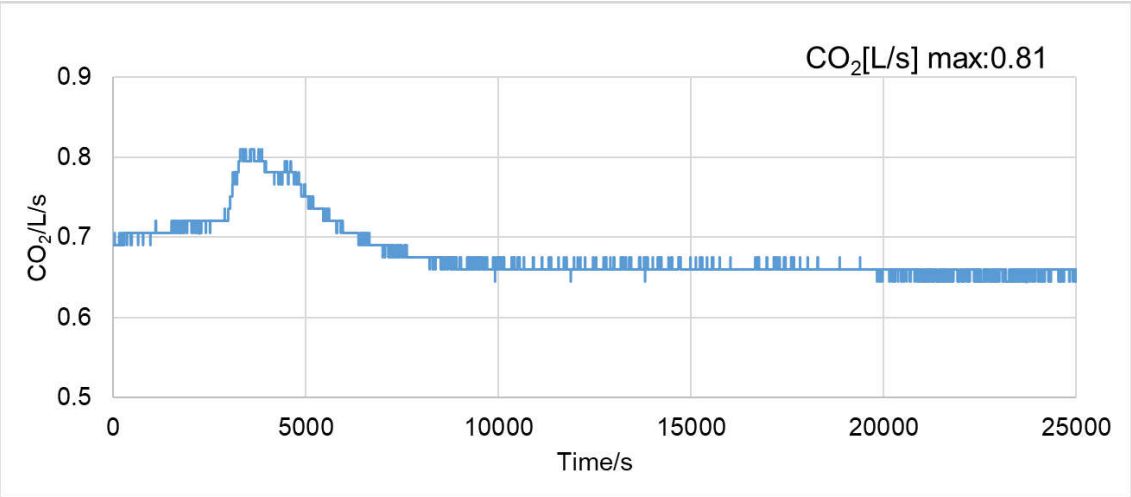

Figure 1 of Attachment 7: Gas generation and composition data chart.

Remark: Flow rate in exhaust duct was 1.5 m^3/s.

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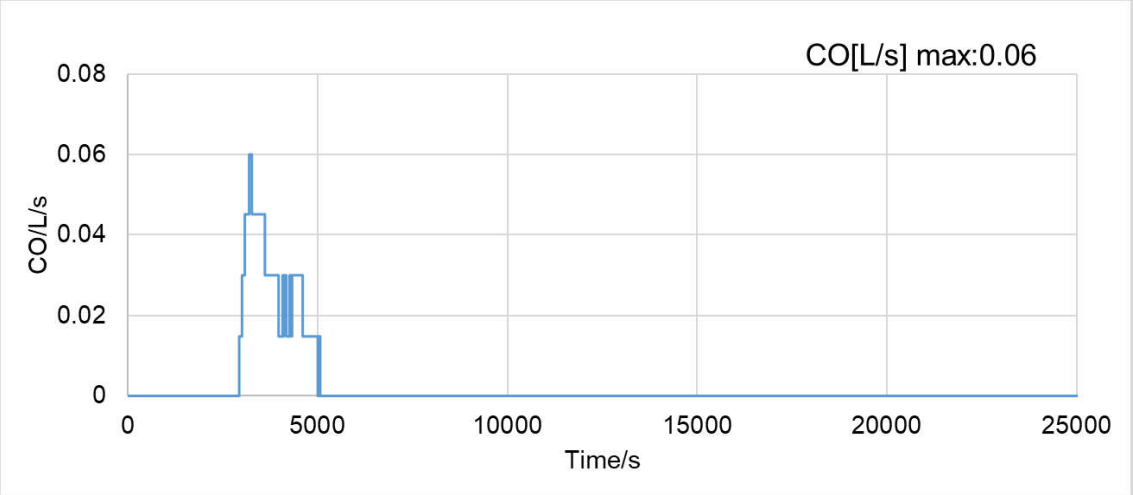

Figure 2 of Attachment 7: Gas generation and composition data chart.

Remark: Flow rate in exhaust duct was 1.5 m^3/s.

