


1.0 Reference and Address			
Report Number	221000877SHA-001	Original Issued: 20-Mar-2023	Revised: None
Standard(s)	Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications [ANSI/CAN/UL 1973:2018 Ed.2]		
Applicant	Shenzhen Lithium Valley Technology Co., Ltd.	Manufacturer 1	Dongguan Lithium Valley Energy Co., Ltd.
Address	Room 2018, Huilong Business Center Minzhi Street, Longhua District, Shenzhen, Guangdong	Address	Fuzhu 4th Street, Zhangyang community, Zhangmutou town Dongguan City, 523637 Guangdong
Country	China	Country	China
Contact	Zhou Yuxiao	Contact	Zhou Yuxiao
Phone	0769-8202 9309	Phone	0769-8202 9309
FAX	NA	FAX	NA
Email	christin@lithiumvalley.com	Email	christin@lithiumvalley.com

2.0 Product Description	
Product	Rechargeable Li-ion Battery
Brand name	Lithium Valley 
Description	<p>The product covered by this report is the Rechargeable Li-ion Battery. The battery is equipped with 16 cells(16S1P), cell model no. is CB27173204EA. Only one protection in module. The other one located in system. BMS software version APP_V1.1.3.0.</p> <p>The voltage control: First U15 pin 1-17 control Mosfet to cut-off, second pin 29-46 of U15 control U11 to operate dry contact.</p> <p>The current control: First U15 pin 18-19 control Mosfet to cut-off, second pin 29-46 of U15 control U11 to operate dry contact.</p> <p>The heating control: First U15 pin 20-22 control Mosfet to cut-off, second pin 29-46 of U15 control U11 to operate dry contact.</p>
Models	LV-BAT-R5.12Ab
Model Similarity	NA
Ratings	51.2V/100Ah/5120Wh
Other Ratings	<p>Nominal Charge Current: 50A Nominal Discharge Current: 50A Max Continuous Charging Current: 50A Max Continuous Discharge current: 100A Upper Limited Charging Voltage: 56.16V Discharge Cut-off Voltage: 45.6V Charging temp. Range: 0-55°C Discharging temp. Range : -20°C~60°C</p>
Conditions of Acceptability	<p>The products covered in this Report are incomplete in construction features or limited in performance capabilities and are intended for use and evaluation in other products. Consideration should be given to the following when the component is used in or with another product.</p> <ol style="list-style-type: none"> 1. Suitability of the enclosure should be evaluated when installed in system. 2. Temperature Testing should be performed on this component when installed in the end system. 3. There is only one protection in pack. Single fault for all clause is not considered in this report. It shall be double check in end system. 4. The battery modules was not evaluated for LER application. 5. 9540A is performed for this model. See report 221000882SHA-001 5. The spacing should be double check in end system. In this report, only module voltage is considered.

