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 Module Level

Report No.: Date of issue: Project handler: Supervisor:	5061925025712-00 2025-12-01 Zhu, Jiacheng You, Duo
Testing laboratory: Address: Testing location:	TÜV SÜD New Energy Vehicle Testing (Jiangsu) Co., Ltd. Building A, No.15 Factory, Jintong International Industrial Park, No.8, Xihu Road, Wujin National Hi-tech Industrial Development Zone, Changzhou, Jiangsu, China Chuweineng Testing Technology (Shanghai) Co., Ltd. Building 3, No. 1065, Beihe Road, Jiading District, Shanghai
Client: Client number: Address: Contact person:	Shanghai PYTES Energy Co., Ltd. 003364 No. 3492 Jinqian Road, Fengxian District, 201406 Shanghai, PEOPLE'S REPUBLIC OF CHINA Yang, Lijuan
Standard: TRF number and revision: TRF originated by:	ANSI/CAN/UL 9540A:2019 Fourth Edition (4Ed) TRF ANSI/CAN/UL 9540A:2019 Rev 0 TÜV SÜD Product Service
Copyright blank test report: General disclaimer:	This test report is based on the content of the standard (see above). The test report considered selected clauses of the a.m. standard(s) and experience gained with product testing. It was prepared by TÜV SÜD Product Service. TÜV SÜD Group takes no responsibility for and will not assume liability for damages resulting from the reader's interpretation of the reproduced material due to its placement and context. This test report may only be quoted in full. Any use for advertising purposes must be granted in writing. This report is the result of a single examination of the object in question and is not generally applicable evaluation of the quality of other products in regular production.
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: National deviations:	☒ No ☐ Yes, see details under *Summary of testing* N/A
Number of pages *(Report)*: Number of pages *(Attachments)*:	39 17 (page 23 – 39)

Compiled by: (+ signature)	Zhu, Jiacheng Zhu Jiacheng	Compiled by: (+ signature)	You, Duo You Duo	Approved by: (+ signature)	Frank, Marco

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TÜV SÜD New Energy Vehicle Testing (Jiangsu) Co., Ltd.
Building A, No.15 Factory, Jintong International Industrial Park, No.8, Xihu Road, Wujin National Hi-tech Industrial Development Zone, Changzhou, Jiangsu, China

Test sample:	Batteries
Type of test object:	Rechargeable Li-ion Battery
Trademark:	Pytes
Model and/ or type reference:	HV48100 SE BMU
Rating(s):	51.2 Vd.c., 100 Ah

Manufacturer:	Shanghai PYTES Energy Co., Ltd.
Manufacturer number:	003364
Address:	No. 3492 Jinqian Road, Fengxian District, 201406 Shanghai, PEOPLE'S REPUBLIC OF CHINA
Name and address of factory(ies)	
Shanghai PYTES Energy Co., Ltd. No. 3492 Jinqian Road, Fengxian District, 201406 Shanghai, PEOPLE'S REPUBLIC OF 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:	2024-10-22
Date of receipt of test item:	2025-04-22
Date(s) of performance of test:	2025-04-23 to 2025-04-24

Test item particulars:

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

Purpose of the product (description of intended use):

The Rechargeable Li-ion Battery Module, model: HV48100 SE BMU, is used in Battery Energy Storage Systems.

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Characteristic data (not shown on the marking plate):	
Product name	Rechargeable Li-ion Battery Module
Type/model	HV48100 SE BMU
Nominal voltage	51.2 Vd.c.
Rated capacity	100 Ah
Charging voltage specified by manufacturer	56 V
Upper limit charging voltage	57.6 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	44.5 V
Operating ambient temperature range	0 °C to 30 °C
Standard charging method specified by manufacturer	Charge at constant current 50 A until voltage reaches 56 V, then charge at constant voltage 56 V till charge current is 5 A
Standard discharging method specified by manufacturer	Discharge at constant current 50 A until the voltage reaches 44.5V
Dimension	D×W×H: 484 mm × 530 mm× 140 mm
Weight	Approx. 45.16 kg
Number of cells in module and module configuration	(8S)2S

Attachments:
Attachment 1: Exploded-view drawing of module & Identification/location of cells within the module Attachment 2: Pre-conditioning profile Attachment 3: Photo for sample before test and test setup with thermocouple location Attachment 4: Photo for sample after test Attachment 5: Monitored voltage and temperature chart Attachment 6: Flammable gas generation and composition data chart Attachment 7: Heat release rate versus time data chart Attachment 8: Peak smoke release rate and total smoke release data chart Attachment 9: Summary of Heat release rate & Peak smoke release rate and total smoke release data
If additional information is necessary, please provide N/A

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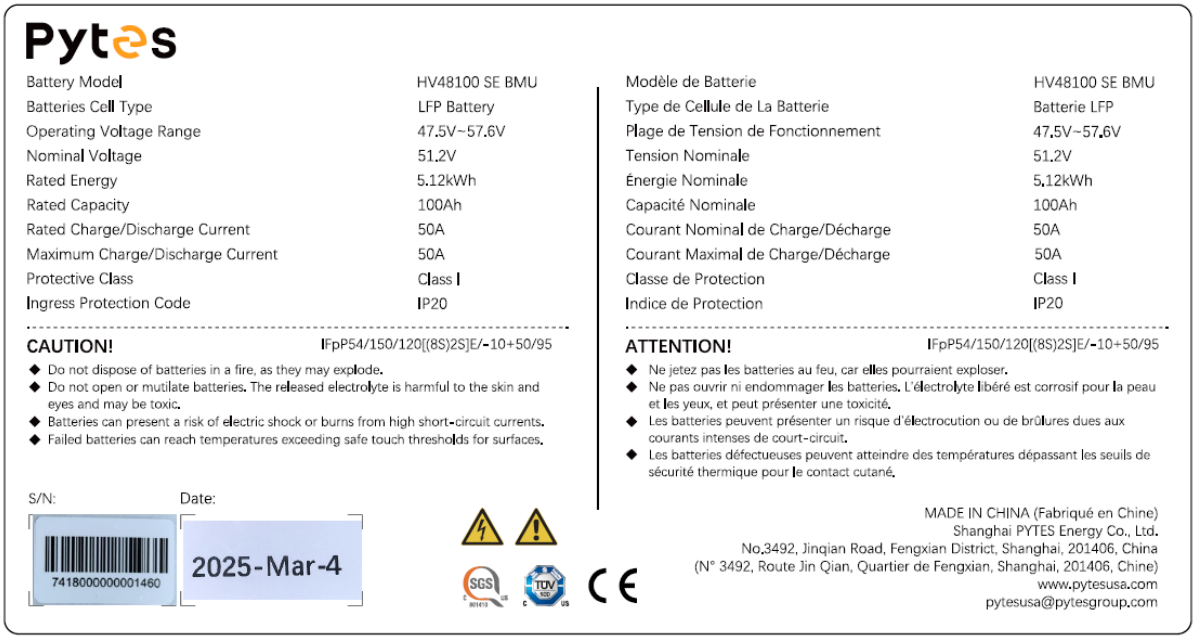
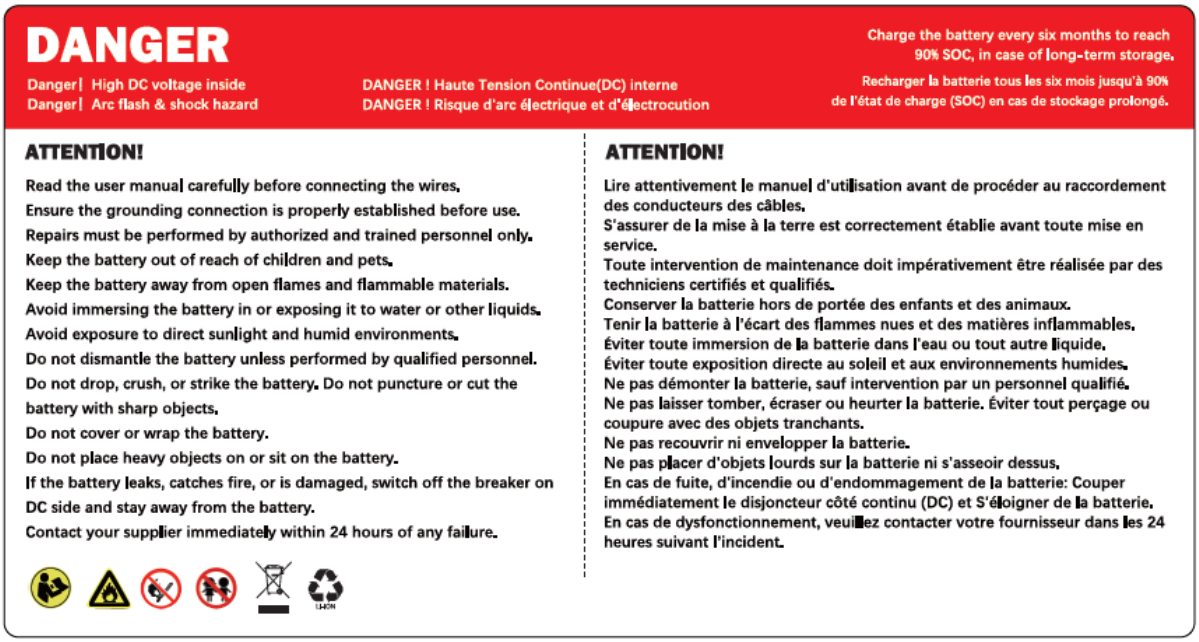
Copy of marking plate:

For Rechargeable Li-ion Battery, model: HV48100 SE BMU



Label for warning:



Remark:

1. The S/N code can be used to trace the manufacture information of the battery.
"+" and "-" are marked near the connector of the battery.
2. "2025-Mar-4" represents the date of manufacture, meaning the battery was produced on Mar 4th, 2025. This is not the manufacture date of actual samples and only for example.
3. Polarity "+" and "-" are marked near the connector of the battery.