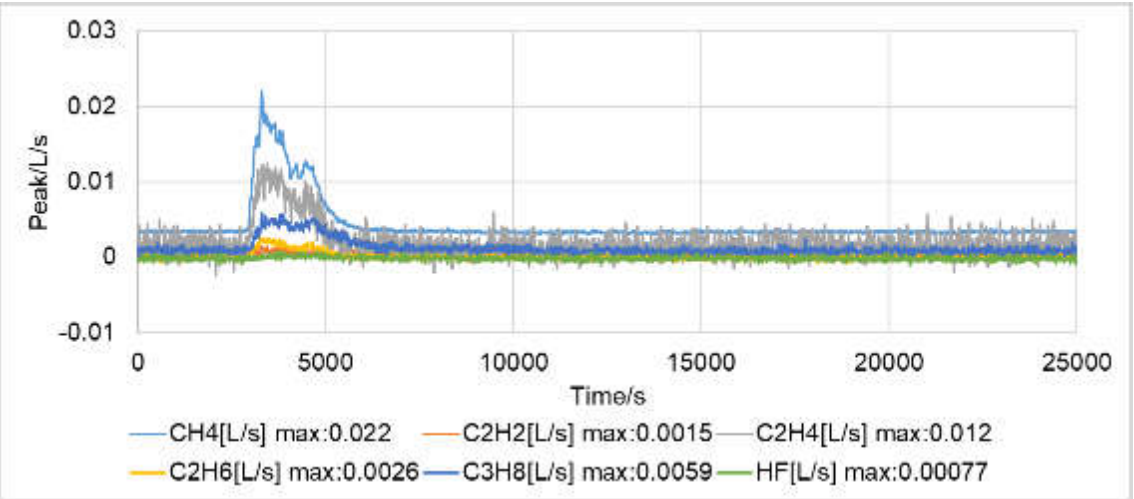

Figure 3 of Attachment 7: Gas generation and composition data chart (Detected by FTIR).

Remark: Flow rate in exhaust duct was 1.5 m^3/s.

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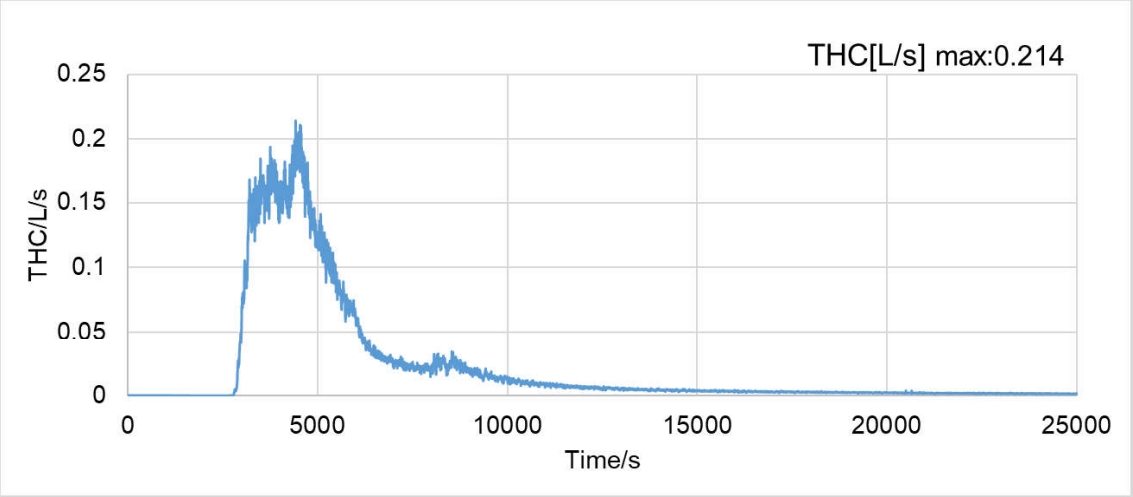
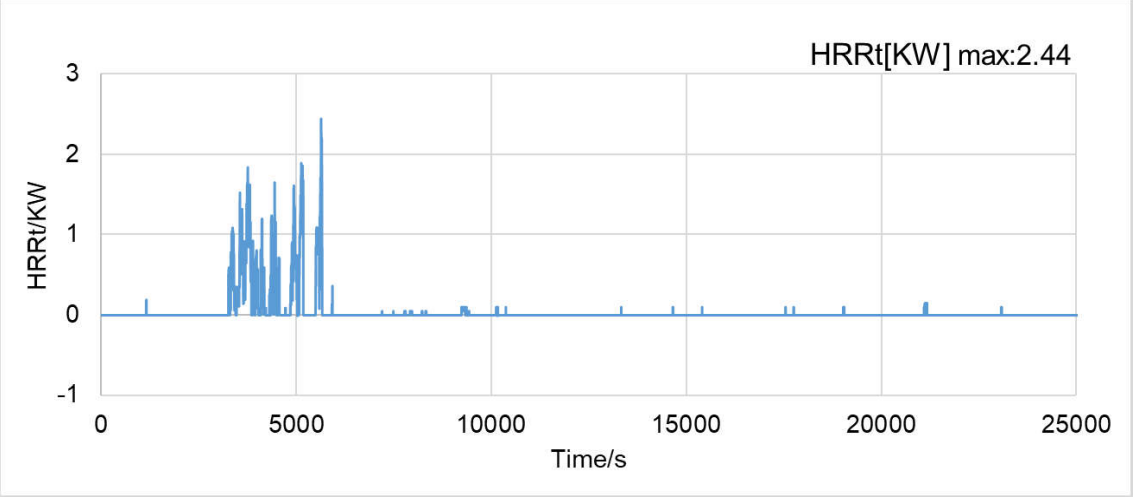


Figure 5 of Attachment 7: THC (Total Hydrocarbons) chart (Detected by FID).

