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TEST REPORT
ANSI/CAN/UL 9540A:2019
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Report Reference No. ..... :	230300277SHA-001
Tested by (name + signature) ..... :	Chuanhui Xie
Approved by (name + signature) .... :	Robin Xu
Total number of pages ..... :	33
Date of issue ..... :	2023-05-18
Testing Laboratory ..... :	Intertek Testing Services Shanghai
Address ..... :	Building No.86, 1198 Qinzhou Road (North), Shanghai 200233, China
Testing location/ procedure ..... :	Witness testing
Testing location/ address ..... :	No. 158, Changbangcun Road, Fengxian District, Shanghai
Applicant's name ..... :	Hocan Group Co., Ltd
Address ..... :	Room 905 Working Berg, Commercial Bldg, 41-47 MARBLE RD Hong Kong SAR
Test specification:	
Standard ..... :	ANSI/CAN/UL 9540A:2019 (Fourth Edition) + UL CRD's
Test procedure ..... :	Module level test (clause 8.1-8.4)
Non-standard test method..... :	N/A
Test Report Form No. ..... :	ANSI/CAN/UL 9540A_Module
Test Report Form(s) Originator ..... :	Intertek
Master TRF ..... :	Dated 2022-01

Test item description ..... :	Lithium-ion battery
Trade Mark ..... :	SOK (SK)
Manufacturer ..... :	Zhuhai SEPICN Electronics And Technology Co., Ltd
Model/Type reference ..... :	SK48V100
Ratings ..... :	51.2 V, 100 Ah

General disclaimer:

List of attachments:

Attachment 1 – Photos

Attachment 2 – Module conditioning (charge/discharge) profiles

Attachment 3 – Module thermal runaway record

Attachment 4 – Temperature and voltage profile during thermal runaway

Attachment 5 – Chemical heat release rate measurement

Attachment 6 – Gas generation measurement

Attachment 7 – Smoke release rate measurement

Attachment 8 – Equipment list

Test video 230300277-1.mp4 is provided in addition to this test report.

Summary of testing:

Thermal runaway Propagation .....:	One cell thermal runaway due extermal heating, seven cell thermal runaway due to thermal runaway propagation.
Peak chemical heat release rate HRR (kW).....:	7.97 kW
Peak smoke release rate SRR (m^2/s).....:	1.15 m^2/s
Total smoke release TSR (m^2) .....:	597.88 m^2
Total Hydrocarbons (equivalent to C_3H_8, measured by FID)...:	39.3 L
Module weight loss .....:	6.0 kg

Conclusion:

Thermal runaway is contained by module design, but cell vent gas is flammable as determined by the cell level test. According to the standard, a unit level testing in accordance with UL 9540A need to be conducted on a unit employing this module.

Possible test case verdicts:

- test case does not apply to the test object.....:	N/A
- test object was not evaluated for the requirement.....:	N/E
- test object does meet the requirement.....:	Pass (P)
- test object does not meet the requirement .....:	Fail (F)

Testing:

Date of receipt of test items .....:	2023-03-03
Date(s) of test performaned.....:	2023-04-26 to 2023-04-27

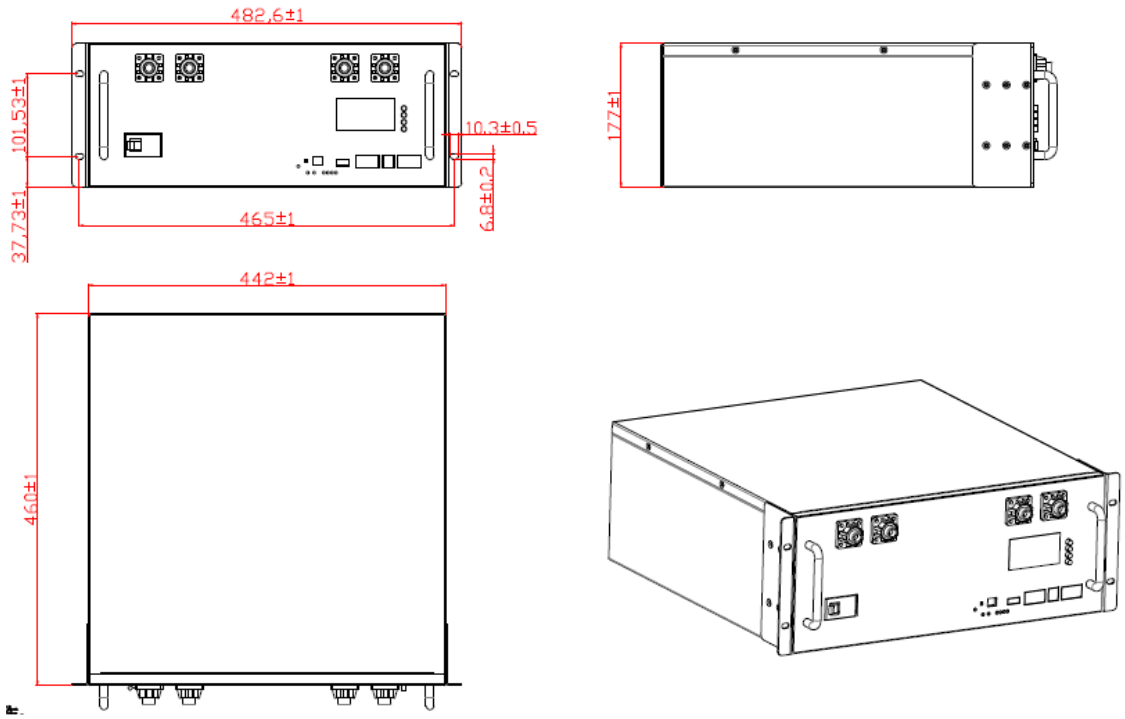
General remarks:

"(see Attachment #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.
The tests results presented in this report relate only to the object tested.
This report shall not be reproduced except in full without the written approval of the testing laboratory.
List of test equipment must be kept on file and available for review.
Additional test data and/or information is provided in the attachments to this report.
Throughout this report a ☐ comma / ☒ **point** is used as the decimal separator.
Determination of the test results includes consideration of measurement uncertainty from the test equipment and methods.

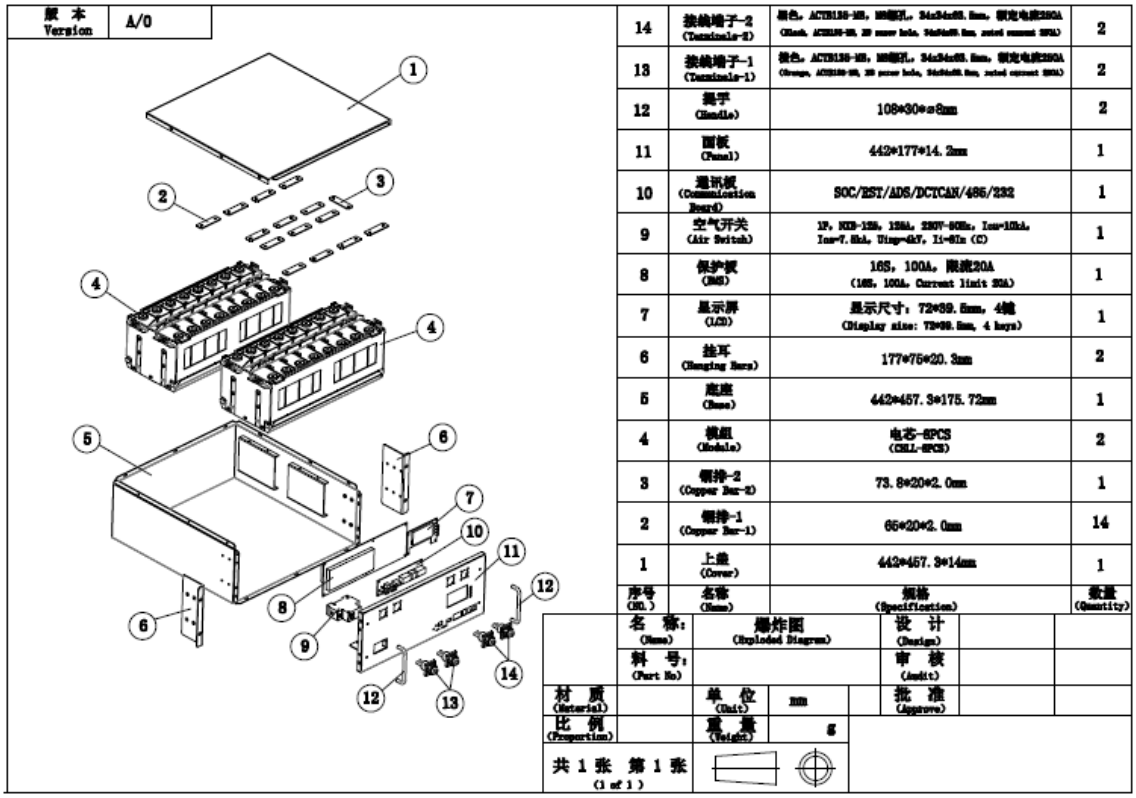
Product information:		
Cell inforamtion		
Manufacturer	:	JIANGXI GANFENG BATTERYTECHNOLOGY CO.,LTD
Model name	:	48173125-100Ah
Chemistry	:	$LiFePO_4$
Physical configuration	:	Prismatic
Dimension (W*L*H)	:	(173.8±0.5) mm * (71.45±0.5) mm * (207.15±1.0) mm
Weight	:	≤2.30 kg
Nominal voltage	:	3.2 V
Rated capacity	:	100 Ah
If the cell compliance with UL 1973	:	UL MH63648
Standard charge method		
Charge current	:	50 A
End of charge voltage	:	3.65 V
Cut off current	:	5 A
Standard discharge method		
Discharge current	:	50 A
End of discharge voltage	:	2.5 V (0°C<T≤60°C) 2.0 V (-20°C≤T≤60°C)
Test result from cell level 9540A test report		
Cell level test report	:	Report No. CN228KRW 001 (TUV Rheinland)
Average cell venting temperature	:	202.0 °C
Average cell thermal runaway onset temperature	:	272.4 °C
Gas composition	:	CO: 5.3%, CO_2:26.8%, H_2:52.5%, Hycarbon:15.4%
LFL at ambient temperature	:	6.3% at 25±2°C and 101±2kPa
LFL cell venting temperature	:	5.1% at 200±2°C and 101±2kPa
Burning velocity	:	80.5 cm/s
P_{max}	:	0.720 MPa