Pictures of the product:

Overview of Rechargeable Li-ion Battery, model: HV48100 SE BMU

Front view

Back view

Summary of testing:	
Module model number	HV48100 SE BMU
Nominal voltage and rated capacity	51.2 Vd.c., 100 Ah
Number of cells in module and module configuration	(8S)2S
Whether UL 1973 compliant	Rechargeable Li-ion Battery module, model: HV48100 SE BMU is not compliant with UL 1973. Rechargeable Li-ion Battery Systems which use the Rechargeable Li-ion Battery module (model: HV48100 SE BMU) connected in series, are compliant with UL 1973, models: HV48100 SE BMU-3, HV48100 SE BMU-4, HV48100 SE BMU-5, HV48100 SE BMU-6, HV48100 SE BMU-7, HV48100 SE BMU-8, HV48100 SE BMU-9, HV48100 SE BMU-10, HV48100 SE BMU-11, HV48100 SE BMU-12, HV48100 SE BMU-13, HV48100 SE BMU-14, HV48100 SE BMU-15 Report No.: 64.280.25.60508.01 Certificate No.: U10 003364 0023 Rev. 01
Module voltage corresponding to the tested SOC	55.39 V (100 % SOC)
Method used to initiate thermal runaway	Heating the cell with externally applied 2 pieces flexible film heaters that cover each large surface of the cell. Film heater specifications: 101.6 mm × 127.0 mm (220 V, 250 W/pc)

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Thermal runaway of other cells within module:	Thermal runaway was observed on all cells of the module.
Heat release rate versus time data	see Attachment 7 and Attachment 9
Peak smoke release rate and total smoke release data	see Attachment 8 and Attachment 9
Flammable gas generation and composition data	see Table 2 and Attachment 6
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
Re-ignitions	N/A
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 no flammable as determined by the cell level test.	Cell vent gas is flammable according to cell level test report (external report with project number 4790342745).
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.	Cell chemistry: LFP Physical cell format: Prismatic	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 complies 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 non-metallic) 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 Attachment 1.	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.	Rechargeable Li-ion Battery module, model: HV48100 SE BMU is not compliant with UL 1973. Rechargeable Li-ion Battery Systems which use the	N/A

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
		Rechargeable Li-ion Battery module (model: HV48100 SE BMU) connected in series, are compliant with UL 1973, models: HV48100 SE BMU-3, HV48100 SE BMU-4, HV48100 SE BMU-5, HV48100 SE BMU-6, HV48100 SE BMU-7, HV48100 SE BMU-8, HV48100 SE BMU-9, HV48100 SE BMU-10, HV48100 SE BMU-11, HV48100 SE BMU-12, HV48100 SE BMU-13, HV48100 SE BMU-14, HV48100 SE BMU-15 Report No.: 64.280.25.60508.01 Certificate No.: U10 003364 0023 Rev. 01	
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**		—
5.4	**Flow Batteries**		—
	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**		—

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
8	**Module Level**		
8.1	**Sample**		
8.1.1	Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a minimum of 2 cycles, using a manufacturer specified methodology to verify that the module is functional. Each cycle shall be defined as a charge to 100% SOC and allowed to rest a maximum of 8 h and then discharged to an end of discharge voltage (EODV) specified by the module manufacturer. During conditioning the ambient temperature and conditions shall be maintained in accordance with 8.2.1.	See Attachment 2: Pre-conditioning profile. Charge method: Charge at constant current 50A until voltage reaches 56 V, then charge at constant voltage 56V till charge current drops to 5A. Discharge method: Discharge at constant current 50 A until the voltage reaches 44.5 V.	P
8.1.2	The module to be tested shall be charged to 100% SOC and allowed to rest a maximum of 8 h before the start of the test. The module voltage shall be determined by measuring at the module terminals after charging up to the fully charged condition and before beginning testing. The sample module shall stabilize for a minimum of one hour prior to testing	See Table 1.	P
8.1.3	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.		P
8.2	**Test method**		
8.2.1	Ambient indoor laboratory conditions shall be 25 ±5°C (77 ±9°F) and 50 ±25% RH at the initiation of the test.	See Table 1.	P
8.2.2	The test shall be conducted under a smoke collection hood that is sized appropriately to collect the gasses generated from the module.		P
8.2.3	The weight of the module shall be recorded before and after testing is completed to determine weight loss.	See Table 1.	P
8.2.4	The number of cells within the module that are forced into thermal runaway can be one or multiple cells, and is dependent upon the energy contained within the individual cells. A sufficient number of cells shall be forced into thermal runaway to create a condition of cell to cell propagation within the module. For example, it may be necessary to force nine, 3-Ah cells into thermal runaway as opposed to one, 30-Ah cell in order to get cell to cell propagation. The location of the cell (s) forced into thermal runaway shall be selected to present the greatest thermal	One cell was forced into thermal runaway. Cell to cell propagation occurred within the module.	P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	exposure to adjacent cells that are not forced into thermal runaway. Factors to be taken into consideration shall include selecting locations within the module where heat transfer is maximized to other cells, cooling by ventilation is restricted or limited, and thermal sensors, detection and suppression discharge points are remote.		
8.2.5	The methodology used for initiating thermal runaway pursuant to 7.2 shall be used to initiate thermal runaway within the module.	Two film heaters were used to initiate thermal runaway. 101.6 mm × 127.0 mm (220 V, 250 W/pc) film heater were covered on each large surface of the initiating cell. The cell was heated with the externally applied flexible film heater at a heating rate of 5 K/min until thermal runaway occurred.	P
8.2.6	With reference to 8.2.5, occurrence of thermal runaway shall be verified by sustained temperature above the cell surface temperature at the onset of thermal runaway, as determined in Section 7.		P
8.2.7	The module shall be placed on top of a noncombustible horizontal surface with the module orientation representative of its intended final installation.	See Figure 1 of Attachment 3.	P
8.2.8	The chemical heat release rate of the module in thermal runaway shall be measured with oxygen consumption calorimetry.	See Attachment 7 and 9.	P
8.2.9	The chemical heat release rate shall be measured for the duration of the test. See 8.2.10.	See Attachment 7 and 9.	P
8.2.10	The chemical heat release rate shall be measured by a measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple. The instrumentation shall be located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influence of bends or exhaust devices. See 8.2.11.	See Attachment 7 and 9.	P
8.2.11	With reference to 8.2.10, calculate the chemical heat release rate at each of the flows as follows: $HRR_1 = \left[E \times \varphi - (E_{co} - E) \times \frac{1-\varphi}{2} \times \frac{X_{co}}{X_{O_2}}\right] \times \frac{\dot{m}_e}{1+\varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^o_{H_2O}) \times X^o_{O_2}$		P
8.2.12	Vent 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	See Table 2 and Attachment 6.	P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
	least 2 m (6.6 ft), or equivalent gas analyzer, and velocity and temperature measurements respectively shall be obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.		
8.2.13	The hydrocarbon content of the vent gas shall be measure using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.	See Table 2 and Attachment 6.	P
8.2.14	The light transmission in the exhaust duct of the heat release rate calorimeter 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. See 8.2.15.	See Attachment 7 and 8.	P
8.2.15	Smoke release rate shall be calculated as follows: $$SRR = 2.303\left(\frac{V}{D}\right) Log_{10}\left(\frac{I_o}{I}\right)$$		P
8.3	**Module level test report**		
8.3.1	The report on module level testing shall include the following:	(See appended table)	P
	a) Module manufacturer name and model number (and whether UL 1973 compliant)	Name of the manufacturer: Shanghai PYTES Energy Co., Ltd. Rechargeable Li-ion Battery module, model: HV48100 SE BMU is not compliant with UL 1973. Rechargeable Li-ion Battery Systems which use the Rechargeable Li-ion Battery module (model: HV48100 SE BMU) connected in series, are compliant with UL 1973, models: HV48100 SE BMU-3, HV48100 SE BMU-4, HV48100 SE BMU-5, HV48100 SE BMU-6, HV48100 SE BMU-7, HV48100 SE BMU-8, HV48100 SE BMU-9, HV48100 SE BMU-10, HV48100 SE BMU-11, HV48100 SE BMU-12,	N/A

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
		HV48100 SE BMU-13, HV48100 SE BMU-14, HV48100 SE BMU-15 Report No.: 64.280.25.60508.01 Certificate No.: U10 003364 0023 Rev. 01	
	b) Number of cells in module;	16 cells in module.	P
	c) Module configuration with cells in series and parallel;	(8S)2S	P
	d) Module construction features per 5.2;	See Attachment 1.	P
	e) Module voltage corresponding to the tested SOC;	See Table 1.	P
	f) Thermal runaway initiation method used including number and locations of cells for initiating thermal runaway;	See Table 1 and Attachment 1.	P
	g) Heat release rate versus time data;	See Attachment 7 and 9.	P
	h) Flammable gas generation and composition data;	See Table 2 and Attachment 6.	P
	i) Peak smoke release rate and total smoke release data.	See Attachment 8 and 9.	P
	j) Observation(s) of flying debris or explosive discharge of gases;	See Table 1.	P
	k) Observation(s) of sparks, electrical arcs, or other electrical events;	See Table 1.	P
	l) Identification/location of cells(s) that exhibited thermal runaway within the module;	See Table 1.	P
	m) Locations and visual estimations of flame extension and duration from the module shall be documented;	See Table 1.	P
	n) Module weight loss based on measurements per 8.2.3; and	See Table 1	P
	o) Video of the test.		P

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MODULE LEVEL			
Clause	Requirement + Test	Result – Remark	Verdict
8.4	**Performance at module level testing**		—
8.4.1	Unit level testing in Section 9 is not required if the following performance conditions are met during the module level test:		—
	a) Thermal runaway is contained by module design; and	Thermal runaway is contained by module design; and	—
	b) Cell vent gas is non-flammable as determined by the cell level test.	Cell vent gas is flammable according to cell level test report (external report with project number 4791504604).	—
9	**Unit Level**		—
10	**Installation 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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MODULE LEVEL

	TABLE: Critical components information				
Object/part no.	**Manufacturer/ trademark**	**Type/model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Rechargeable Lithium-ion cell	REPT BATTERO Energy Co., Ltd.		3.2 Vd.c., 100 Ah	ANSI/CAN/UL 1973: 2022	UL MH64238-20220923
Rechargeable Lithium-ion cell	REPT BATTERO Energy Co., Ltd.		3.2 Vd.c., 100 Ah	ANSI/CAN/UL 9540A: 2019	External report with project number 4790342745
Supplementary information: N/A					

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MODULE LEVEL

MODULE LEVEL TEST RESULT:

Table 1: Thermal runaway test result	
Initial ambient temperature:	23.2 °C
Initial relative humidity:	62 % RH
Pre-conditioning time	From 2025-04-22 11:22:44 to 2025-04-23 09:02:36
Thermal runaway test start time	2025-04-23 13:32:12
Module voltage (OCV) before test:	55.39 V
Methods used to initiate thermal runaway	Heating the cell with two externally applied flexible film heaters with 5 K/min heating rate until thermal runaway occurs.
Average heating rate:	T12: 5 K/min, T13: 5 K/min
Surface temperature at which gases were first vented:	T5: 148.1 °C, T12: 276.8°C, T13: 278.5 °C (Thermocouple location see Attachment 1)
Time when gases were first vented:	Cell 4: 2025-04-23 14:36:50
Surface temperature when thermal runaway:	T5: 158.8 °C, T12: 270.9°C, T13: 290.2 °C
Time when thermal runaway:	Cell 4: 2025-04-23 14:38:45
Module voltage (OCV) after test:	0 V
Location of cell(s) for initiating thermal runaway	Cell 4 (see Attachment 1)
Thermal runaway of other cells within module:	Thermal runaway was observed on all 8 cells in the same row as the initiating cell of the module.
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:	46.1 kg
Module weight after test:	43.1 kg
Module weight loss:	3.0 kg

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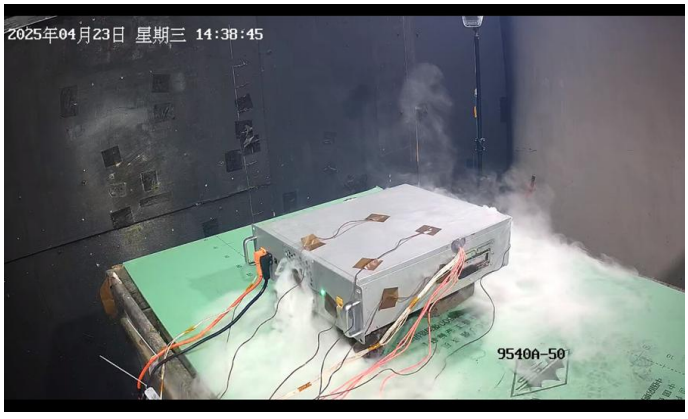
MODULE LEVEL

Timeline of thermal runaway test		
Time (hh:mm:ss)	Event	Description
2025-04-23 13:32:12	Start testing.	
2025-04-23 14:36:50	The initiating cell 4 first vented.	
2025-04-23 14:38:45	The battery module generates a large amount of gas and the temperature of initiating cell 4 started to rise sharply, thermal runaway occurred.	