3.0 Product Photographs

Photo 1 - External view of product



Photo 2 - PCB

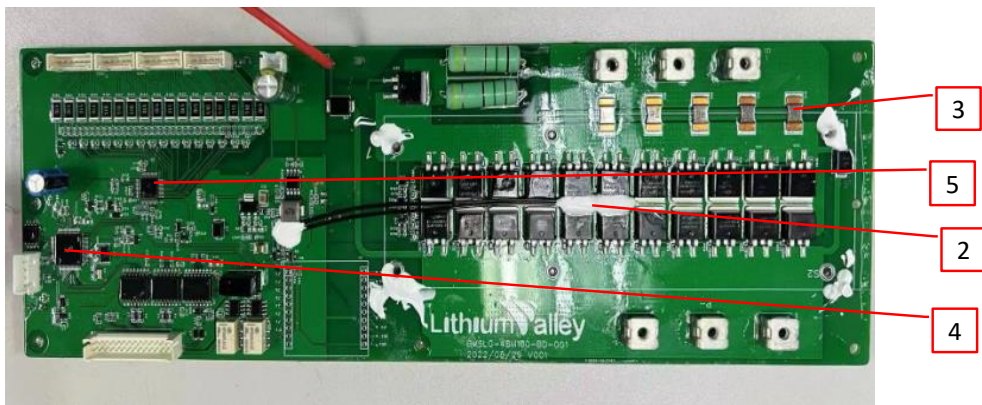
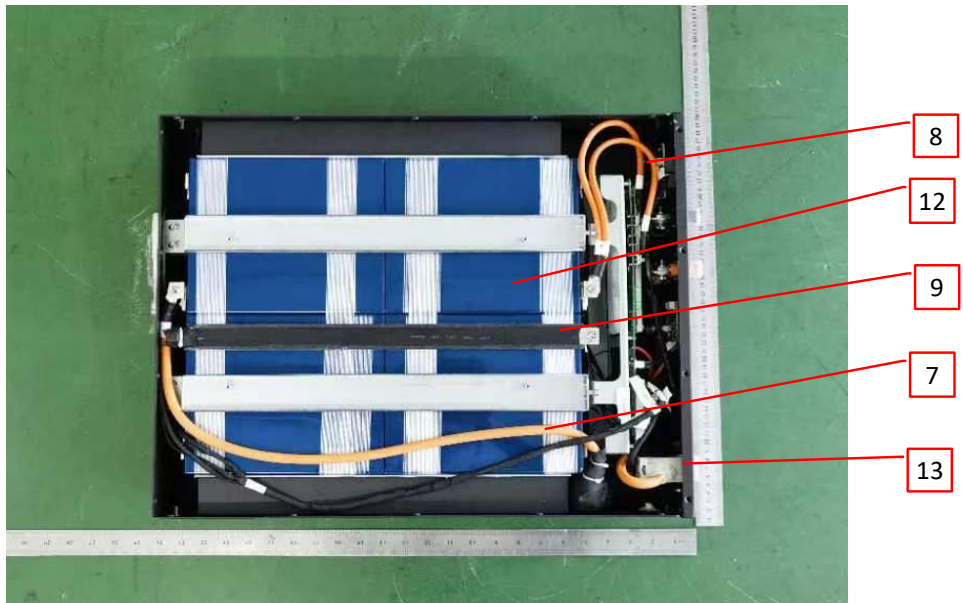


Photo 3 - PCB



3.0 Product Photographs

Photo 4 - Internal view of product



4.0 Critical Components						
Photo #	Item no. ¹	Name	Manufacturer/ trademark ²	Type / model ²	Technical data and securement means	Mark(s) of conformity ³
2	1	PCB	Q & D CIRCUITS CO LTD UL E251497	M-F	V-0,105°C,Min. thickness: 1.6mm	cURus
2	2	NTC	SEMITEC CORP UL E92669	103AT-2	for TS1,TS2,TS3,NTC1,NTC2,NTC3 R25°C 10KΩ±1%, Tmoa:110°C	cURus
2	3	Shunter	Shenzhen Milliohm Electronics Co., Ltd	HoLRS1050-5mR	For R68,R69,R70,R78,R81,R83,R85, R103,R182,R185 Rate Power:5W;5mΩ±1%	NR
2	4	IC	SINO WEALTH MICROELECTRONICS CO LTD	SH367309	for U15 VBAT:-0.3V to 70V,Overcharge protection voltage:3.6V to 4.5V,Overdischarge protection voltage :2.0V to 3.1V, overcurrent protection voltage:0.5mV to 2.6mV,charge overcurrent protection voltage :2.6mV to -0.5mV,Topr:-40°C to 85°C	NR
2	5	IC	Beijing Zhaoyi Innovation Technology Co. Ltd.	GD32F303RCT6	For U11 VDD:-0.3V to 3.6V topr:-40°C to 85 °C	NR
2&3	6	MOSFET	CR MICRO Technology Co. Ltd.	CRSS042N10N	For Q1,Q8,Q9,Q10,Q11,Q12,Q13,Q15,Q16,Q20,Q31,Q35,Q36,Q37,Q38,Q40,Q41,Q43,Q44,Q45,Q46,Q48,Q49,Q51,Q52,Q53,Q55,Q56,Q57,Q58,Q59,Q60,Q61,Q62,Q63,Q64,Q65,Q801,Q802,Q803,Q804,Q805,Q806,Q807 VDS:100V, ID:120A, Gate-Source voltage:±20V	NR
4	7	Internal Wiring B+/P+	DONGGUAN HAODE WIRE & CABLE TECHNOLOGY CO LTD UL E364036	3239	4AWG,200°C,600V	cURus