Module information		
Manufacturer	:	Zhuhai SEPICN Electronics And Technology Co., Ltd
Address	:	No. 16, 1st, Jinyuan Rd, Jinding, ZHUHAI CITY Guangdong 519085
Model name	:	SK48V100
Physical configuration		
Enclosure material	:	Metal
Dimension	:	(460±1) mm*(465±1) mm*(177±1) mm
Weight	:	51 kg
Cells in series/parallel:	:	16S1P
Total number of cells:	:	16 cells
Cooling method	:	Nature cooling
Separation between cells	:	PC plastic (Thickness: 1.5mm)
Electrical rating		
Rated capacity	:	100 Ah
Rated energy	:	5120 Wh
Nominal voltage	:	51.2 V
Standard charge method		
Charge current	:	20 A
End of charge voltage	:	57.6 V
Cut off curent	:	2 A
Standard discharge method		
Discharge current	:	20 A
End of discharge voltage	:	42.5 V (Cell end of discharge voltage 2.50V)
If the module compliance with UL 1973	:	Certificate No. 220510031GZU-001

Diagram of module with overall dimension



Contents (main components) of the module



版本 Version	A/0		
14	接线端子-2 (Terminals-2)	颜色，ACTB130-HB，M8螺孔，34x34x68.8mm，额定电流250A (Black, ACTB130-HB, M8 screw hole, 34x34x68.8mm, rated current 250A)	2
13	接线端子-1 (Terminals-1)	颜色，ACTB130-HB，M8螺孔，34x34x68.8mm，额定电流250A (Orange, ACTB130-HB, M8 screw hole, 34x34x68.8mm, rated current 250A)	2
12	提手 (Handle)	108*30*≈8mm	2
11	面板 (Panel)	442*177*14.2mm	1
10	通讯板 (Communication Board)	SOC/EST/ADS/DCTCAN/485/232	1
9	空气开关 (Air Switch)	1P, HXB-125, 125A, 250V-60Hz, Icu=10kA, Ics=7.5kA, Ui=690V, Uimp=6kV, Ii=63A (C)	1
8	保护板 (BMS)	16S，100A，限流20A (16S，100A，Current limit 20A)	1
7	显示屏 (LCD)	显示尺寸：72*39.6mm，4键 (Display size: 72*39.6mm，4 keys)	1
6	挂耳 (Hanging Ears)	177*75*20.3mm	2
5	底座 (Base)	442*457.3*175.72mm	1
4	模组 (Module)	电芯-8PCS (CELL-8PCS)	2
3	铜排-2 (Copper Bar-2)	73.8*20*2.0mm	1
2	铜排-1 (Copper Bar-1)	65*20*2.0mm	14
1	上盖 (Cover)	442*457.3*14mm	1
序号 (NO.)	名称 (Name)	规格 (Specification)	数量 (Quantity)

	名 称: (Name)	爆炸图 (Exploded Diagram)		设 计 (Design)	
	料 号: (Part No)			审 核 (Audit)	
材 质 (Material)		单 位 (Unit)	mm	批 准 (Approve)	
比 例 (Proportion)		重 量 (Weight)	g		
共 1 张 第 1 张 (1 of 1)					

Module structure diagram and cell series and/or parallel configuration

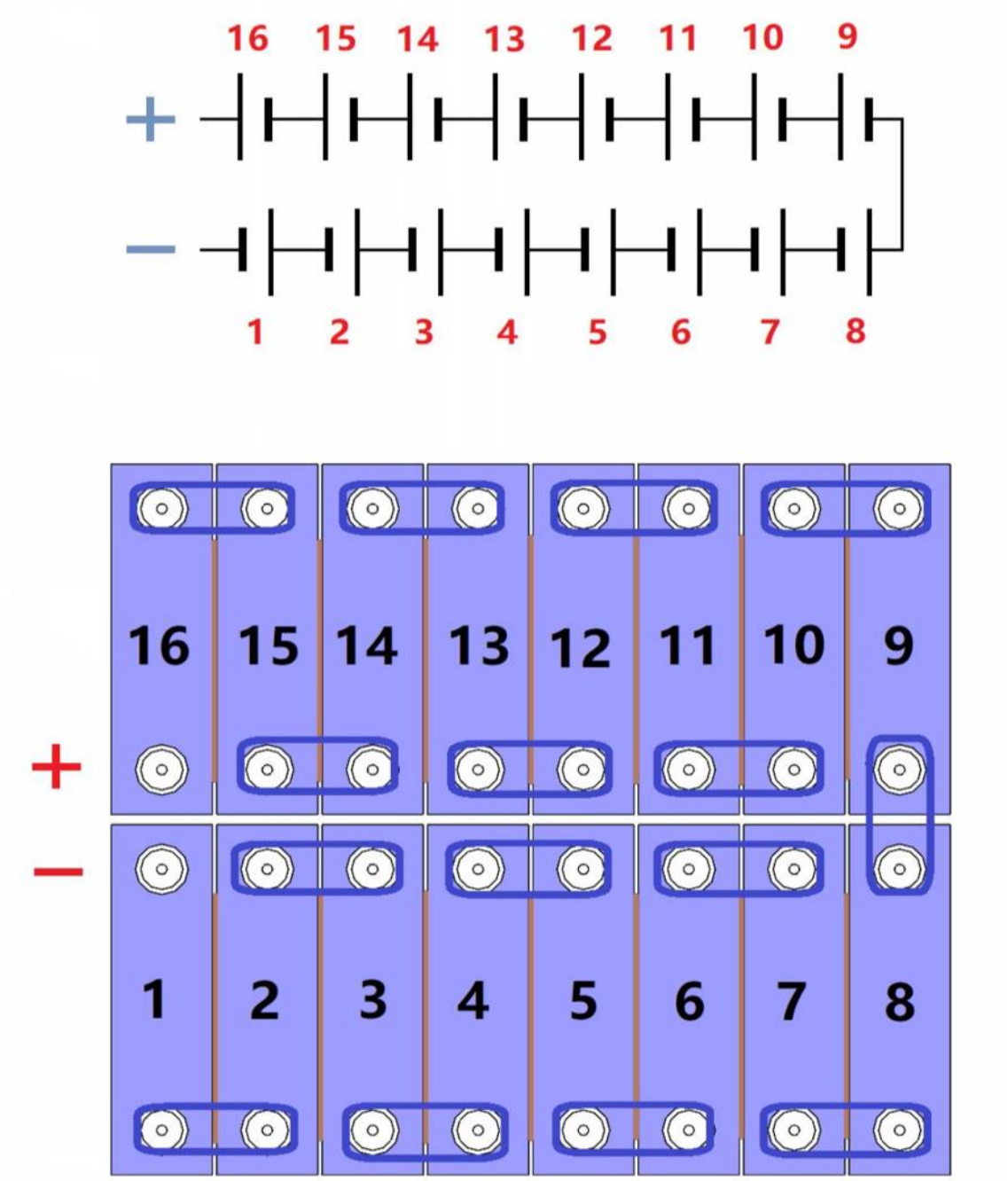
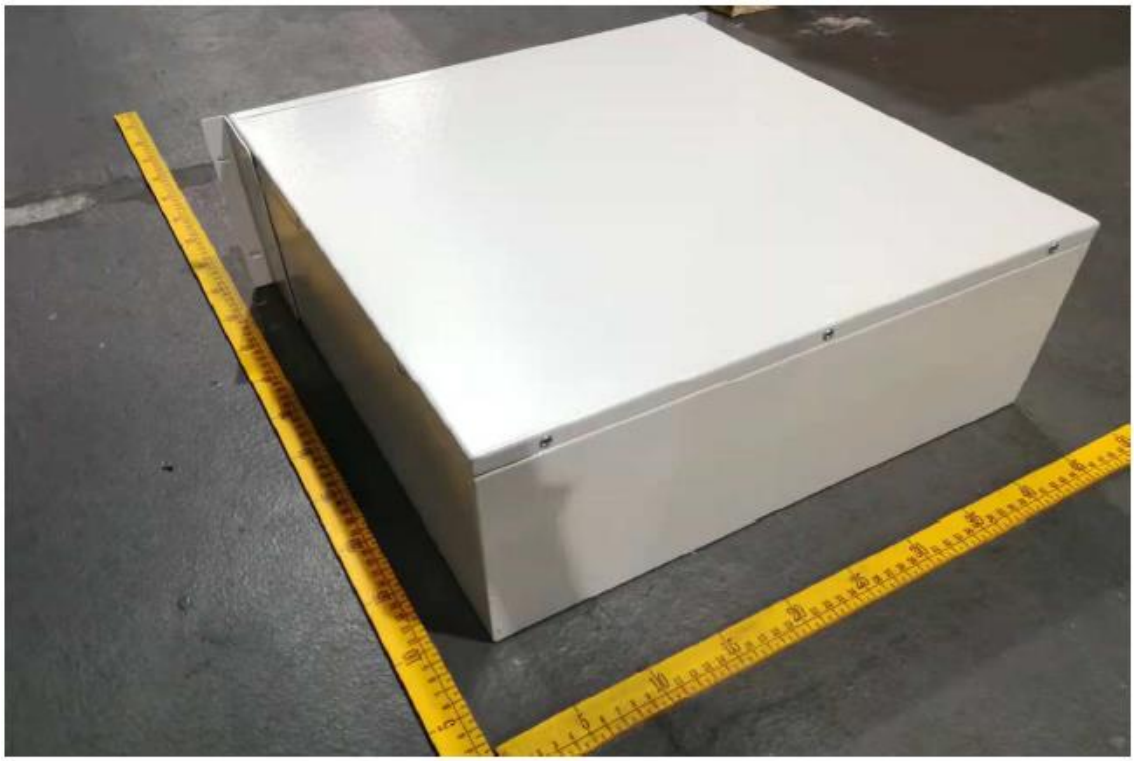