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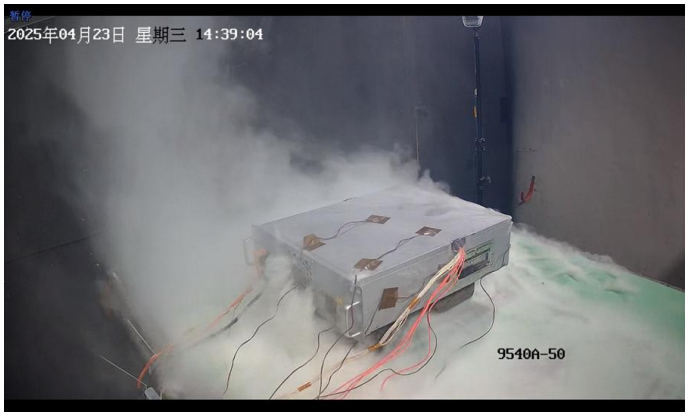
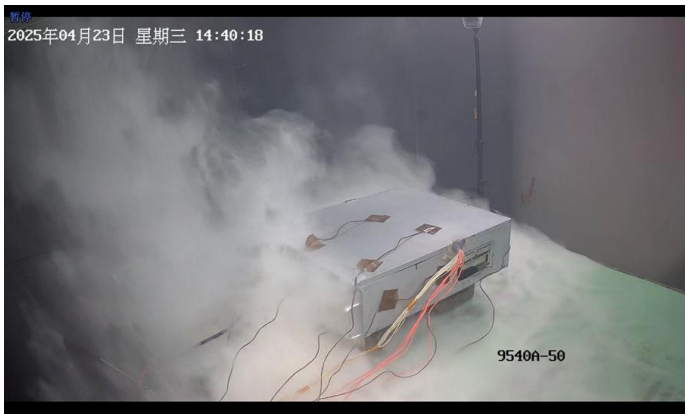
MODULE LEVEL		
2025-04-23 14:39:04	The cell 5 vented.	
2025-04-23 14:39:25	The cell 3 vented.	
2025-04-23 14:40:18	The cell 5 went into thermal runaway based on the temperature measurement data.	

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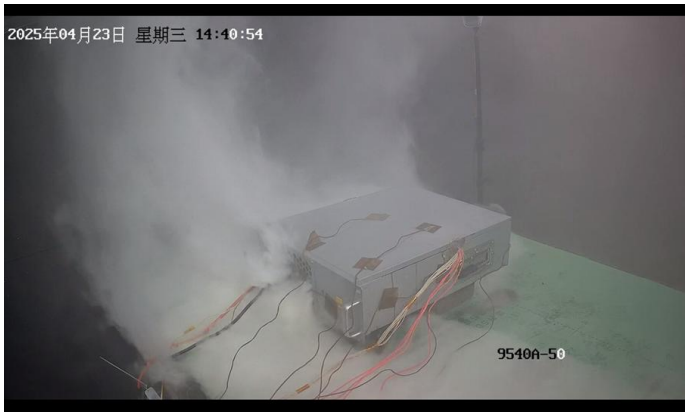
MODULE LEVEL		
2025-04-23 14:40:54	The cell 3 went into thermal runaway based on the temperature measurement data.	
2025-04-23 14:42:29	The cell 6 vented.	
2025-04-43 14:43:01	The cell 2 vented.	

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MODULE LEVEL		
2025-04-23 14:43:38	The cell 6 went into thermal runaway based on the temperature measurement data.	
2025-04-23 14:43:50	The cell 2 went into thermal runaway based on the temperature measurement data.	
2025-04-23 14:47:23	The cell 7 vented.	

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MODULE LEVEL		
2025-04-23 14:47:35	The cell 7 went into thermal runaway based on the temperature measurement data.	
2025-04-23 14:48:55	The cell 8 vented.	
2025-04-23 14:49:11	The cell 1 vented.	

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MODULE LEVEL		
2025-04-23 14:50:50	The cell 8 went into thermal runaway based on the temperature measurement data.	
2025-04-23 14:51:07	The cell 1 went into thermal runaway based on the temperature measurement data.	
2025-04-23 15:55:00	Based on observations, no more gas or smoke was released.	
Remark: Refer to Attachment 3 for details of sample before test and test setup with thermocouple location.		

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MODULE LEVEL

Table 2: Vent gas composition			
Composition	Chemical formula	Measurement peak (L/min)	Analysis Method
Carbon monoxide	CO	4.50	NDIR
Carbon dioxide	CO2	66.60	NDIR
Methane	CH4	2.74	FTIR
Acetylene	C2H2	0.13	FTIR
Ethene	C2H4	1.32	FTIR
Ethane	C2H6	0.45	FTIR
Propane	C3H8	0.52	FTIR
Butane	C4H10	/	FTIR
Pentane	C5H12	/	FTIR
Benzene	C6H6	/	FTIR
Hexane	C6H14	/	FTIR
Hydrofluoric acid	HF	1.07	FTIR
Hydrogen chloride	HCl	0.01	FTIR
Hydrogen	H2	16.20	Hydrogen sensor
Total Hydrocarbons	(Methane Equivalent)	53.60	FID
Flow rate in exhaust duct (m^3/s)		1.5	

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MODULE LEVEL

Attachment 1: Exploded-view drawing of module & Identification/location of cells within the module

Exploded-view drawing of module HV48100 SE BMU as below:

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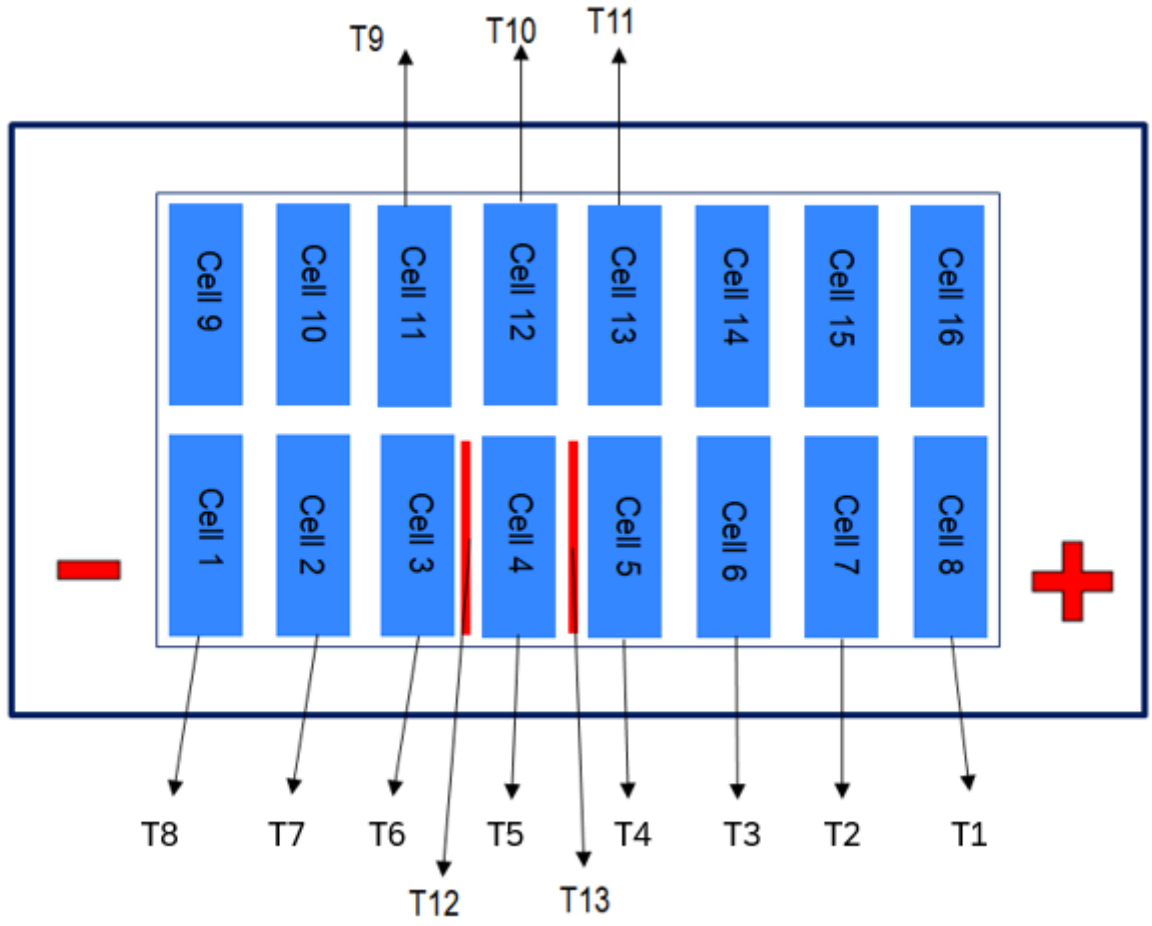
MODULE LEVEL

Identification/location of cells within the module as below (Cell 4 as initiating cell):



Schematic Illustration of film heaters and thermocouple locations in DUT.

Cell 4 is the initiating cell. T1 to T13 means thermocouples T1 to T13.

Thermocouples T12 and T13 are centred under the film heaters

View from top.