4.0 Critical Components						
Photo #	Item no. ¹	Name	Manufacturer/ trademark ²	Type / model ²	Technical data and securement means	Mark(s) of conformity ³
4	8	Internal Wiring B-/P-	DONGGUAN HAODE WIRE & CABLE TECHNOLOGY CO LTD UL E364036	3239	8AWG,200°C,600V	cURus
4	9	Insulation Sleeving	SHENZHEN WOER HEAT-SHRINKABLE MATERIAL CO LTD UL E203950	RSFR	600V, 125°C	cURus
1	10	Connector P+/P-	General Connectivity System Co., Ltd UL E527614	PSR6XABM5A	Rated voltage: 1000V; rated current: 120A; rated temperature:-40 °C 125 °C; IP:67	cURus
1	11	Enclosure	DongGuan XinCheng Metal Product Co., Ltd.	LV-BAT-R5.12Ab	PCC, Thickness min.: 1.5mm; Dimensions: 550*440*130 mm	NR
4	12	Cell	REPT BATTERO Energy Co., Ltd. (TUV CU 72213577 02)	CB27173204EA	3.2Vd.c. ,100Ah Max. charging current: 100A Max. discharging current: 100A Temp. of charging:0-60°C	TUV CU
4	13	Fuse	Various	Various	500Vdc 250A	cURus
1	14	Label (not shown)	Various	Various	comply with UL969	cURus
2	15	BMS(not shown)	Shenzhen Lithium Valley Technology Co., Ltd.	BMSLG48M100	Version: APP_V1.1.3.0	NR

NOTES:

- 1) Not all item numbers are indicated (called out) in the photos, as their location is obvious.
- 2) "Various" means any type, from any manufacturer that complies with the "Technical data and securement means" and meets the "Mark(s) of conformity" can be used.
- 3) Indicates specific marks to be verified, which assures the agreed level of surveillance for the component. "NR" - indicates Unlisted and only visual examination is necessary. "See 5.0" indicates Unlisted components or assemblies to be evaluated periodically refer to section 5.0 for details.

5.0 Critical Unlisted CEC Components

No Unlisted CEC components are used in this report.

6.0 Critical Features

Recognized Component - A component part, which has been previously evaluated by an accredited certification body with restrictions and must be evaluated as part of the basic product considering the restrictions as specified by the Conditions of Acceptability.

Listed Component - A component part, which has been previously Listed or Certified by an accredited Certification Organization with no restrictions and is used in the intended application within its ratings.

Unlisted Component - A part that has not been previously evaluated to the appropriate designated component standard. It may also be a Listed or Recognized component that is being used outside of its evaluated Listing or component recognition.

Critical Features/Components - An essential part, material, subassembly, system, software, or accessory of a product that has a direct bearing on the product's conformance to applicable requirements of the product standard.

Construction Details - For specific construction details, reference should be made to the photographs and descriptions. All dimensions are approximate unless specified as exact or within a tolerance. In addition to the specific construction details described in this Report, the following general requirements also apply.

1. Mechanical Assembly - Components such as switches, fuseholders, connectors, wiring terminals and display lamps are mounted and prevented from shifting or rotating by the use of lockwashers, starwashers, or other mounting format that prevents turning of the component.
2. Corrosion Protection - All ferrous metal parts are protected against corrosion by painting, plating or the equivalent.
3. Grounding - All exposed dead-metal parts and all dead-metal parts within the enclosure that are exposed are connected to the the equipment grounding terminal.
4. Internal Wiring - Internal wiring is routed away from sharp or moving parts. Internal wiring leads terminating in soldered connections are made mechanically secure prior to soldering. Recognized Component separable (quick disconnect) connectors of the positive detent type, closed loop connectors, or other types specifically described in the text of this report are also acceptable as internal wiring terminals. At points where internal wiring passes through metal walls or partitions, the wiring insulation is protected against abrasion or damage by plastic bushings or grommets. All wiring is minimum 8AWG, with a minimum rating of 600V, 200°C.
5. Schematics - Refer to Illustration 2 and 2a to 2d for schematics requiring verification during Field Representative Inspection Audits.
6. Markings - The product is marked <on a labeling system as described in item no. 14 of Section 4.0 or by molding into polymeric enclosure> as follows:
Applicant's name or brand name
model number;
date of manufacturer;
electrical ratings
7. Installation, Operating and Safety Instructions - Instructions for installation and use of this product are provided by the manufacturer. Refer to Illustrations 1 for details.