Remark: Flow rate in exhaust duct was 1.5 m^3/s.

Attachment 8: Heat release rate versus time data chart



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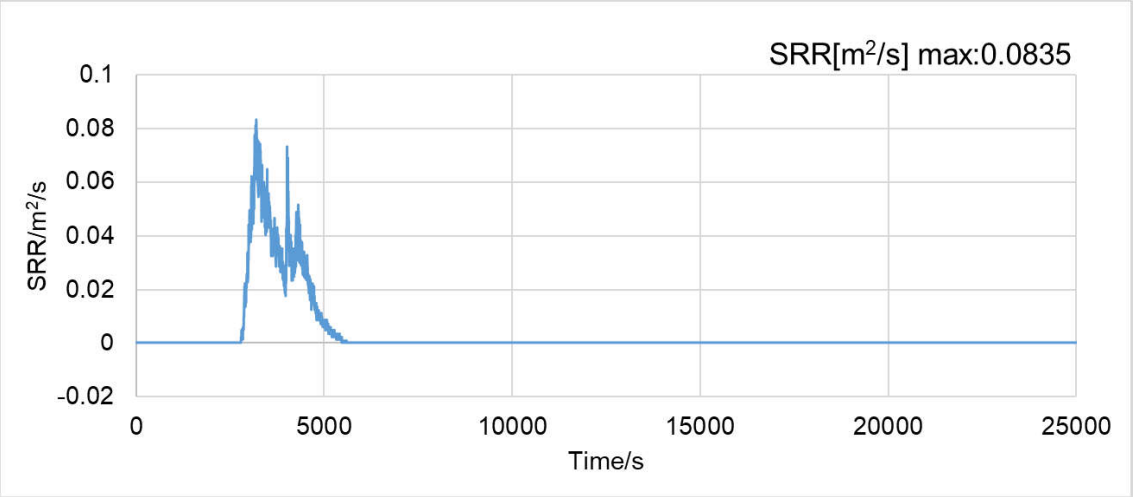
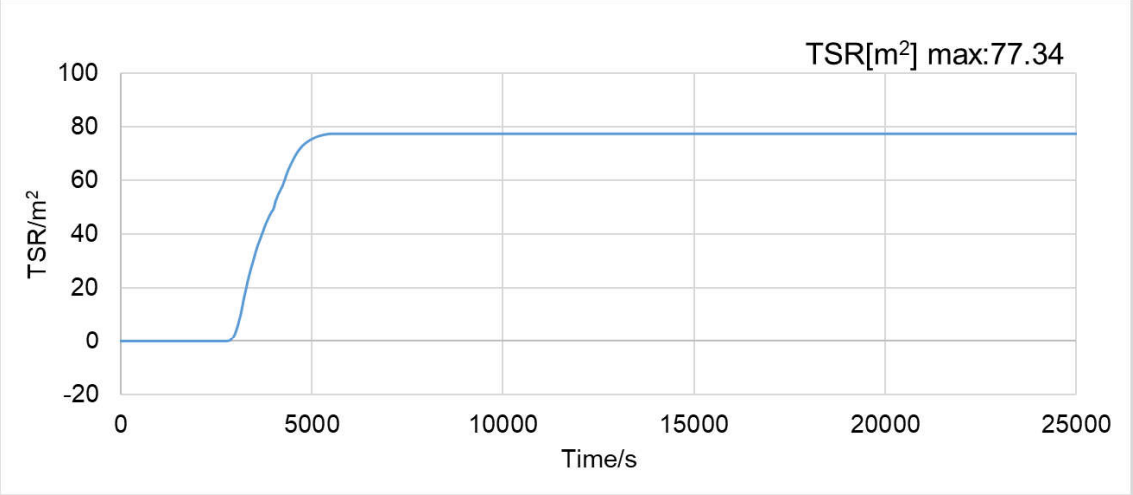
Attachment 9: Peak smoke release rate and total smoke release data chart





Attachment 10: Summary of Heat release rate & Peak smoke release rate and total smoke release data

Peak heat release rate	2.44 kW
Peak convective heat release rate	0 kW
Total smoke release	77.34 m^2
Peak smoke release rate	0.0835 m^2/s

---------- END REPORT ----------

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