For detailed thermocouple locations, refer to Table 3 below:

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MODULE LEVEL

Table 3: Thermocouple location	
Thermocouple No.	Thermocouple location
T01	Middle of the large surface of Cell 8
T02	Middle of the large surface of Cell 7
T03	Middle of the large surface of Cell 6
T04	Middle of the large surface of Cell 5
T05	Middle of the large surface of Cell 4
T06	Middle of the large surface of Cell 3
T07	Middle of the large surface of Cell 2
T08	Middle of the large surface of Cell 1
T09	Middle of the large surface of Cell 11
T10	Middle of the large surface of Cell 12
T11	Middle of the large surface of Cell 13
T12	Under Film heater 1, between Cell 3 and Cell 4
T13	Under Film heater 2, between Cell 4 and Cell 5
T14	Front surface
T15	Rear surface
T16	Left-side panel
T17	Right-side panel
T18	Top cover
T19	Bottom base
T20	Above the initiating cell on the battery module cover
T21	Ambient temperature

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MODULE LEVEL

Attachment 2: Pre-conditioning profile

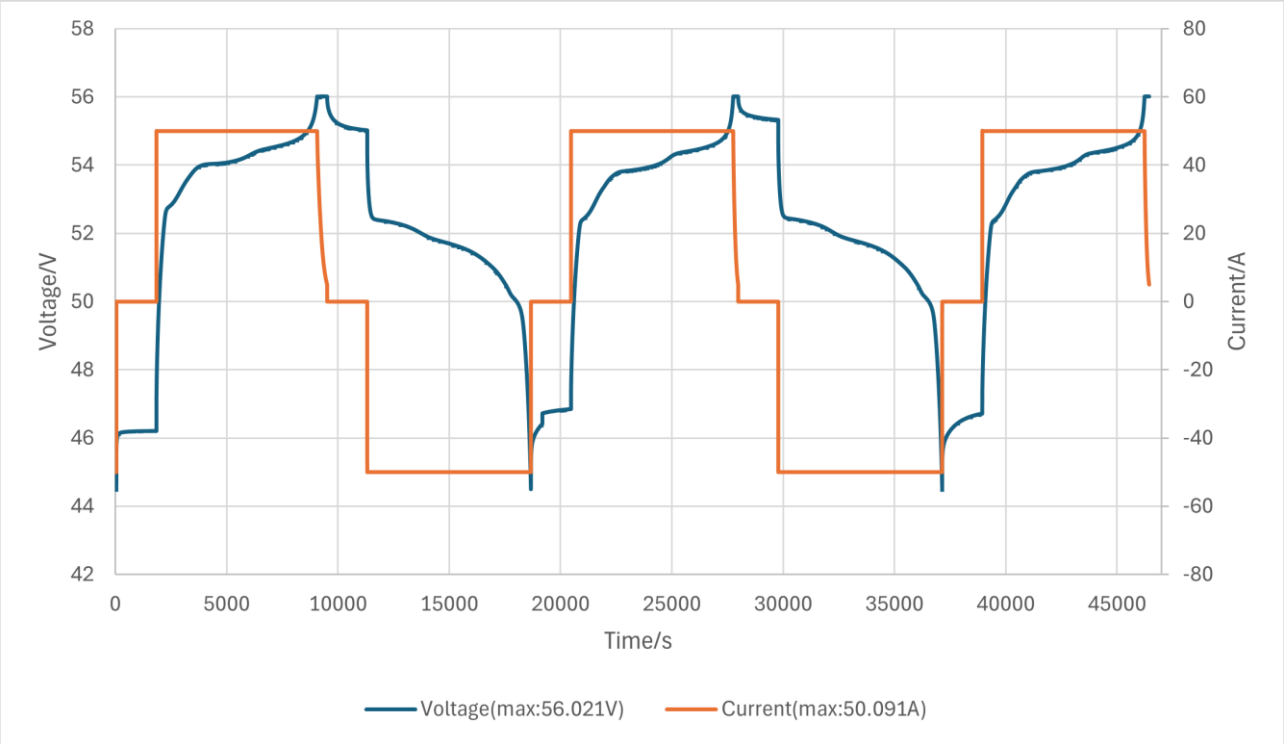
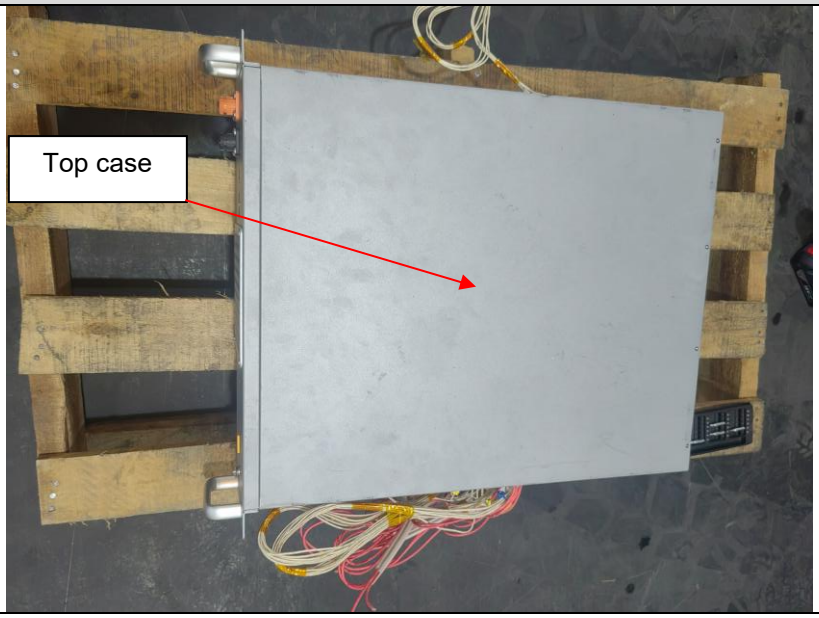


Figure 1 of Attachment 2: Charge and discharge cycles chart for module.

Attachment 3: Photo for sample before test and test setup with thermocouple location

Details of:	Figure 1 of Attachment 3: Overview of sample & thermocouple location_before test
	

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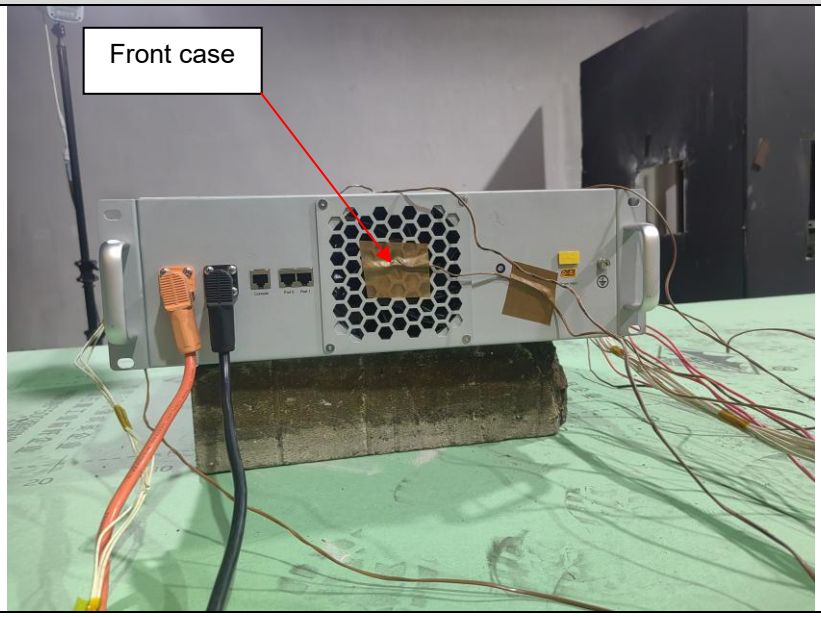
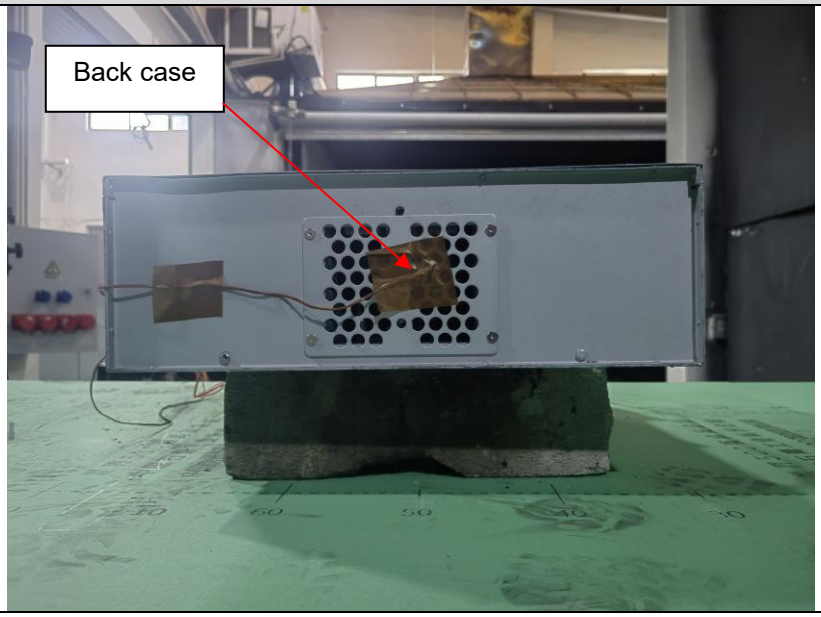
MODULE LEVEL

Details of:	Figure 2 of Attachment 3: Overview of sample & thermocouple location_before test
	

Details of:	Figure 3 of Attachment 3: Overview of sample & thermocouple location_before test
	

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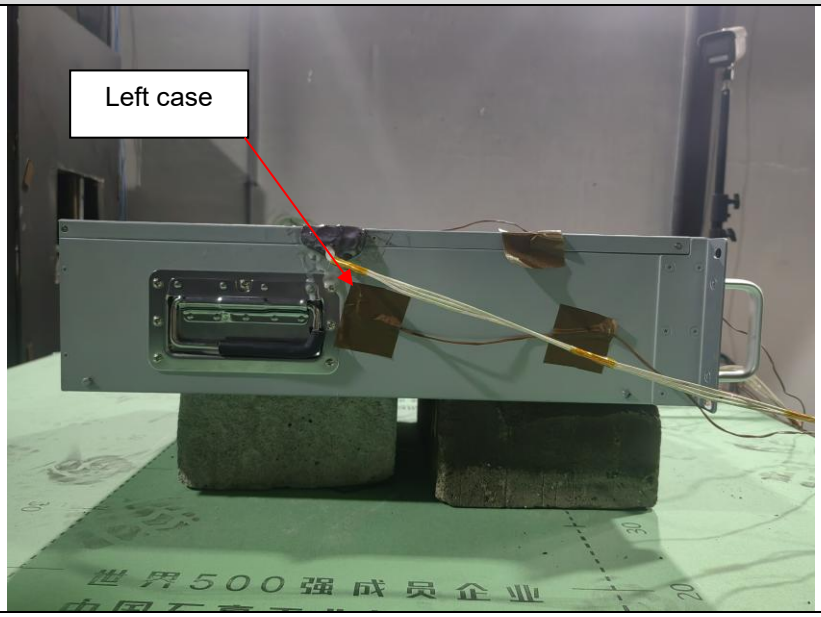
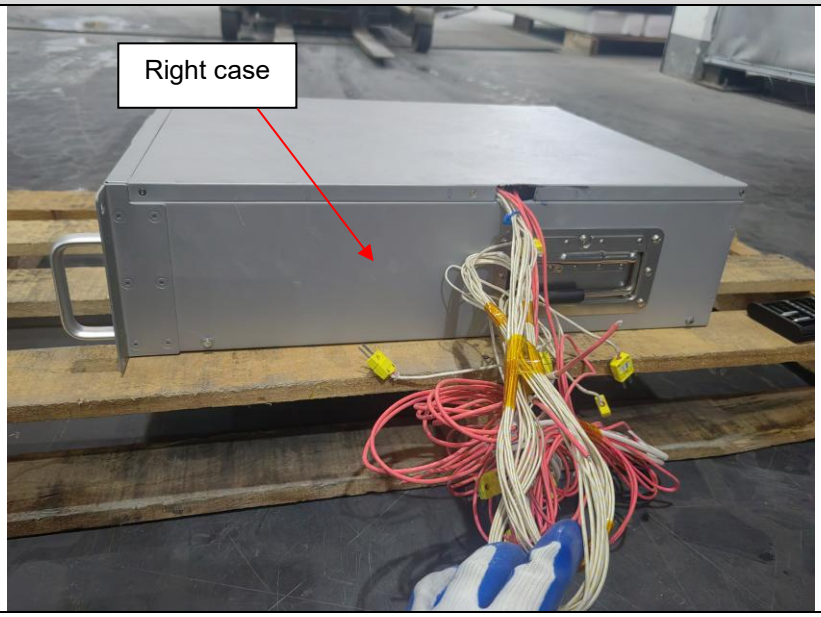
MODULE LEVEL