7.0 Illustrations

Illustration 1 - Manual



电池组规格书 BATTERY SPECIFICATION

A2022101101

Specification of Lithium Ion Battery
 Spécification de Lithium Ion Battery
锂离子电池组规格书

Battery model Modèle de batterie 电池组型号: **LV-BAT-R5.12Ab** LV-BAT-R5.12Ab
Product description Description du produit 产品描述: **16S1P(Cell+PCM+Wire)** 16S1P (cellule + PCM + fil)
Product No. N° de produit 产品编码: **LV-BAT-R5.12Ab** LV-BAT-R5.12Ab

AMENDMENT RECORDS
 DOSSIERS DE MODIFICATION
 规格变更记录

Revision 版本	Description 描述	Prepared by (R&D) 编制(R&D)	Checked by (R&D) 审核(R&D)	Approved by(R&D) 批准(R&D)	Approved by(QA) 批准(QA)	Date 日期
V01	New release 新发放	余西宁				2022.10.11

Customer Approval 客户确认	Signature 签名	
	Date 日期	
	Company Name: 公司名称:	
	Company Stamp: 公司盖章:	
	Customer materiel number: 客户物料编号:	

LV Confidential Proprietary

1/10

V02

Illustration 2 - Circuit diagram

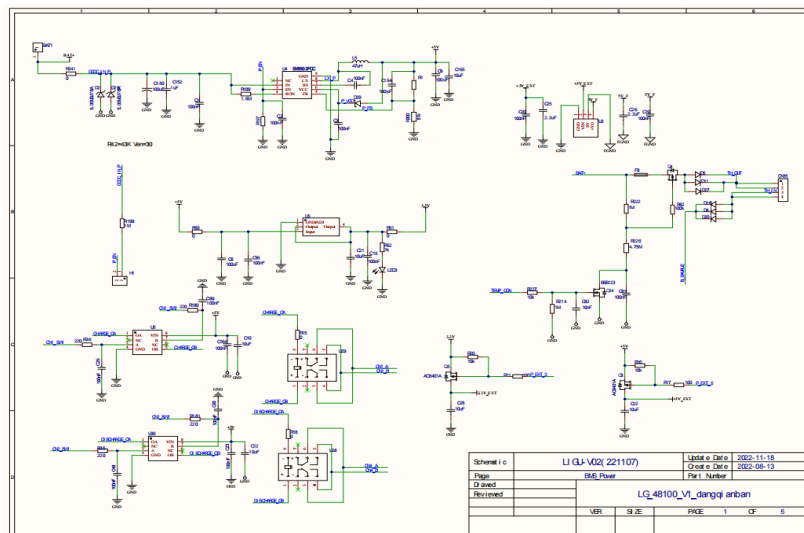


Illustration 2a - Circuit diagram

7.0 Illustrations

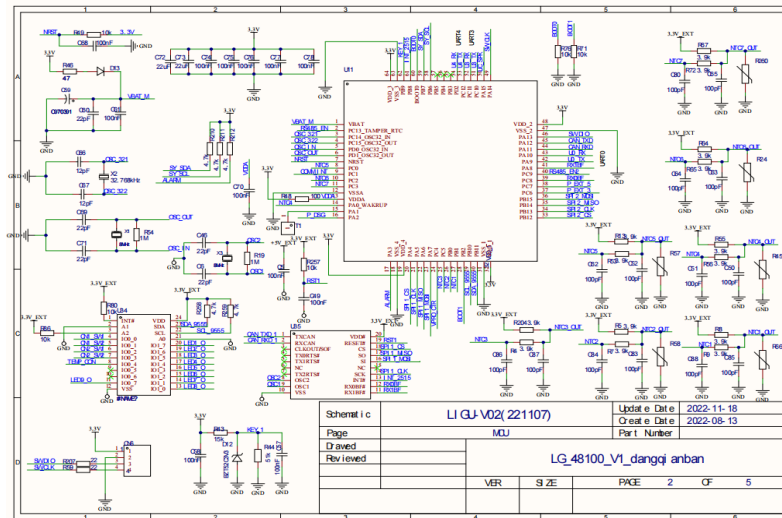


Illustration 2b - Circuit diagram

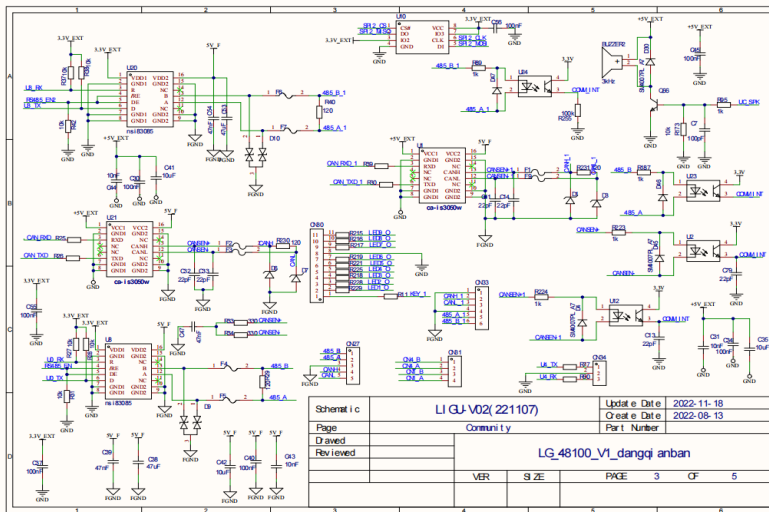


Illustration 2c - Circuit diagram

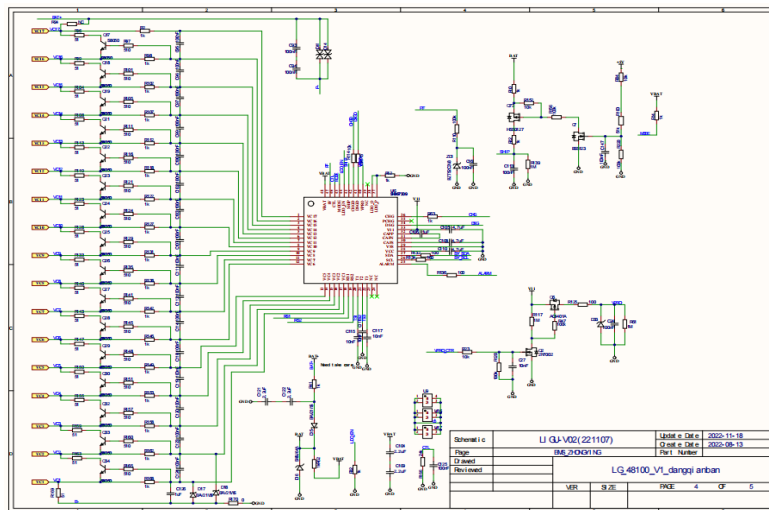


Illustration 2d - Circuit diagram

7.0 Illustrations

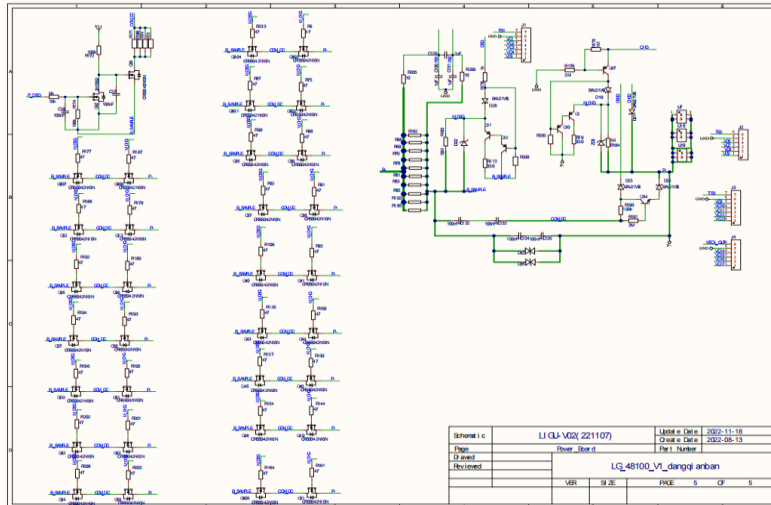


Illustration 3 - Layout TOP

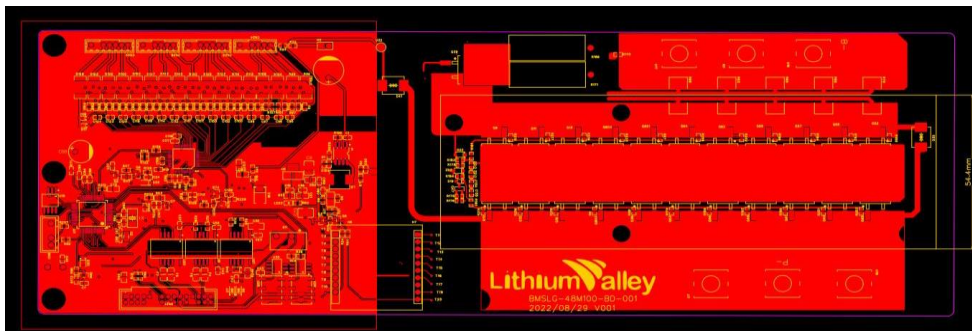