Photo of the module



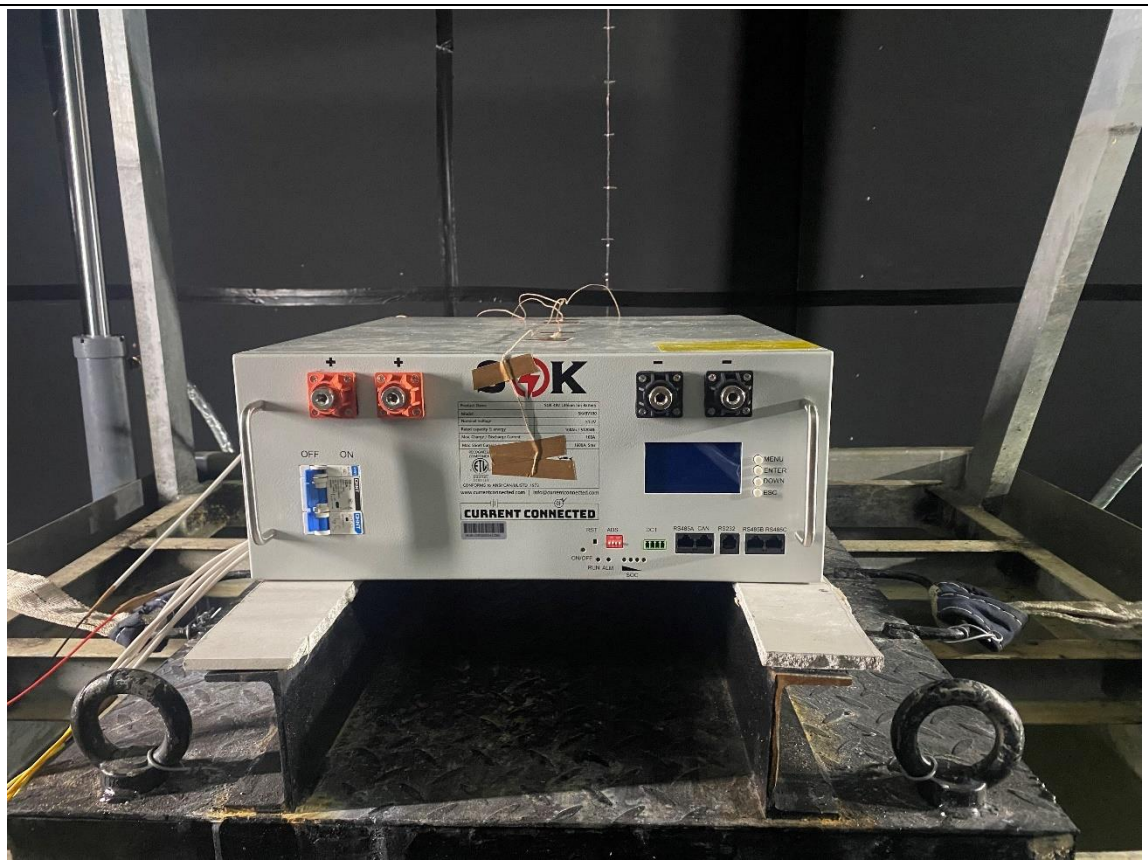
ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
5	**Construtions – General**		
5.1	**Cell**		**--**
5.1.1	The cell info associated with the BESS includes:		Pass
	• cell chemistry (e.g. NMC, LFP);	LFP	Pass
	• the physical format of the cell;	Prismatic	Pass
	• the cell electrical rating in capacity and nominal voltage;	100Ah,3.2V	Pass
	• the overall dimensions of the cell, and weight.	See cell information	Pass
5.1.2	The cells associated with the BESS comply with ANSI/CAN/UL 1973 or not.	UL MH63648	Pass
5.1.3	Further details are included in the cell level test report.		Pass
5.2	**Module**		**--**
5.2.1	The modules info associated with the BESS includes:		Pass
	• the generic enclosure material;	Metal	Pass
	• the general layout of the module contents;		Pass
	• the electrical configuration of the cells in the modules and the modules in the BESS.	16S1P	Pass
5.2.2	The modules associated with the BESS comply with UL 1973 or not.	Report Number: 220510031GZU-001	Pass
5.2.3	Further details are included in the module level test report.	Refer to 8.3	Pass
5.3	**Battery energy storage system unit**		**--**
5.3.1	The BESS unit info includes:		N/A
	• the units comply with UL 9540 or not;		N/A
	• the manufacturer and model number;		N/A
	• electrical ratings;		N/A
	• energy capacity of all BESS.		N/A
5.3.2	For BESS units, which UL 9540 compliance cannot be determined, to include:		N/A
	• the number of modules in the BESS;		N/A
	• electrical configuration of the module;		N/A
	• physical layout of the modules in the BESS;		N/A
	• battery management system (BMS); and		N/A
	• other major components of the BESS;		N/A
	• the BESS enclosure overall dimensions and generic material;		N/A
	• battery system(s) may be tested as representative of the BESS;		N/A
	• battery system complies with UL 1973 or not.		N/A
5.3.3	Any fire detection and suppression systems that are an integral part of the BESS.		N/A

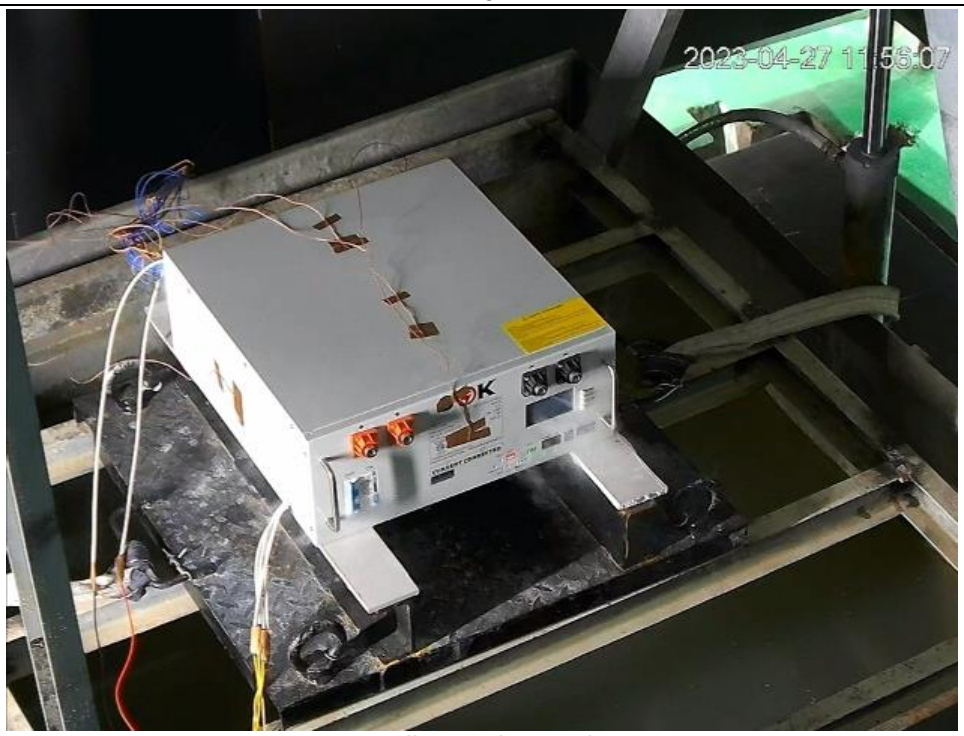
ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
5.3.4	Further details included in the unit level and if applicable, installation level test reports.		N/A
5.4	**Flow Batteries**		**--**
5.4.1	For flow batteries, to include the following info:		N/A
	• the chemistry;		N/A
	• a generic description of the electrolyte (s);		N/A
	• the overall dimensions of the individual stack;		N/A
	• the electrical rating in capacity and nominal voltage of the cell stack.		N/A
	And the Information of the complete flow battery system:		N/A
	• the manufacturer's name and model number of the system;		N/A
	• the electrical rating in volts and rated storage capacity in Ah or Wh;		N/A
	• the number of cells and stacks in the system;		N/A
	• the maximum volume of electrolyte(s) for the system.		N/A
5.4.2	The flow battery system complies with UL 1973 or not.		N/A
5.4.3	Further details included in the flow battery thermal runaway determination level test report.		N/A
6	**Performance – General**		
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices, which may result in various kind of hazards.		Pass
6.2	At the conclusion of testing, samples discharged in accordance with the manufacturer' specifications.		Pass
	All samples disposed of in accordance with local regulations.		Pass
8	**Moudle Level**		
8.1	**Sample**		**--**
8.1.1	Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a min. of 2 cycles, to verify that the module is functional.	See attachment 2	Pass
8.1.2	The module shall be charged to 100% SOC and allowed to rest a maximum of 8 h before the start of the test.		Pass
8.1.3	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.	BMS protections disabled during the testing	Pass
8.2	**Test method**		**--**
8.2.1	Ambient indoor laboratory conditions 25±5°C and 50±25% RH at the initiation of the test.	See attachment 3	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
8.2.2	The test conducted under a smoke collection hood sized appropriately to collect the gasses generated.		Pass
8.2.3	The weight of the module shall be recorded before and after testing is completed.	See attachment 3	Pass
8.2.4	The number of cells within the module that are forced into thermal runaway.	1	Pass
8.2.5	The methodology used for initiating thermal runaway for cells are used to initiate thermal runaway within the module.	See attachment 3	Pass
8.2.6	Occurrence of thermal runaway shall be verified by sustained temperature above the cell surface temperature at the onset of thermal runaway.	See attachment 4	Pass
8.2.7	The module shall be placed on top of a noncombustible horizontal surface.	Module orientation as intended for final installation	Pass
8.2.8	The chemical heat release rate of the module in thermal runaway shall be measured with oxygen consumption calorimetry system.	See attachment 5	Pass
8.2.9	The chemical heat release rate shall be measured for the duration of the test.	See attachment 5	Pass
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.		Pass
8.2.11	Chemical heat release rate is calculate at each of the flows as follows: $HRR_t = \left[E \times \varphi - (E_{CO} - E) \times \frac{1-\varphi}{2} \times \frac{X_{CO}}{X_{O_2}}\right] \times \frac{\dot{m}_e}{1+\varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^{\circ}_{H_2O}) \times X^{\circ}_{O_2}$	See attachment 5	Pass
8.2.12	(Corrected by UL CRD-20200520) The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor		Pass
8.2.13	(Corrected by UL CRD-20200520) The hydrocarbon components of the vent gas composition may additionally be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or an equivalent gas analyzer, 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.	See attachment 6	Pass
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.	Light transmission is integerated into the testing system	Pass
8.2.15	Smoke release rate shall be calculated as follows: $SRR = 2.303\left(\frac{V}{D}\right) Log_{10}\left(\frac{I_o}{I}\right)$	See attachment 7	Pass