Details of:	Figure 4 of Attachment 3: Overview of sample & thermocouple location_before test



Details of:	Figure 5 of Attachment 3: Overview of sample & thermocouple location_before test



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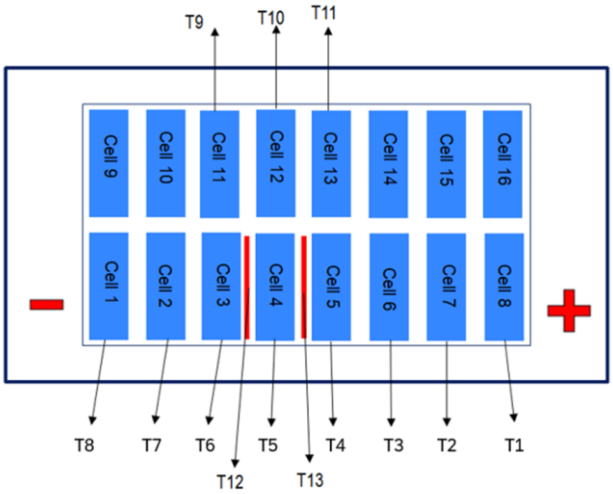
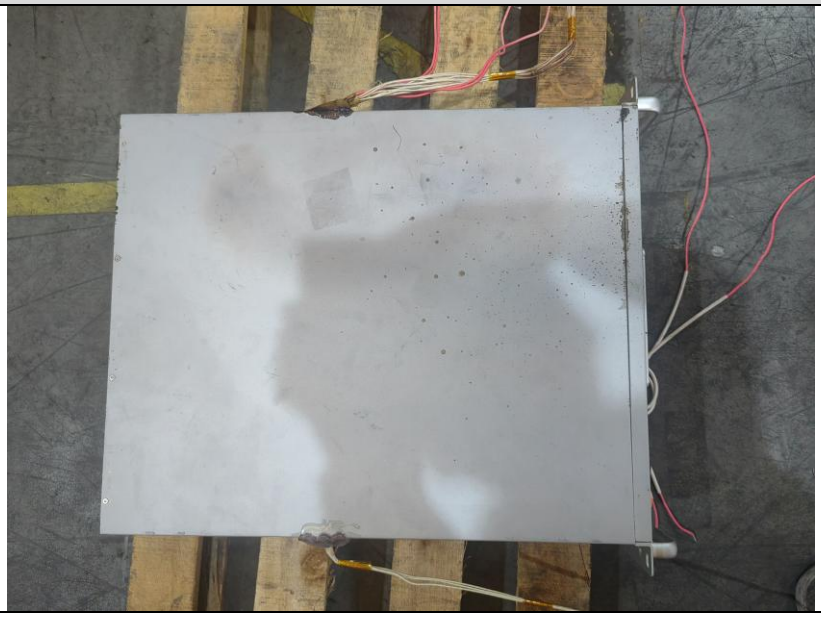
MODULE LEVEL

Details of:	Figure 6 of Attachment 3: Overview of sample & thermocouple location_before test
	 Schematic Illustration of film heaters and thermocouple locations in DUT. Cell 4 is the initiating cell. T1 to T13 means thermocouples T1 to T13. Thermocouples T12 and T13 are centered under the film heaters View from top.

Attachment 4: Photos for sample after test

Details of:	Figure 1 of Attachment 4: Top view of module_after test
	

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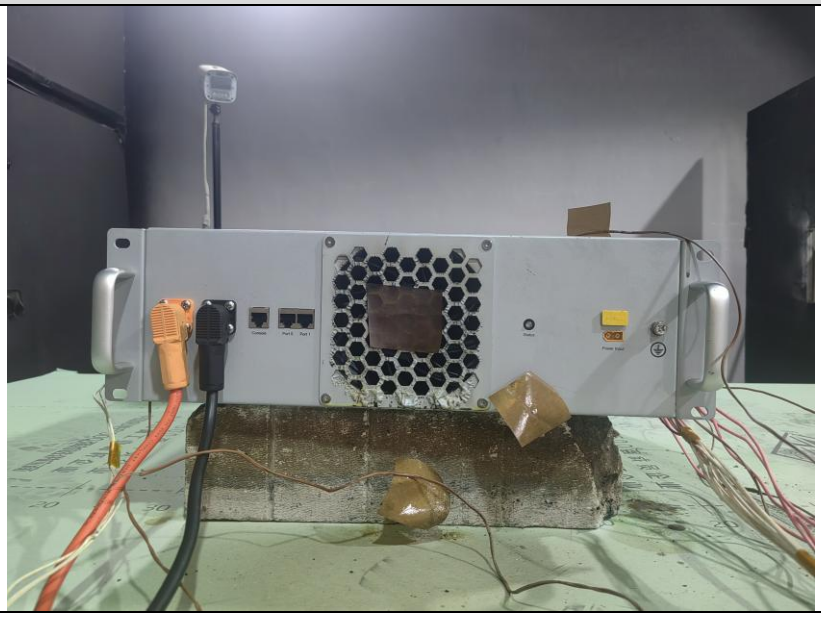
MODULE LEVEL

Details of:	Figure 2 of Attachment 4: Front view of module_after test
	

Details of:	Figure 3 of Attachment 4: Back view of module_after test
	

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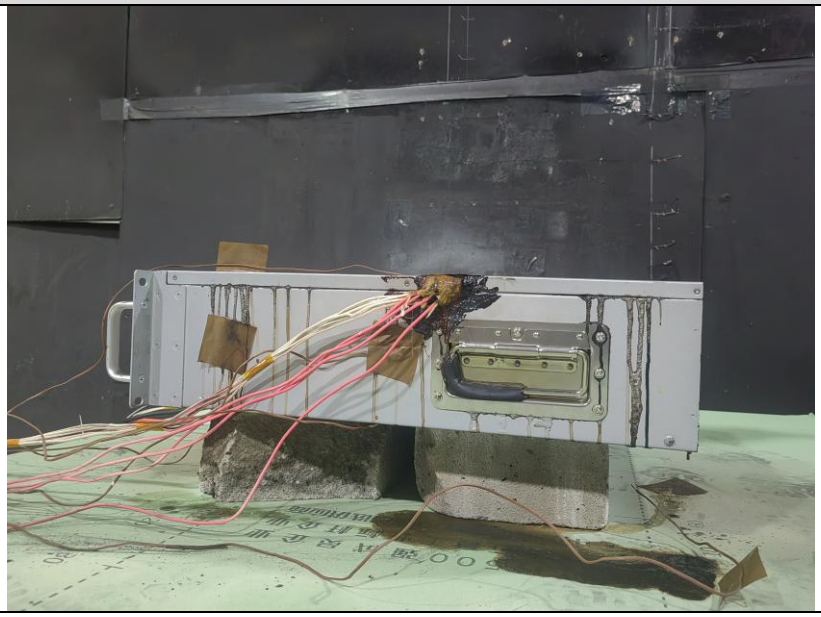
MODULE LEVEL

Details of:	Figure 4 of Attachment 4: Left side view of module_after test
	

Details of:	Figure 5 of Attachment 4: Right side view of module_after test
	

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MODULE LEVEL

Details of:	Figure 6 of Attachment 4: Top view of module_after test, without top cover.
	Internal view of DUT.

Details of:	Figure 7 of Attachment 4: View of module top cover (inner side)_after test
	 Internal view of DUT.

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MODULE LEVEL

Attachment 5: Monitored voltage and temperature chart

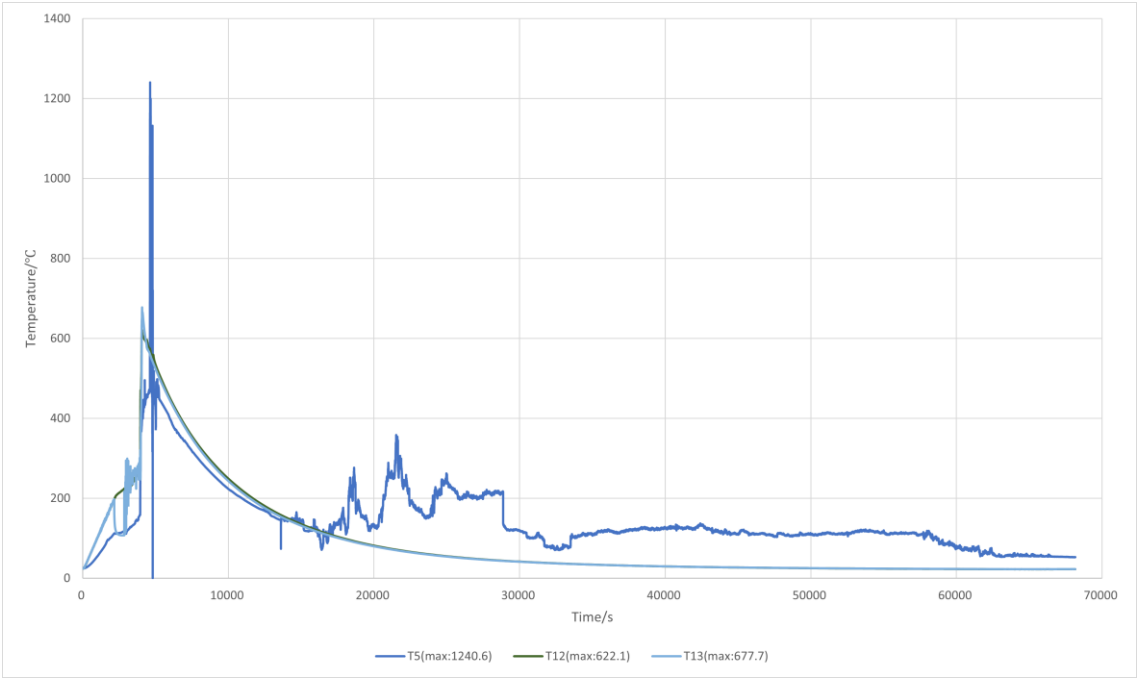

Figure 1 of Attachment 5: Temperatures of initiating cell in module
Remark: Measurement errors observed on T5, probably caused due to electrolyte leakage.