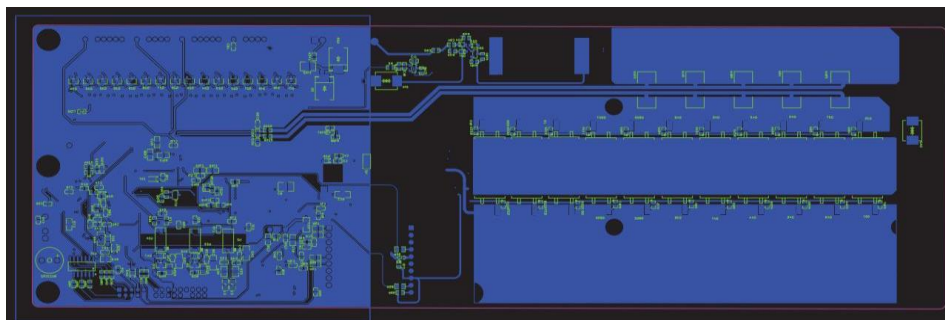
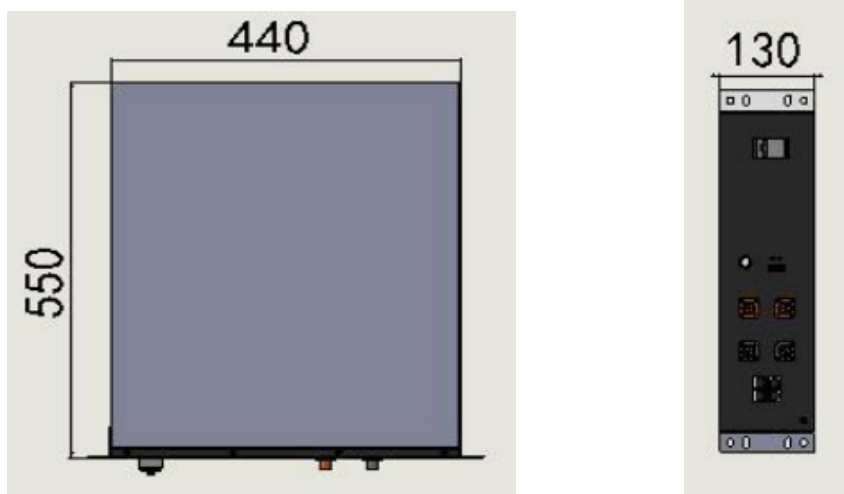


Illustration 3a - Layout BOT





7.0 Illustrations

Illustration 4- External dimension view



8.0 Test Summary			
Evaluation Period	23-Dec-2022 to 13-Mar-2023		Project No. 221000877SHA
Sample Rec. Date	23-Dec-2022	Condition Prototype	Sample ID. 221223-086
Test Location	Intertek Testing Services Shanghai Limited		
Test Procedure	Testing Lab		
Determination of the result includes consideration of measurement uncertainty from the test equipment and methods. The product was tested as indicated below with results in conformance to the relevant test criteria.			
The following tests were performed:			
Test Description	ANSI/CAN/UL 1973:2018 Ed.2		UL 60730-1:2016 Ed.5 Clause
Overcharge Test	15		--
Short Circuit Test	16		--
Overdischarge Protection Test	17		--
Temperature and Operating Limits Check Test	18		--
Imbalanced Charging Test	19		--
Continuity Test	21		--
Working Voltage Measurements	23		--
Static Force Test	28		--
Impact Test	29		--
Drop Impact Test	30		--
Software evaluation for electronic controls	--		Annex H

8.1 Signatures			
A representative sample of the product covered by this report has been evaluated and found to comply with the applicable requirements of the standards indicated in Section 1.0.			