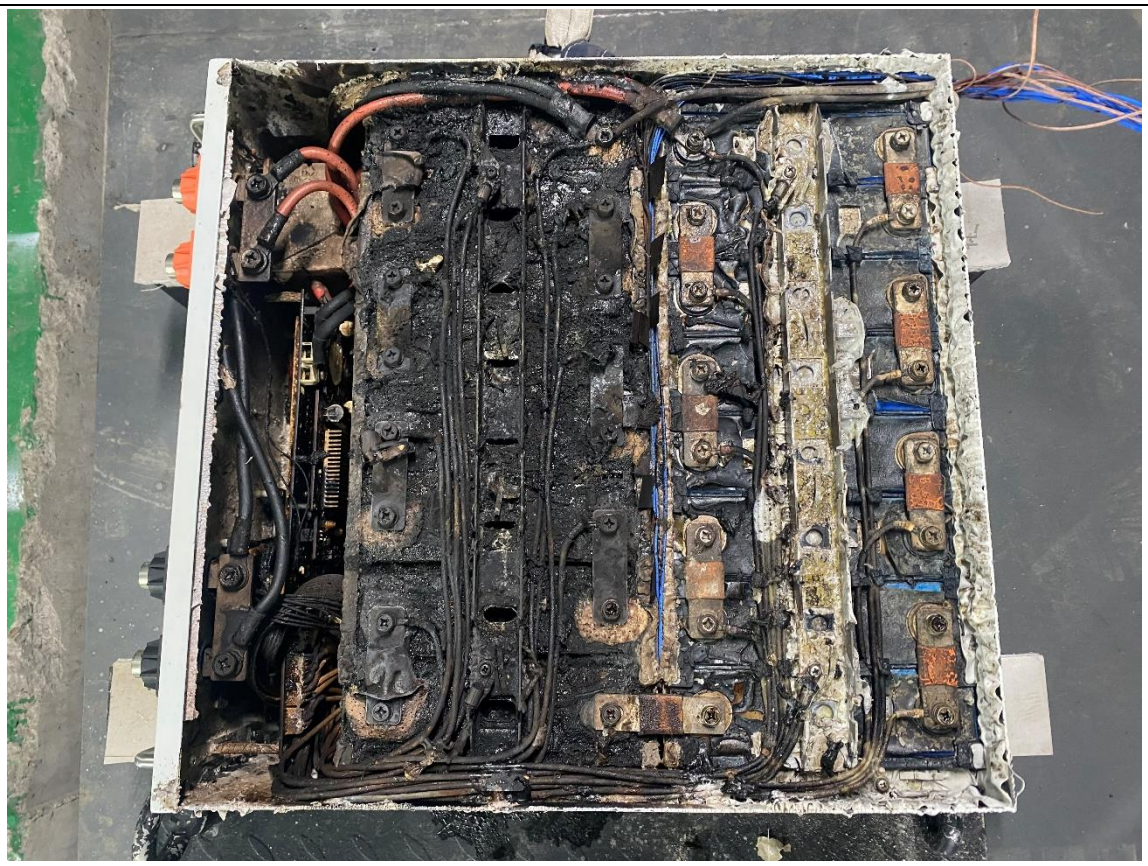
ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
8.3	**Module level test report**		**--**
8.3.1	The report on module level testing shall include the following:		Pass
	a) Module manufacturer name and model number (and whether UL 1973 compliant);	See module information.	Pass
	b) Number of cells in module;	16	Pass
	c) Module configuration with cells in series and parallel;	16S1P See module information	Pass
	d) Module construction features per 5.2;	See module information	Pass
	e) Module voltage corresponding to the tested SOC	See Attachment 3	Pass
	f) Thermal runaway initiation method was used including number and locations of cells for initiating thermal runaway;	See Attachment 3	Pass
	g) Heat release rate versus time data;	See Attachment 5	Pass
	h) Flammable gas generation and composition data;	See Attachment 6	Pass
	i) Peak smoke release rate and total smoke release data.	See Attachment 7	Pass
	j) Observation(s) of flying debris or explosive discharge of gases;	See Attachment 4	Pass
	k) Observation(s) of sparks, electrical arcs, or other electrical events;	See Attachment 4	Pass
	l) Identification/location of cells(s) that exhibited thermal runaway within the module;	See Attachment 4	Pass
	m) Locations and visual estimations of flame extension and duration from the module shall be documented;	See Attachment 4	Pass
	n) Module weight loss based on measurements per 8.2.3;	6.0 kg	Pass
	o) Video of the test.	230300277-001.mp4 is provided	Pass

Attachment 1 Photos

Before test



During test
 Cell vent observed
 Thermal runaway observed

After test

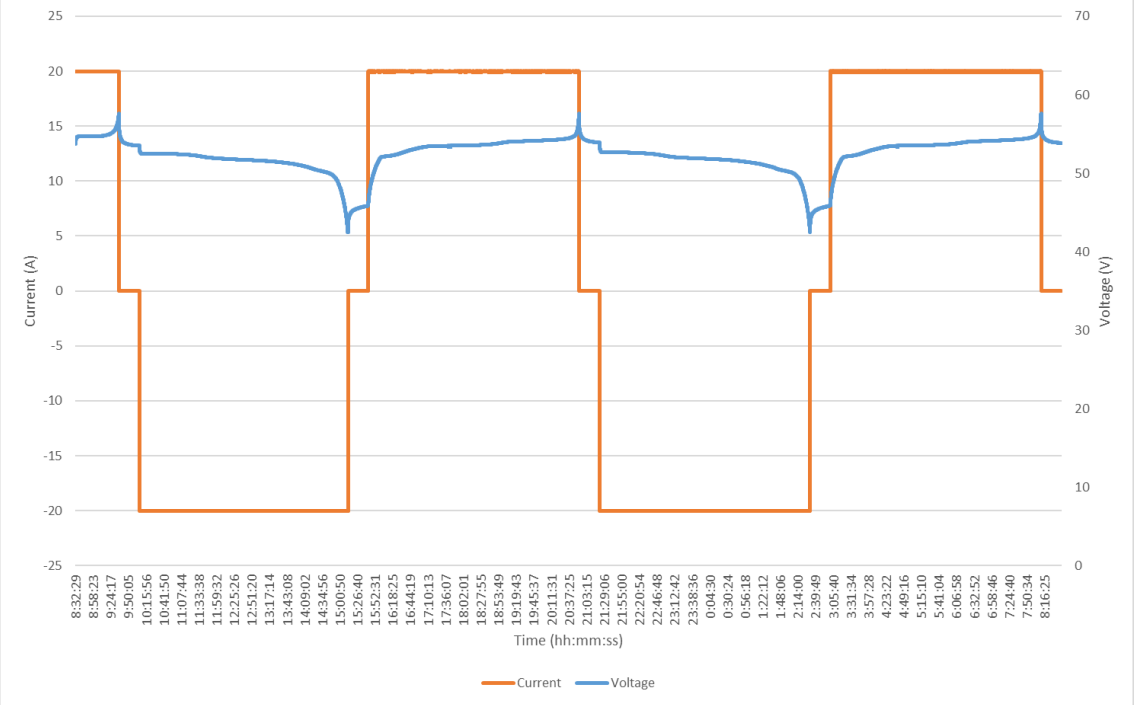


Attachment 2 Module Conditioning (charge/discharge) profiles

The module was conditioned, prior to testing, through charge and discharge cycles for 2 cycles using a manufacturer specified methodology to verify that the module is functional.

As manufacturer specified, the module was charged with 20A current to module end charge voltage 57.6 V, then keep the module stabilized for 30 minutes. After being stabilized, the module was discharged with 20A current to module end discharge voltage 42.5 V, then keep the module stabilized for 30 minutes.

After repeat the cycle above twice and then module was fully charged with 20A current to module end charge voltage 57.6 V, and before testing, the module was stabilized for about 3 hours. During conditioning the ambient temperature was maintained in 25 ±5°C and 50 ±25% RH.

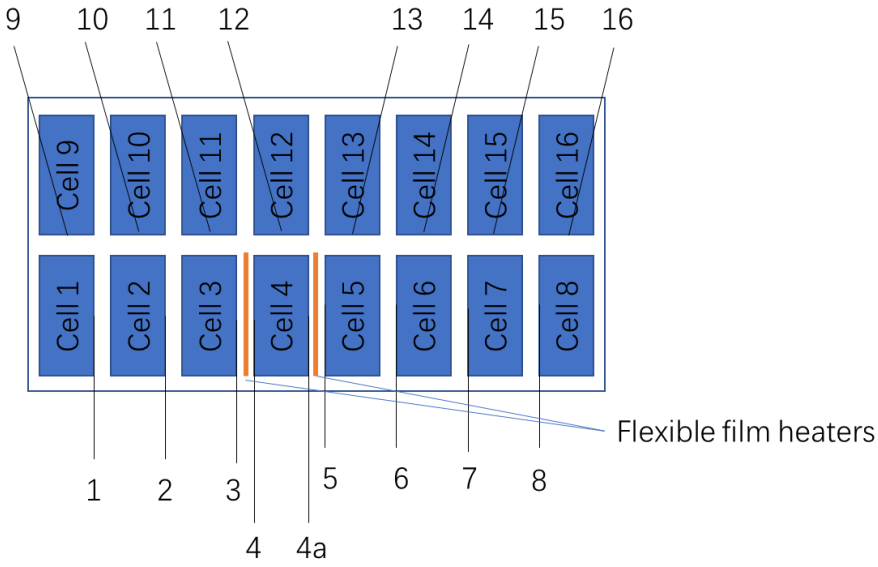


Module charge and discharge voltage/current profiles

Attachment 3 Module thermal runaway record

External heating method was used to initiate thermal runaway in the module. 2 flexible film heaters, rated 220VAC/297W, sized 165*120mm, were pasted on big sides of cell 4.

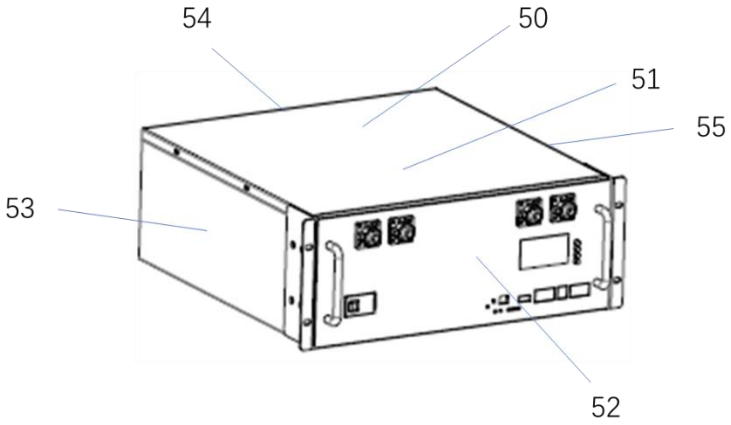
To monitor the cells temperature inside the module, 17 thermocouples, Type K, were used inside the module. See below figure and table for detail location of the film heaters and thermocouples.