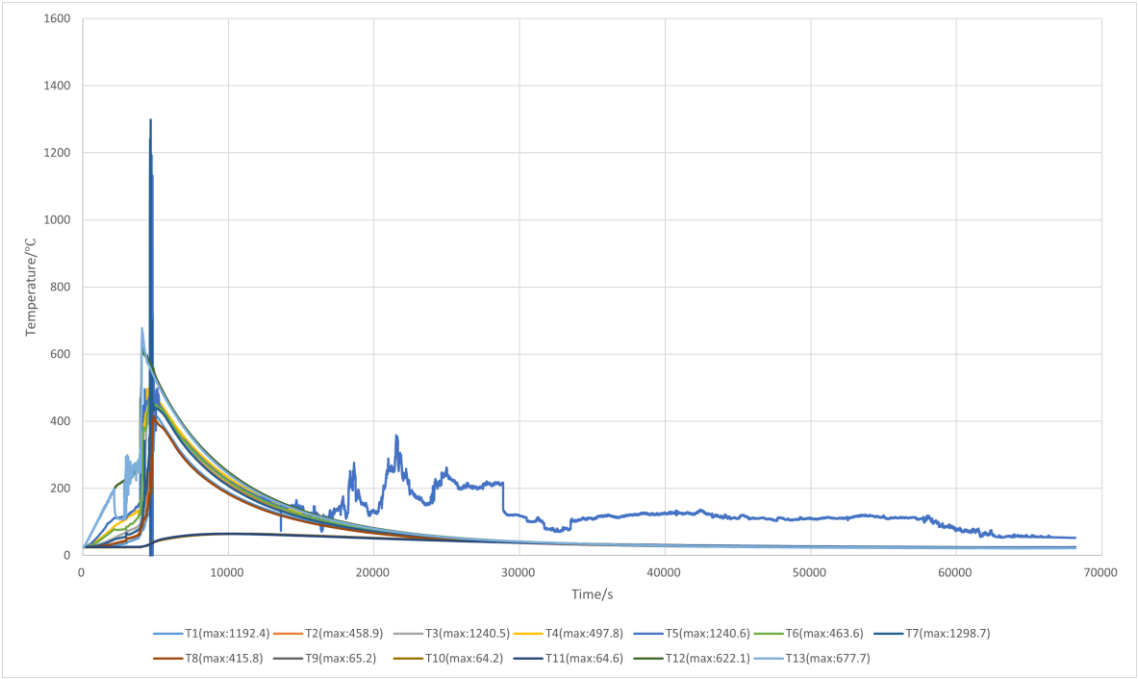

Figure 2 of Attachment 5: Temperatures of other cells in module.
Remark: Measurement errors observed on T5, probably caused due to electrolyte leakage.

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MODULE LEVEL

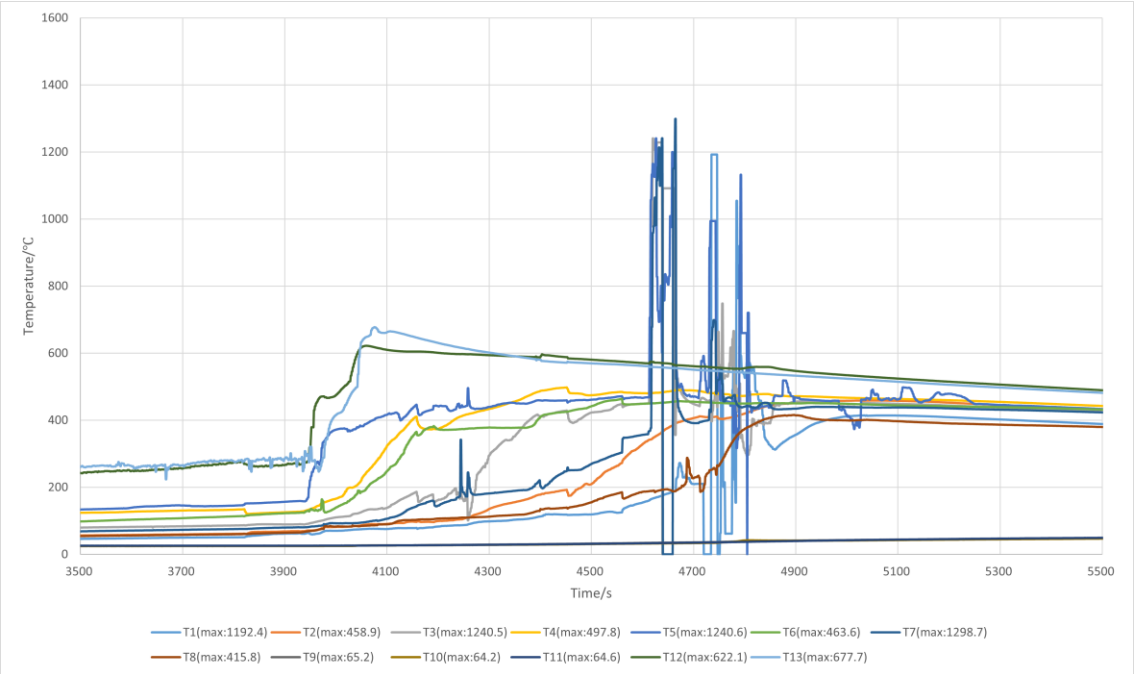

Figure 3 of Attachment 5: Zoomed view of temperatures, including initiating cell and other cells.

Remark: Between 4600s and 5300s after the test started, multiple cells had triggered thermal runaway. During this period, there were measurement errors in the three temperature sensors T3, T5, and T7, which may be caused by electrolyte leakage.

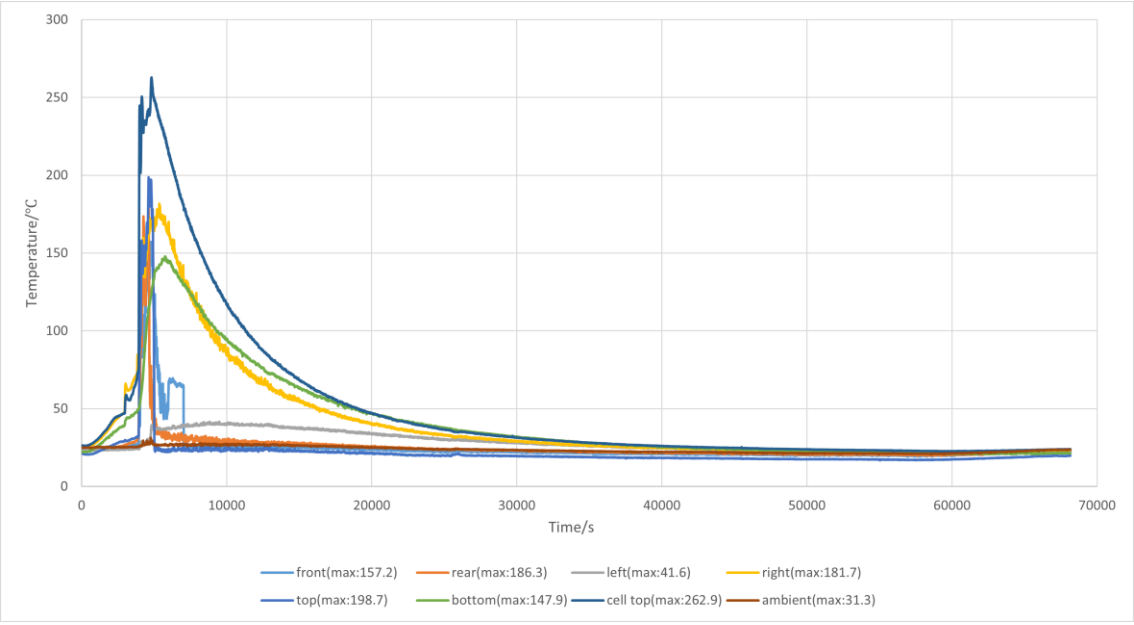

Figure 4 of Attachment 5: Temperatures of module case and ambient.

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MODULE LEVEL

Attachment 6: Flammable gas generation and composition data chart

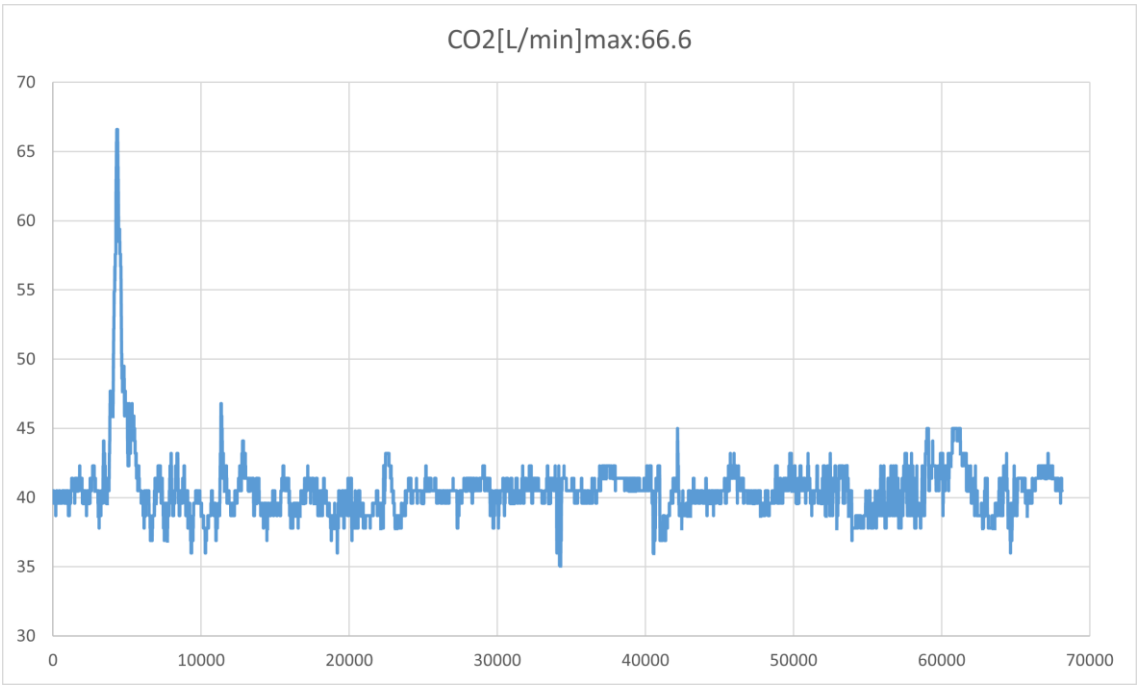

Figure 1 of Attachment 6: Gas generation and composition data chart (Measured by NDIR).
Remark: Flow rate in exhaust duct was 1.5 m^3/s.