Completed by:	Susanna Xu	Reviewed by:	Robin Xu
Title:	Engineer	Title:	Manager
Signature:		Signature:	

9.0 Correlation Page For Multiple Listings	
The following products, which are identical to those identified in this report except for model number and Listee name, are authorized to bear the ETL label under provisions of the Intertek Multiple Listing Program.	
BASIC LISTEE	Shenzhen Lithium Valley Technology Co., Ltd.
Address	Room 2018, Huilong Business Center Minzhi Street, Longhua District, Shenzhen, Guangdong
Country	China
Product	Rechargeable Li-ion Battery

MULTIPLE LISTEE 1	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	
MULTIPLE LISTEE 1 MODELS	
BASIC LISTEE MODELS	

MULTIPLE LISTEE 2	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	
MULTIPLE LISTEE 2 MODELS	
BASIC LISTEE MODELS	

MULTIPLE LISTEE 3	None
Address	
Country	
Brand Name	
ASSOCIATED MANUFACTURER	
Address	
Country	
MULTIPLE LISTEE 3 MODELS	
BASIC LISTEE MODELS	

10.0 General Information

The Applicant and Manufacturer have agreed to produce, test and label ETL Listed products in accordance with the requirements of this Report. The Manufacturer has also agreed to notify Intertek and to request authorization prior to using alternate parts, components or materials.