Location of flexible film heaters and thermocouples inside the module

Thermocouple No.	Location
1-3	Center of right big side of cell 1-cell 3
4	Center of left big side of cell 4, under flexible film heater
4a	Center of right big side of cell 4, under flexible film heater
5-8	Center of right big side of cell 5-cell 8
9-16	Center of narrow side of cell 9 – cell 16, facing cell 1-cell 8

Additional 6 thermocouples, Type K, were located on the surface of module. See below table for detailed location of thermocouple.



location of thermocouples on module enclosure

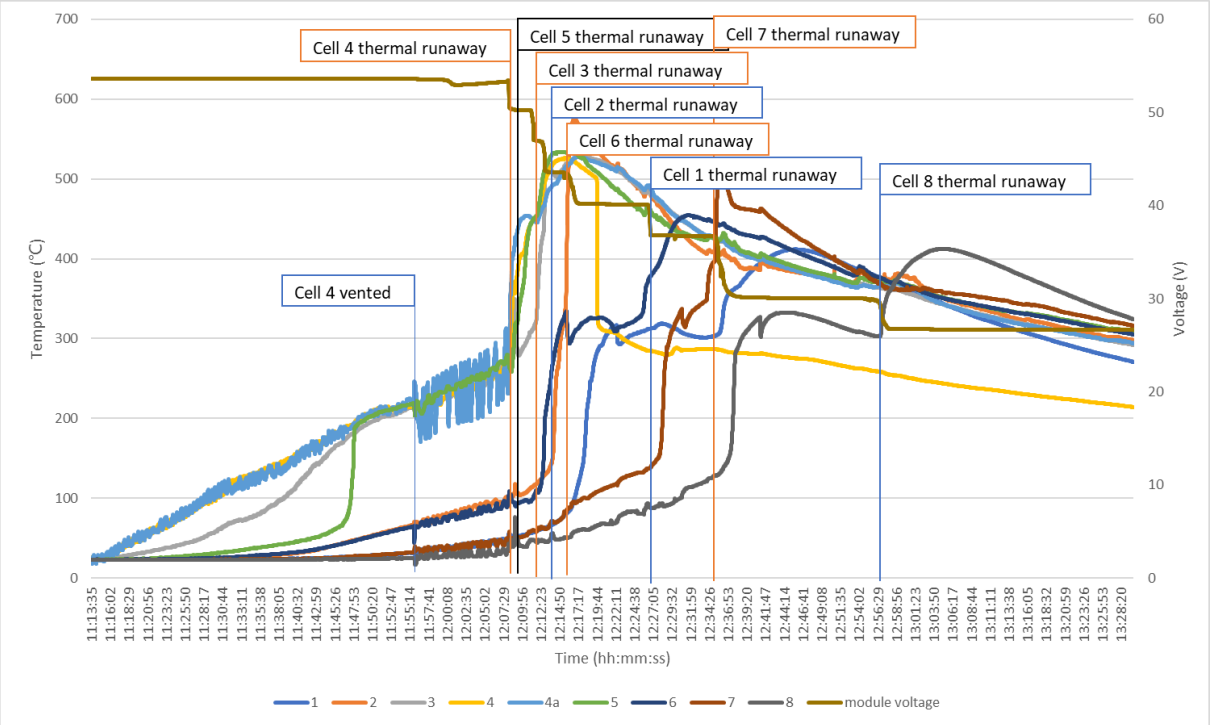
Thermocouple No.	Location
50	Enclosure top surface, correspond to center of cell 9- cell 16
51	Enclosure top surface, correspond to center of cell 1- cell 8
52	Center of enclosure front surface
53	Center of enclosure left surface
54	Center of enclosure rear surface
55	Center of enclosure right surface

Cell 4 was heated as the target cell at a rate of 4°C-7°C per minute until thermal runaway was occurred. Below table summarizes the details:

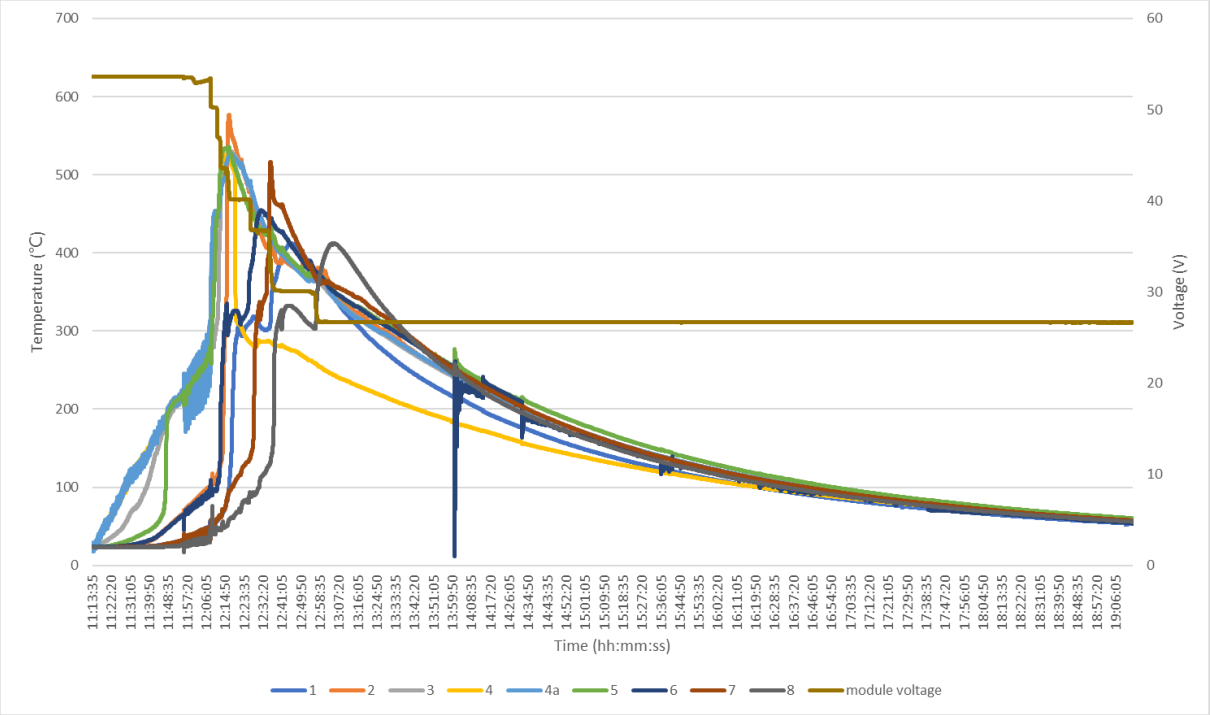
Ambient conditions at the initiation of the test:	23.4°C 61%RH			
Module voltage before test:	53.6 V			
Module voltage after test:	26.6 V			
Module weight before test	54.0 kg (with test auxiliary material)			
Time when test was initiated:	2023.04.27 11:13			
Observations during test:	1st vented	11:56	1st thermal runaway	12:08
	2nd vented	12:08	2nd thermal runaway	12:08
	3rd vented	12:09	3rd thermal runaway	12:10
	4th vented	12:15	4th thermal runaway	12:15
	5th vented	12:16	5th thermal runaway	12:16
	6th vented	12:22	6th thermal runaway	12:25
	7th vented	12:31	7th thermal runaway	12:34
	8th vented	12:41	8th thermal runaway	12:56
	9th vented	Not observed	9th thermal runaway	Not observed
	No flying debris or explosive discharge of gases. No sparks, electrical arcs, or other electrical events. No external flaming was observed			
Post-test evaluation:	Cell 4 went to thermal runaway due to external heating. Cell 1-Cell 3, Cell 5-Cell 8 vented and went to thermal runaway due to thermal runaway propagation.			
Module weight after test	48.0 kg (with test auxiliary material)			
Module weight loss	6.0 kg			

Attachment 4 Temperature and voltage profile during test

Temperature describing cell to cell propagation and module voltage are show in below figure



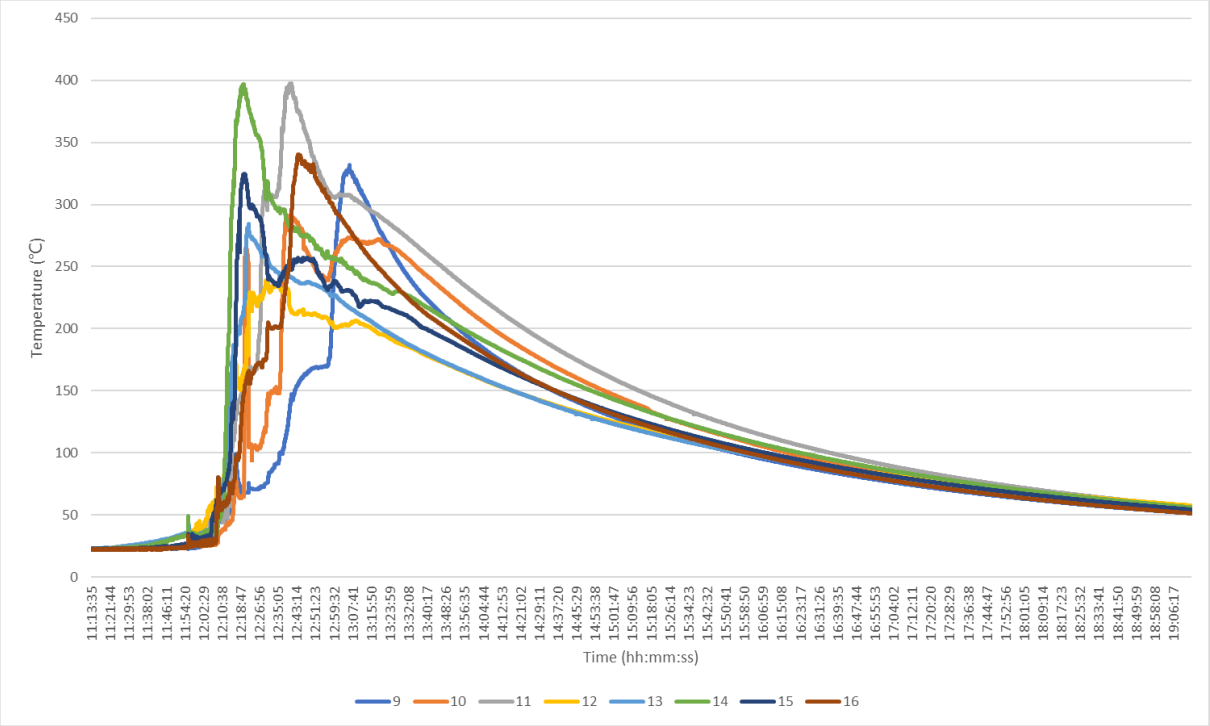
Measured temperature (thermocouple No.1 – No.8) inside the module and module voltage during the test is shown in below figure.



Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
1	Center of right big side of cell 1	411.7
2	Center of right big side of cell 2	576.5
3	Center of right big side of cell 3	529.5
4	Center of left big side of cell 4, under flexible film heater	526.7
4a	Center of right big side of cell 4, under flexible film heater	527.6
5	Center of right big side of cell 5	536.5
6	Center of right big side of cell 6	454.4
7	Center of right big side of cell 7	516.3
8	Center of right big side of cell 8	412.5

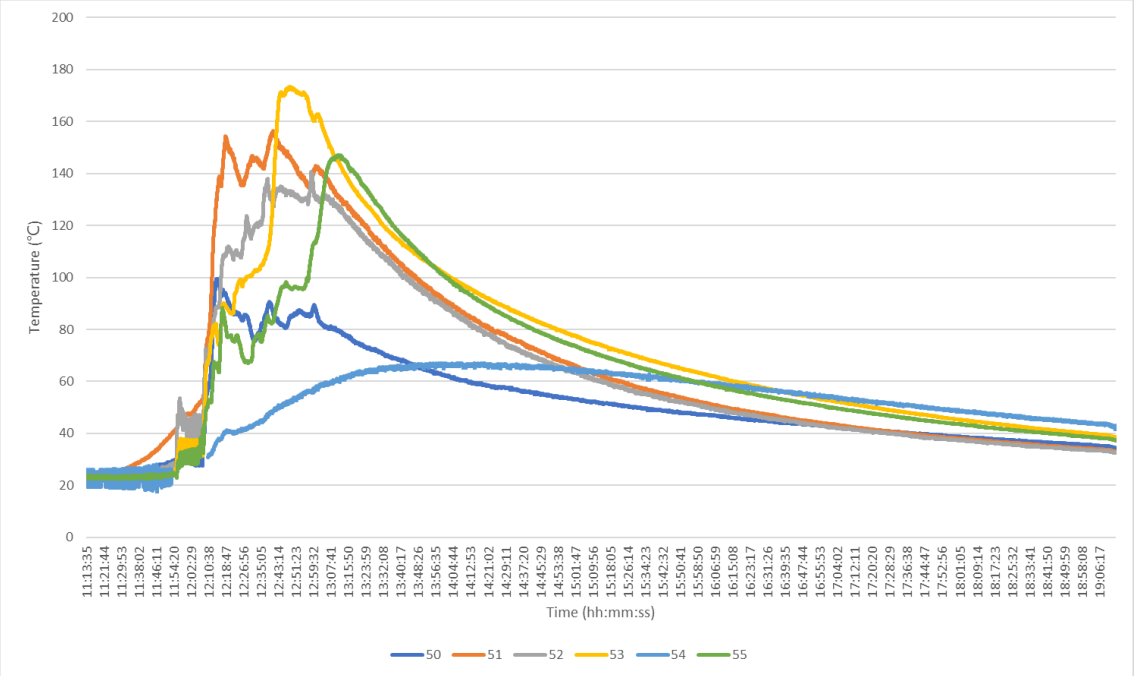
Measured temperature (Thermocouple No.9 - No.16) inside the module during the test are shown in below figure.



Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
9	Center of narrow side of cell 9, facing cell 1	331.8
10	Center of narrow side of cell 10, facing cell 2	291.9
11	Center of narrow side of cell 11, facing cell 3	397.5
12	Center of narrow side of cell 12, facing cell 4	239.1
13	Center of narrow side of cell 13, facing cell 5	284.5
14	Center of narrow side of cell 14, facing cell 6	397.0
15	Center of narrow side of cell 15, facing cell 7	324.9
16	Center of narrow side of cell 16, facing cell 8	340.6

The measured module enclosure temperature during the test is shown in below figure.



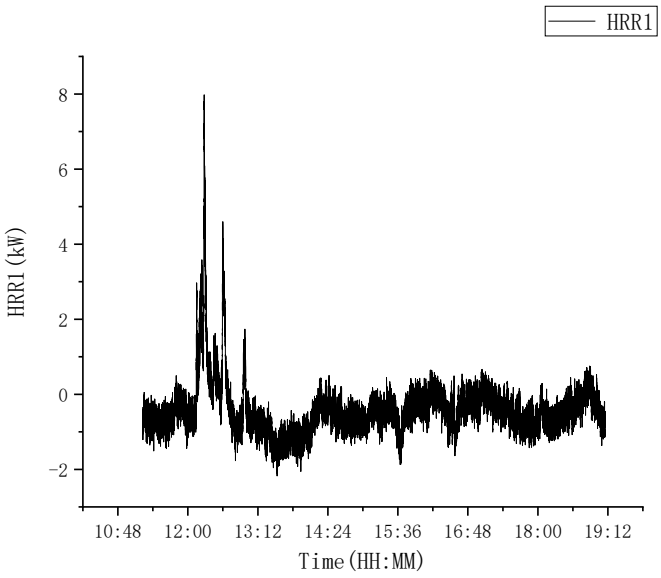
Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
50	Enclosure top surface, correspond to center of cell 9- cell 16	99.5
51	Enclosure top surface, correspond to center of cell 1- cell 8	156.3
52	Center of enclosure front surface	140.6
53	Center of enclosure left surface	173.3
54	Center of enclosure rear surface	67.1
55	Center of enclosure right surface	147.2

Attachment 5 Chemical heat release rate measurement

The chemical heat release rate was measured by a measurement system consisting of a paramagnetic oxygen analyser, non-dispersive infrared carbon dioxide and carbon monoxide analyser, velocity probe, and a Type K thermocouple. The instrumentation was located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influence of bends or exhaust devices.

Measured peak chemical heat release rate HRR=7.9 kW



HRR Curve

Attachment 6 Gas generation measurement

Vent gas compositions were measured using a Fourier-Transform Infrared Spectrometer with a resolution of 0.5 cm^{-1} and a path length of 3 m within the calorimeter's exhaust duct. And the composition, velocity and temperature of the vent gases were measured within the calorimeter's exhaust duct.

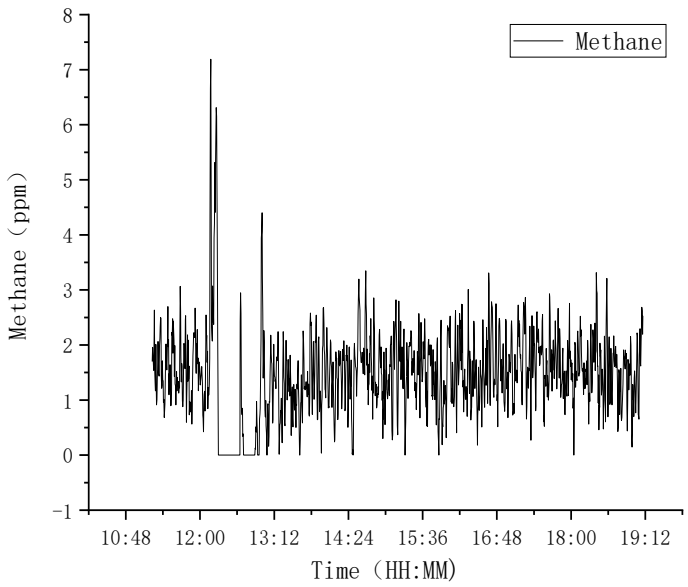
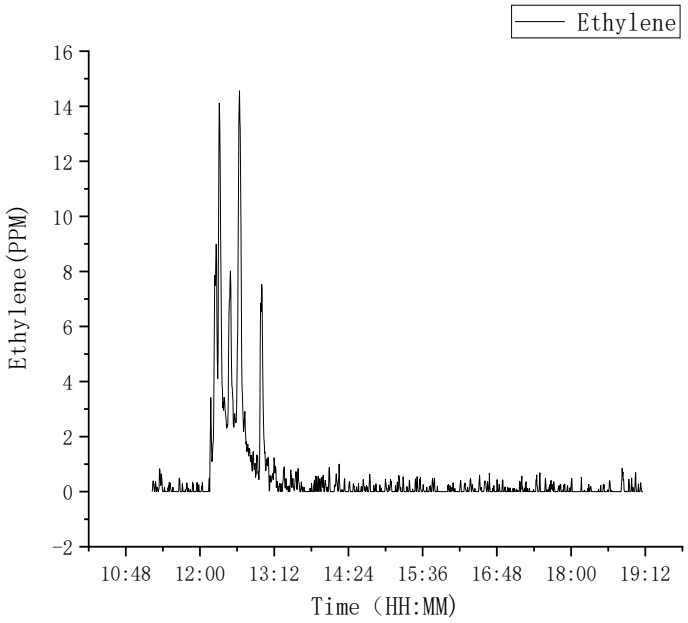
The hydrocarbon content of the vent gas was measured using flame ionization detection.
The hydrogen content was measured with a palladium-nickel thin-film solid state sensor and a heat conduction sensor. The hydrogen was not detected by the palladium-nickel thin-film solid state sensor. The value in below table was measured by heat conduction sensor.