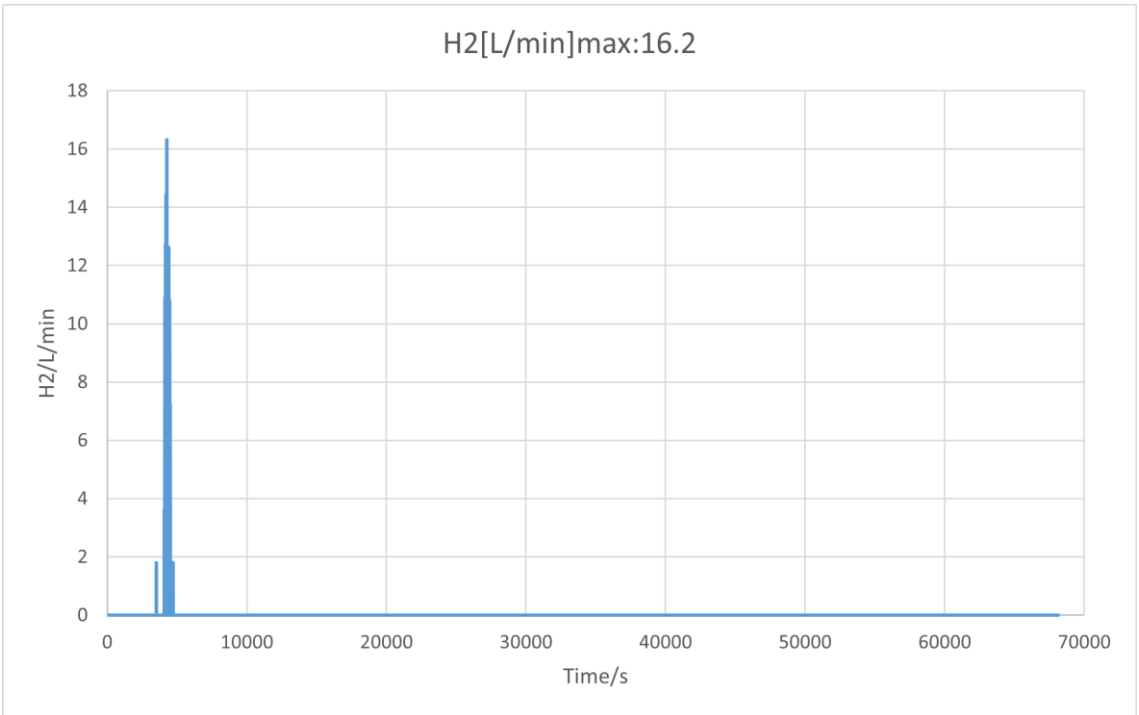

Figure 2 of Attachment 6: Gas generation and composition data chart (Measured by Hydrogen sensor).
Remark: Flow rate in exhaust duct was 1.5 m^3/s.

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MODULE LEVEL

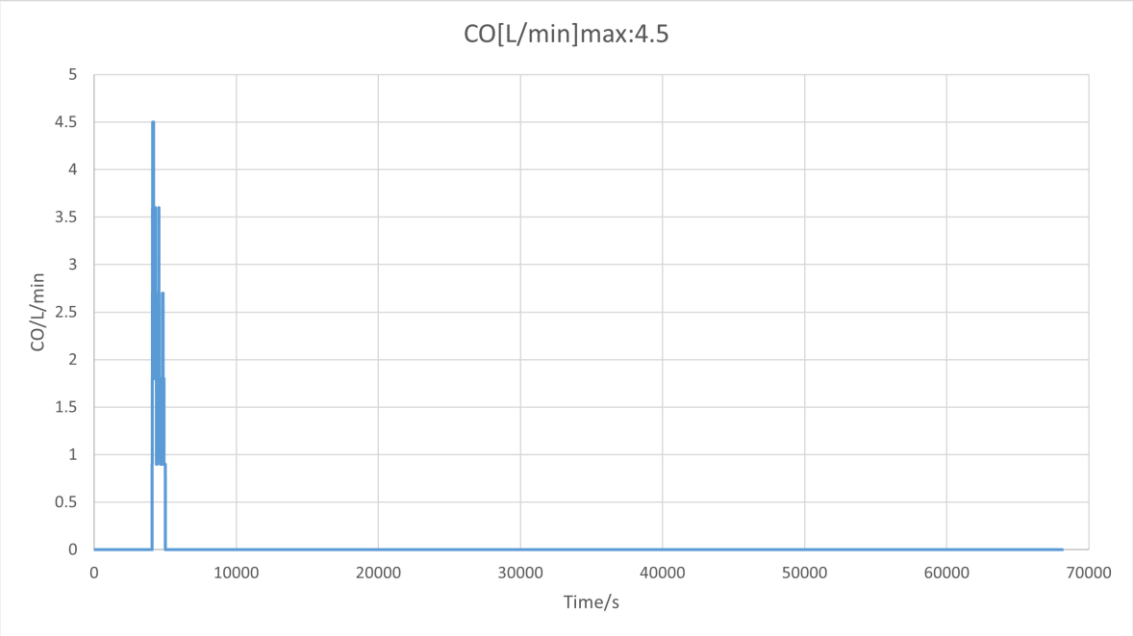

Figure 3 of Attachment 6: Gas generation and composition data chart (Measured by NDIR).
Remark: Flow rate in exhaust duct was 1.5 m^3/s.

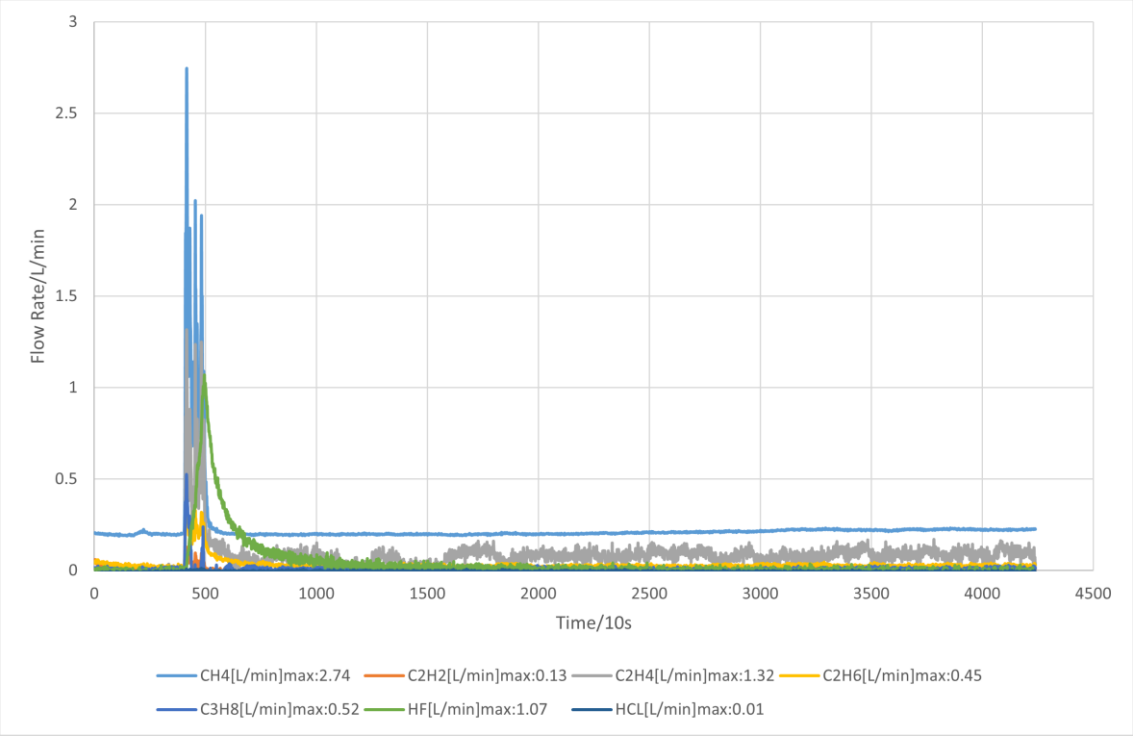

Figure 4 of Attachment 6: Gas generation and composition data chart (Measured by FTIR).
Remark: Flow rate in exhaust duct was 1.5 m^3/s.

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MODULE LEVEL

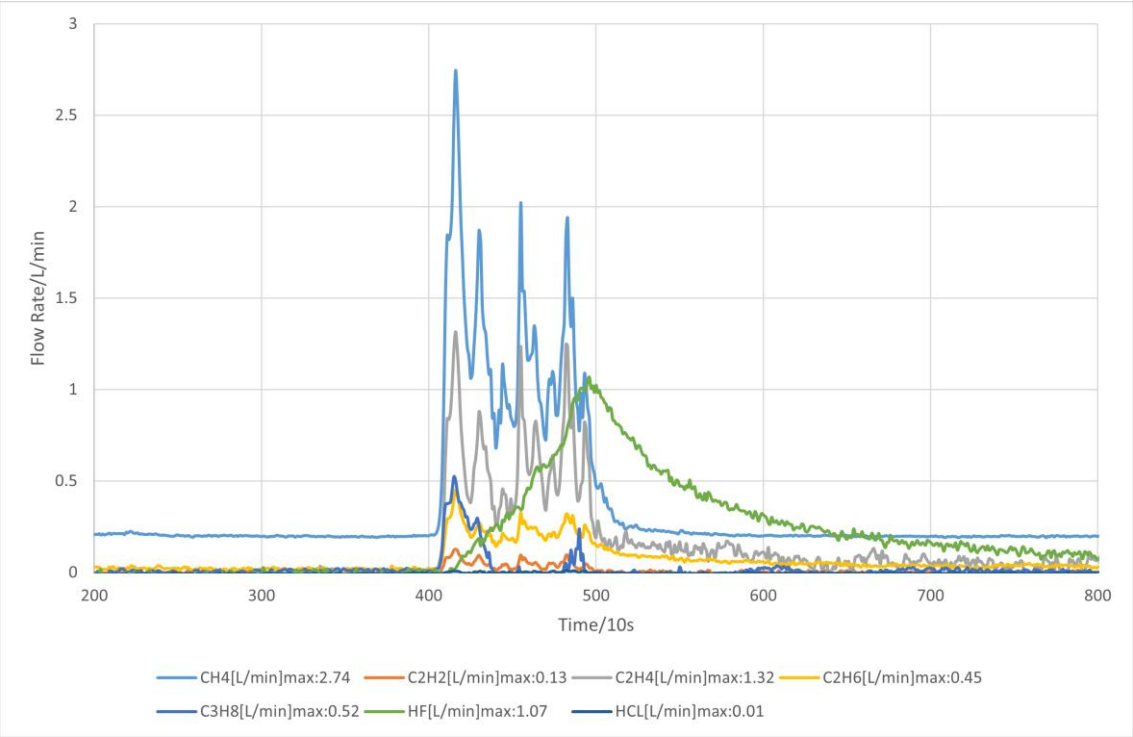

Figure 5 of Attachment 6: Zoomed view of gas generation and composition data chart (Measured by FTIR).
Remark: Flow rate in exhaust duct was 1.5 m^3/s.