COMPONENTS

Components used shall be those itemized in this Intertek report covering the product, including any amendments and/or

LISTING MARK

The ETL Listing mark applied to the products shall either be separable in form, such as labels purchased from Intertek, or on a product nameplate or other media only as specifically authorized by Intertek. Use of the mark is subject to the control of Intertek.

The mark must include the following four items:

- 1) applicable country identifiers "US" and/or "C" or "US", "C" and "EU"
- 2) the word "Listed" or "Classified" or "Recognized Component" (whichever is appropriate)
- 3) a control number issued by Intertek
- 4) a product descriptor that identifies the standards used for certification. Example:

For US standards, the words, "Conforms to" shall appear with the standard number along with the word, "Standard" or "Std." Example: "Conforms to ANSI/UL Std. XX."

For Canadian standards, the words "Certified to CAN/CSA Standard CXX No. XX." shall be used, or abbreviated, "Cert. to CAN/CSA Std. CXX No. XX."

Can be used together when both standards are used.

If all standards on the ATM have the same standard title, the shared title or its abbreviation may be used in place of the examples above. Example: "Medical Electrical Equipment" or "MEE"; "Information Technology Equipment" or "ITE"; "Audio/Video Information And Communication Technology Equipment" or "A/V ICTE".

Note: A facsimile must be submitted to Intertek, Attn: Follow-up Services for approval prior to use.

The facsimile need not have a control number. A control number will be issued **after signed Certification**

Agreements have been received by the Follow-up Services office, approval of the facsimile of your proposed Listing Mark, satisfactory completion of the Listing Report, and scheduling of a factory assessment in your facility.

MANUFACTURING AND PRODUCTION TESTS

Manufacturing and Production Tests shall be performed as required in this Report.

FOLLOW-UP SERVICE

Periodic unannounced audits of the manufacturing facility (and any locations authorized to apply the mark) shall be scheduled by Intertek. An audit report shall be issued after each visit. Special attention will be given to the following:

1. Conformance of the manufactured product to the descriptions in this Report.
2. Conformance of the use of the ETL mark with the requirements of this Report and the Certification Agreement.
3. Manufacturing changes.
4. Performance of specified Manufacturing and Production Tests.

In the event that the Intertek representative identifies non-conformance(s) to any provision of this Report, the Applicant shall take one or more of the following actions:

1. Correct the non-conformance.
2. Remove the ETL Mark from non-conforming product.
3. Contact the issuing product safety evaluation center for instructions.

10.1 Evaluation of Unlisted Components

Because Unlisted Components are uncontrolled, and they do not fall under a third party follow up program, Intertek may require these components to be tested and/or evaluated at least once annually, more often for certain components, as part of the independent certification process. The Unlisted Components in Section 5.0 require testing and/or evaluation as indicated.

The Applicant will be notified, in writing, via the applicable contact methods, as defined in Section 1.0, when these components must be selected and sent to Component Evaluation Center (CEC) for re-evaluation.

Due to particular testing requirements, some components may be requested to be shipped to specific labs. Thus, specific shipment destination(s) for each sample will be provided in the written notification.


Managing CEC Location:
Intertek Testing Services Shanghai Limited
ETL Component Evaluation Center
Building No. 86, 1198 Qinzhou Road (North)
Shanghai 200233, China
Attn: Ms. Emiliana Zhou

Sample Disposition: Due to the destructive nature of the testing, all samples will be discarded at the conclusion of testing unless, the manufacturer specifically requests the return of the samples. The request for return must accompany the initial component shipment.