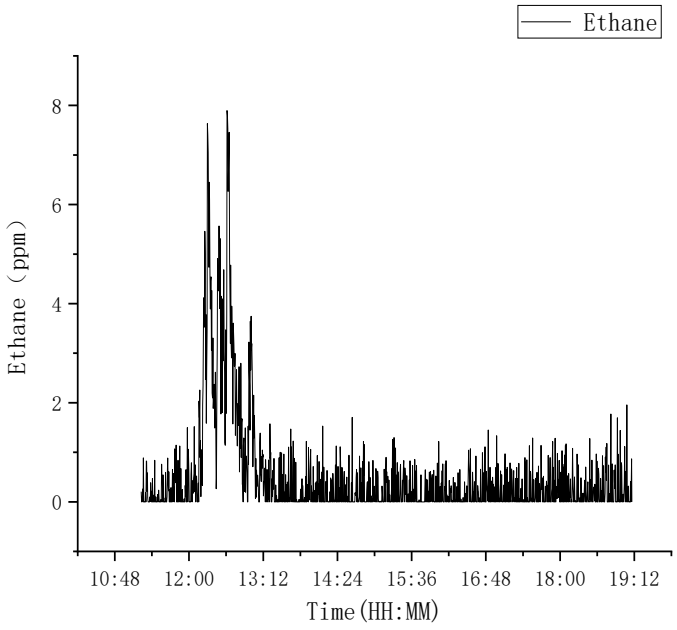
The volumetric flow rate of specific gas components can be calculated as:
Volumetric flow rate (L/s) = Concentration of specific gas composition (ppm) * Volumetric exhaust duct flow rate (m^3/s) *1000
And based on volumetric flow rate and time, the total volume of specific gas can be calculated as
Total volume (L)=summation the product of volumetric flow rate (L/s) * time (s)

The gas composition and volume are shown in below table

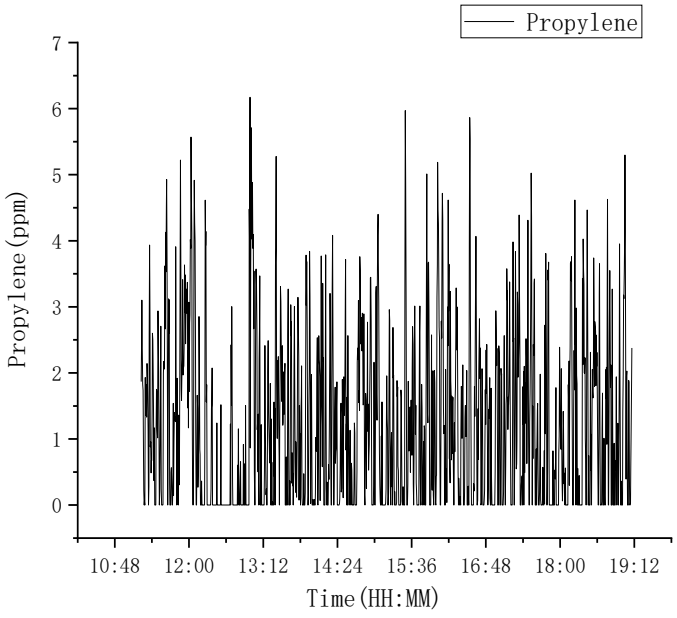
Gas type	Gas components		Volume (L)
Hydrocarbon species	Methane	CH_4	43.8
	Ethylene	C_2H_4	17.5
	Ethane	C_2H_6	16.1
	Propylene	C_3H_6	36.4
	Propane	C_3H_8	12.2
Hydrogen halide species	Hydrogen Fluoride	HF	46.2
Nitrogen containing species	Nitrogen Monoxide	NO	72.1
Other species	Carbon Monoxide	CO	23.4
	Carbon Dioxide	CO_2	95.5
	Hydrogen (Palladium nickel thin film solid state sensor)	H_2	0
	Hydrogen (TCD sensor)	H_2	224
	Methanol	CH_4O	6.2
Total Hydrocarbons (equivalent to C_3H_8, measured by FID)			39.3

Concentration of different gas components according to gas species classification was displayed as following graphs

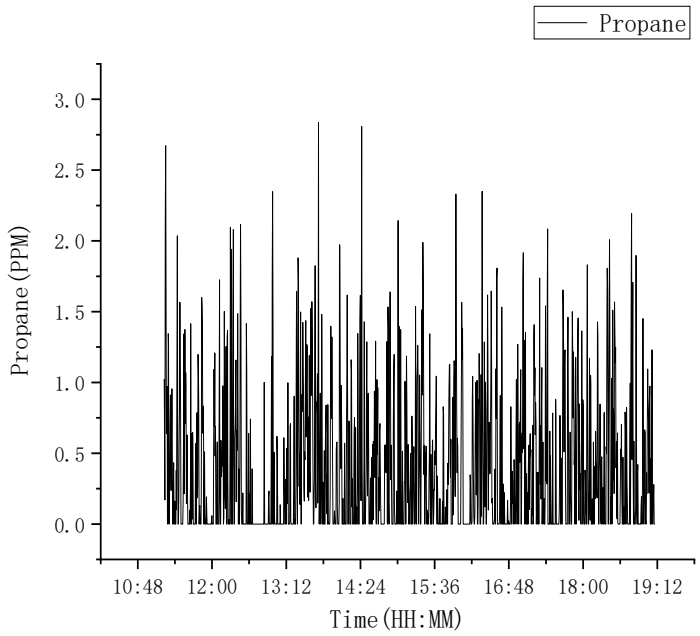
Hydrocarbon species
 Concentration of Methane (CH_4)
 Concentration of Ethylene (C_2H_4)



Concentration of Ethane (C_2H_6)

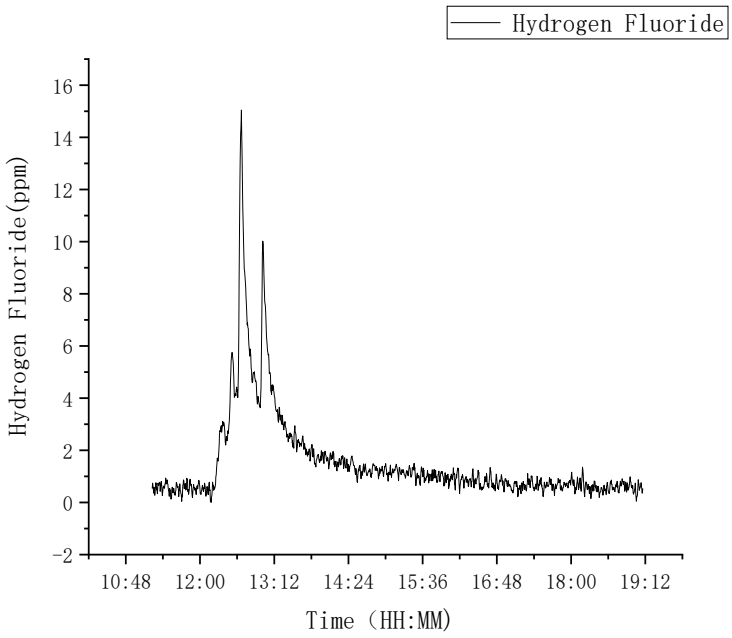


Concentration of Propylene (C_3H_6)



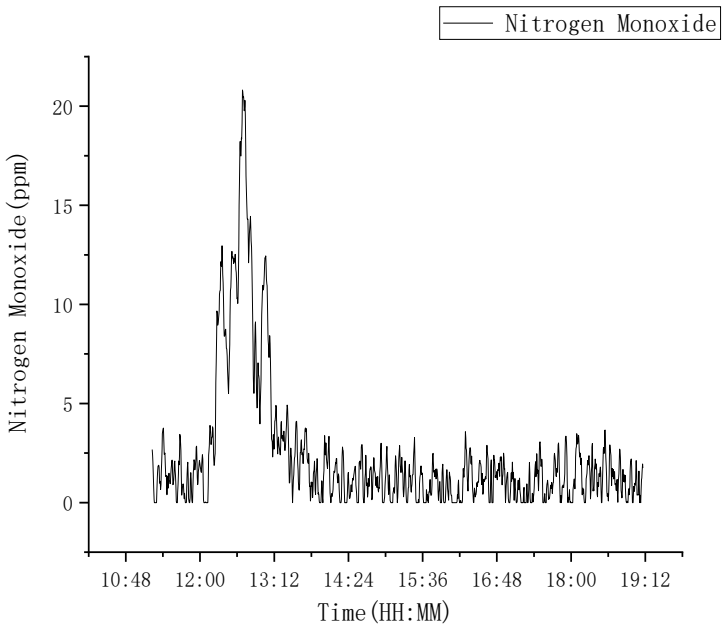
Concentration of Propane (C_3H_8)

Hydrogen halide species



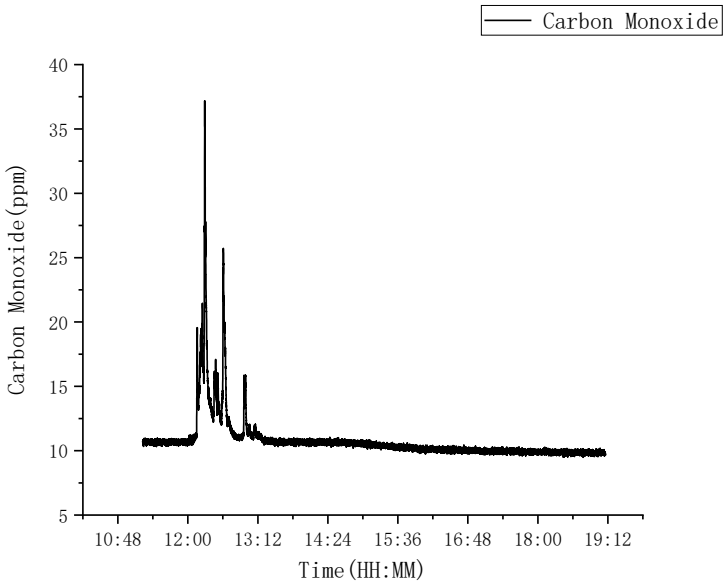
Concentration of Hydrogen Fluoride (HF)

Nitrogen containing species

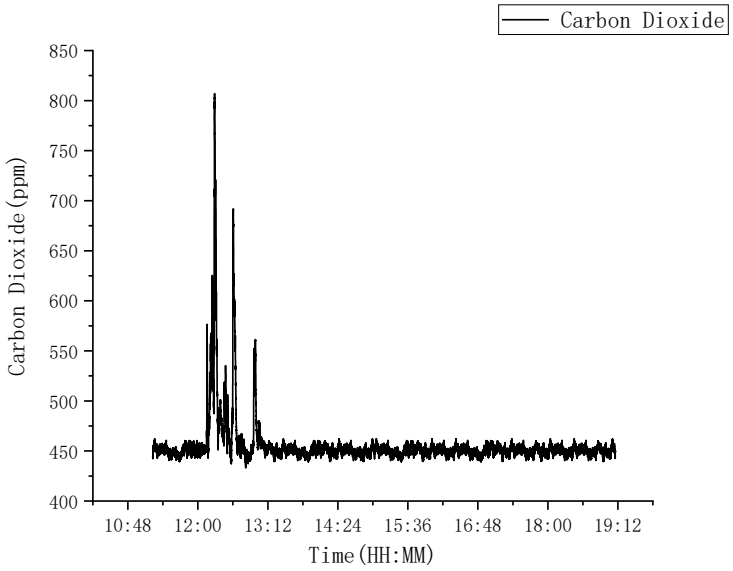


Concentration of Nitrogen Monoxide (NO)