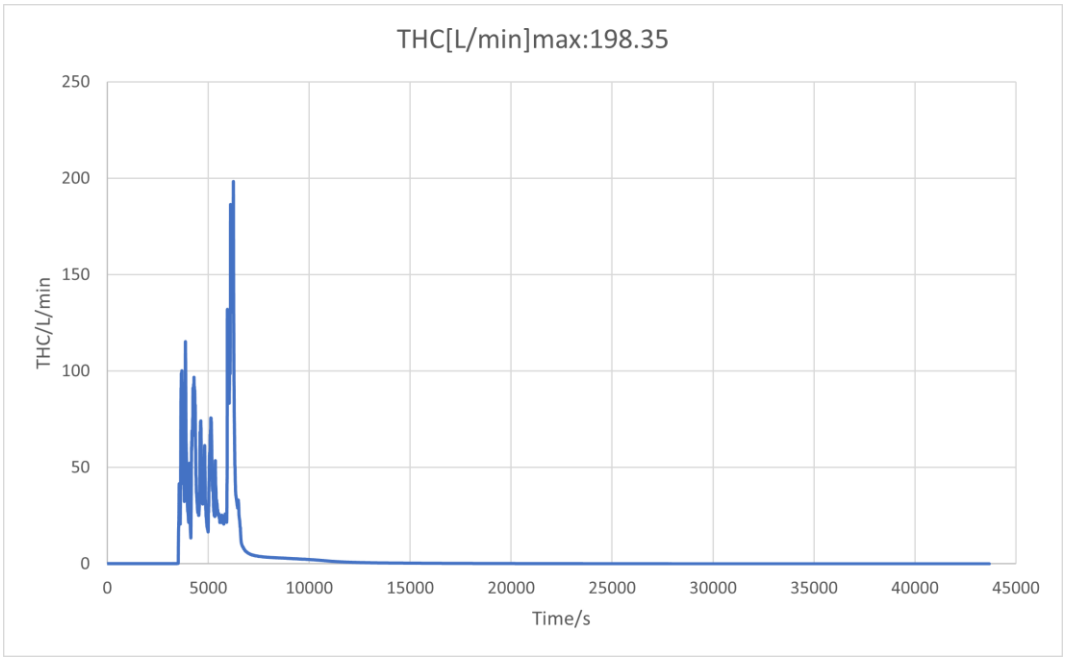

Figure 6 of Attachment 6: THC (Total Hydrocarbons) chart (Measured by FID).
Remark: Flow rate in exhaust duct was 1.5 m^3/s.

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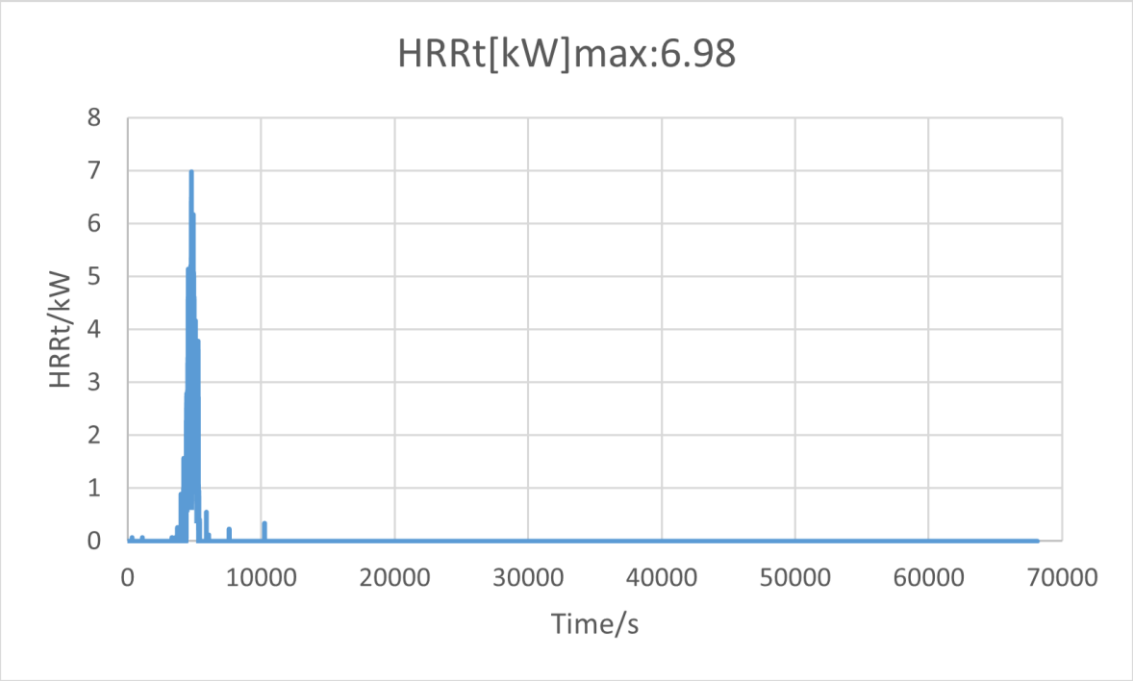
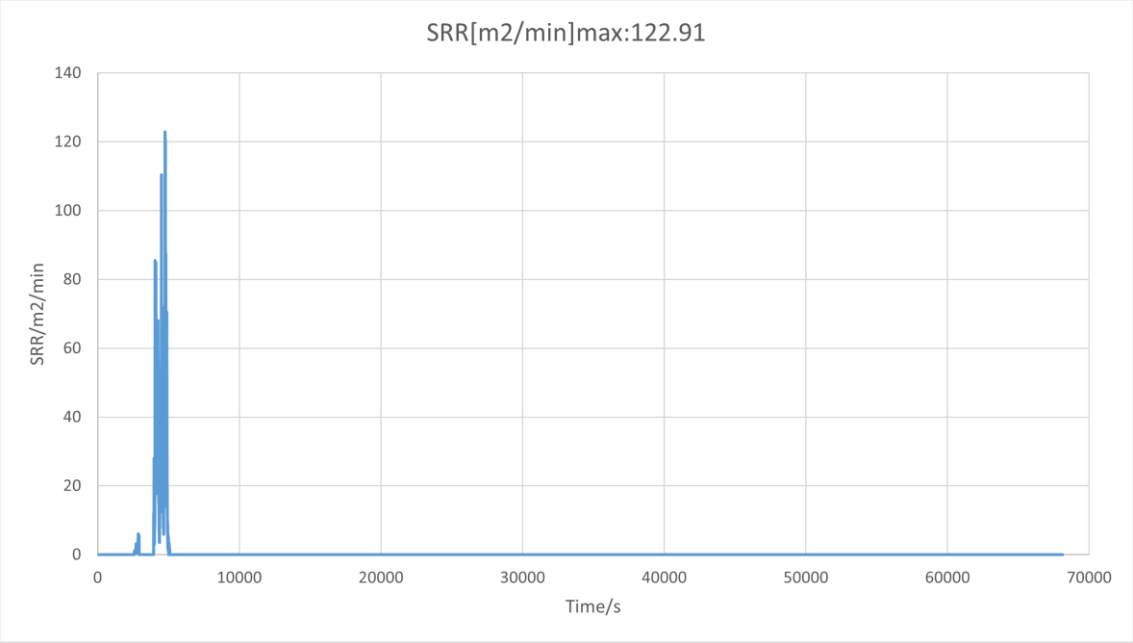
MODULE LEVEL

Attachment 7: Heat release rate versus time data chart



Remark: No flames observed during test.

Attachment 8: Peak smoke release rate and total smoke release data chart



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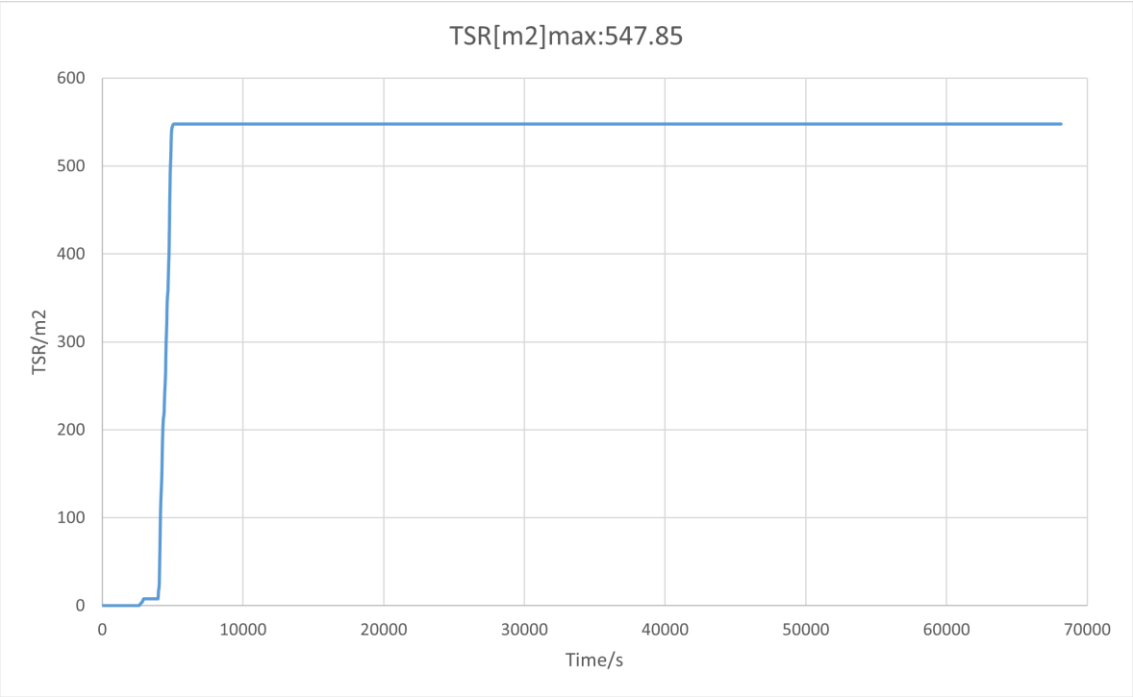
MODULE LEVEL



Attachment 9: Summary of Heat release rate & Peak smoke release rate and total smoke release data

Peak heat release rate	6.98 kW
Total smoke released	547.85 m^2
Peak smoke release rate	122.91 m^2/min

Remark: No flames observed during test

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

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