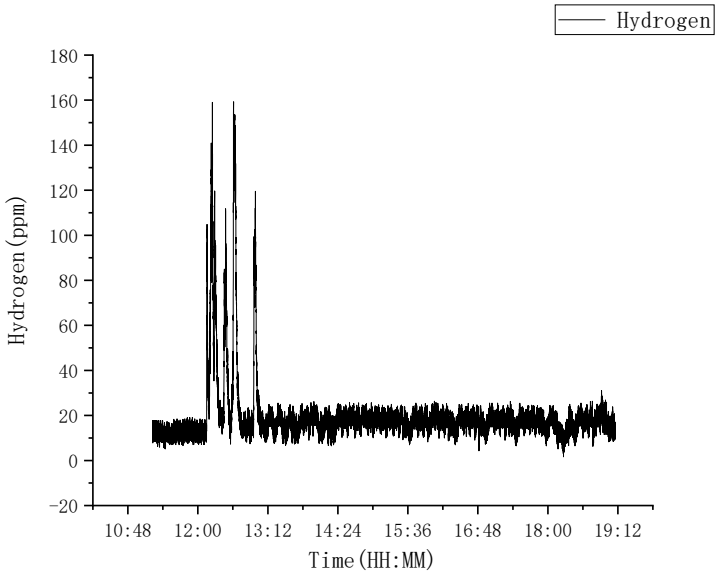
Other species



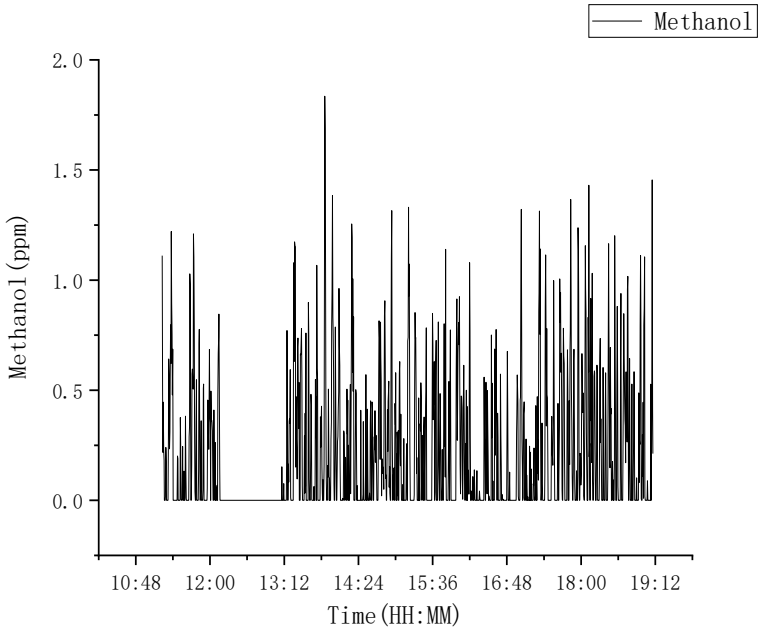
Concentration of Carbon Monoxide (CO)



Concentration of Carbon Dioxide (CO_2)

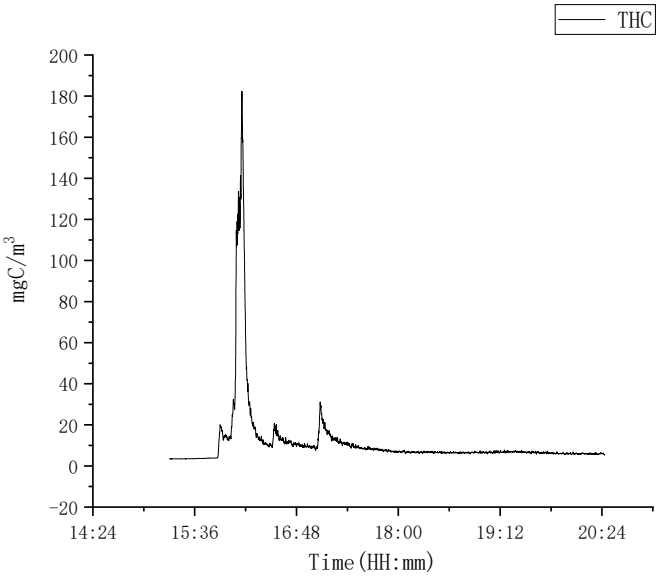


Concentration of Hydrogen (H_2) (Tested by TCD sensor)



Concentration of Methanol (CH_4O)

Total Hydrocarbons (measured by FID)



Concentration of total hydrocarbons (measured by FID)

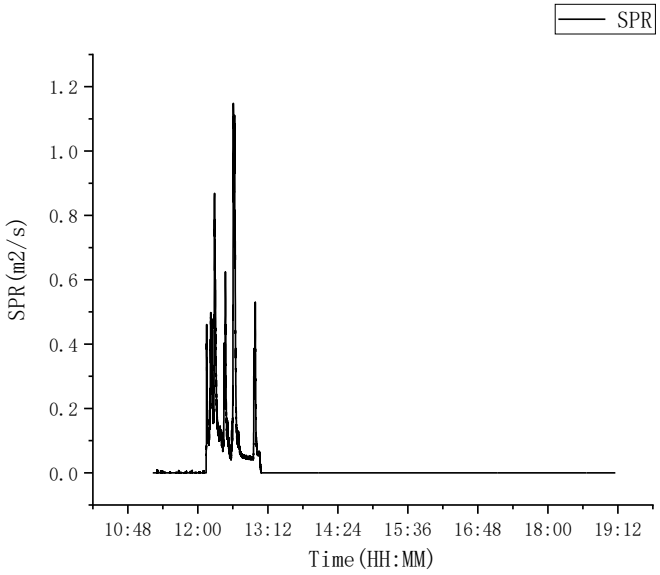
Attachment 7 Smoke release rate measurement

Smoke release rate shall be calculated as follows:

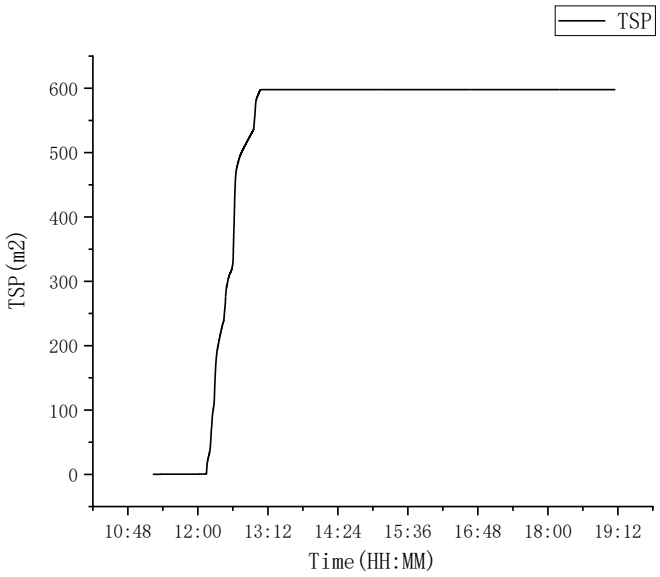
$$SRR = 2.303\left(\frac{V}{D}\right) Log_{10}\left(\frac{I_o}{I}\right)$$

Where:
SRR = Smoke release rate (m^2/s)
V = Volumetric exhaust duct flow rate (m^3/s)
D = duct diameter (m)
Io = Light transmission signal of clear (pre-test) beam (V)
I = Light transmission signal during test (V)

Measured peak smoke release rate SRR: 1.15 m^2/s
Measured total smoke release rate TSR: 597.88 m^2



SRR curve



TSR curve

Attachment 8 Equipment list

No.	Equipment		Model	Rating	Inventory No.	Last Cal. date
1	Ambient monitor		WSB-2-H1	0-40°C 10-90%RH	S-044	2023.01.03
2	Digital multi-meter		FLUKE101	0-600V	S-038	2023.02.23
3	Tape		1000mm 5000mm	0-1000mm 0-5000mm	S-040 S-042	2023.03.14 2023.03.14
4	Electronic scale		TCS-500	0-500kg	S-039	2023.02.23
5	Charge /discharge equipment		MRTS-DC-3869-250	800V, 600A	0221-055	2022.08.10
6	Heating control equipment		DTB4824	0-1000°C	S-046-2	2022.07.19
7	Data acquisition equipment		ADAM-4117 ADAM-4118 MT4W DTM	0-10V 0-1000°C 0-100V 0-1000°C	S-028-1 S-028-2 S-030-5~8 S-029	2022.08.09 2022.08.09 2022.08.09 2022.08.09
8	Oxygen consumption calorimeter measurement system	Paramagnetic oxygen analyzer	ABB AO2020	O_2: 0-21% CO_2: 0-10% CO: 0-1%	S-062-5~7	2022.08.11
		CO and CO_2 sensor				
		Micro-differential pressure transmitter	DP101MD	-100~100Pa	S-024-4	2023.02.23
		Thermopile	TT I 20-CAXL-I I 6U-10-SPW-M	0-1000°C	S-028-5~7	2023.02.26
		Light filter	--	25%, 50%, 75%	S-024-6 S-024-7 S-024-8	2023.03.07
		Gas mass flowmeter	Sevenstar D07-60G	0-8g/s	S-024-9	2023.03.29
9	Palladium-nickel thin-film solid state sensor		710B Model5000	1000ppm-100% 0-4%	S-023-5 S-023-2	2023.03.01
10	Hydrogen sensor (TCD)		ABB AO2020	0-4%	S-62~8	2023.03.01
11	Electrochemical hydrogen sensors		$H_2$40000 $H_2$1000	0-4% 0-0.1%	S-023-3~4	2023.03.01
12	Fourier-Transform Infrared Spectrometer		MG6000	0.01ppm-100%	S-019	2023.03.01
13	Flame Ionization Detector		ABB AO2020	0-30000ppm	S-062~10	2023.08.11

---------- End of test report ----------