11.0 Manufacturing and Production Tests
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None

12.0 Revision Summary					
The following changes are in compliance with the declaration of Section 8.1:					
Date/ Proj #	Site ID	Project Handler/ Reviewer	Section	Item	Description of Change
					None

TEST REPORT ANSI/CAN/UL 9540A:2019 Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	
Report Reference No.....	221000882SHA-001
Tested by (name + signature).....	Chuanhui Xie <i>Chuanhui Xie</i>
Approved by (name + signature)	Robin Xu <i>Robin Xu</i>
Total number of pages.....	36
Date of issue	2023-01-18
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	Shenzhen Lithium Valley Technology Co., Ltd.
Address.....	Room 2018, Huilong Business Center Minzhi Street, Longhua District, Shenzhen, Guangdong P.R.China
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	
This publication may be reproduced in whole or in part for non-commercial purpose as long as Intertek is acknowledged as copyright owner and source of the material. Intertek takes no responsibility and will not assume liability for damages resulting from the reader's interpretation of the reproduced material due to its placement and context.	
Test item description.....	
Rechargeable Li-ion battery	
Trade Mark.....	
	
Manufacturer.....	
Dongguan Lithium Valley Energy Co., Ltd.	
Model/Type reference.....	
LV-BAT-R5.12Ab	
Ratings.....	
51.2 V, 100 Ah	
General disclaimer: This report is for the exclusive use of Intertek's Client and is provided pursuant to the agreement between Intertek and its Client. Intertek's responsibility and liability are limited to the terms and conditions of the agreement. Intertek assumes no liability to any party, other than to the Client in accordance with the agreement, for any loss, expense or damage occasioned by the use of this report. Only the Client is authorized to permit copying or distribution of this report and then only in its entirety. Any use of the Intertek name or one of its marks for the sale or advertisement of the tested material, product or service must first be approved in writing by Intertek. The observations and test results in this report are relevant only to the sample tested. This report by itself does not imply that the material, product, or service is or has ever been under an Intertek certification program.	

List of attachments:

- Attachment 1 – Photos
 - Attachment 2 – Module Conditioning (charge/discharge) profiles
 - Attachment 3 – 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 20221208-1.mp4 is provided in addition to this test report.

Summary of testing:

Thermal runaway Propagation	Yes
Peak chemical heat release rate HRR (kW).....	2.23 kW
Peak smoke release rate SRR (m ² /s).....	0.37 m ² /s
Total smoke release TSR (m ²)	64.67 m ²
Total Hydrocarbons (equivalent to C ₃ H ₈ , measured by FID)....	74.7 L
Module weight loss	7.6 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

Testing:

Date of receipt of test items	2022-10-14
Date(s) of test performed.....	2022-12-07 to 2022-12-08

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 information

Manufacturer.....: RUIPU ENERGY CO., LTD.
 Model name.....: CB27173204EA- 100Ah
 Chemistry.....: LiFePO₄
 Physical configuration.....: Prismatic
 Dimension (W*L*H): (207.01±0.6) mm * (174.7±0.6) mm * (27.5±1.0) mm
 Weight.....: 2100±100 g
 Nominal voltage.....: 3.2 V
 Rated capacity.....: 100 Ah
 If the cell compliance with UL 1973.....: Report No. CN212RU5 001

Standard charge method

Charge current.....: 100 A
 End of charge voltage.....: 3.65 V
 Cut off current.....: 5 A

Standard discharge method

Discharge current.....: 100 A
 End of discharge voltage.....: 2.5 V

Test result from cell level 9540A test report

Cell level test report.....: Report No. CN21GRDU 001 (TUV Rheinland)
 Average cell venting temperature: 209.4 °C
 Average cell thermal runaway onset temperature.....: 270.7 °C
 Gas volume.....: 280L
 Gas composition.....: H₂:52.934%, CO:8.665%, CO₂:22.801%,
 Hydrocarbon:15.6%
 LFL at ambient temperature.....: 5.6% at 24±2°C and 108±2kPa
 LFL cell venting temperature.....: 4.5% at 200±2°C and 108±2kPa
 Burning velocity.....: 83.6 cm/s
 P_{max}.....: 1.015MPa

Module information

Manufacturer.....: Dongguan Lithium Valley Energy Co., Ltd.
 Address.....: Fuzhu 4th Street, Zhangyang community, Zhangmutou town Dongguan City, 523637 Guangdong P.R.China
 Model name.....: LV-BAT-R5.12Ab

Physical configuration

Enclosure material.....: Metal
 Dimension.....: 440 mm*550mm*130mm
 Weight.....: 47 kg
 Cells in series/parallel:: 16S1P
 Total number of cells:: 16 cells
 Cooling method.....: Nature cooling
 Separation between cells: No separation.

Electrical rating

Rated capacity: 100 Ah
 Rated energy: 5120 Wh
 Nominal voltage: 51.2 V

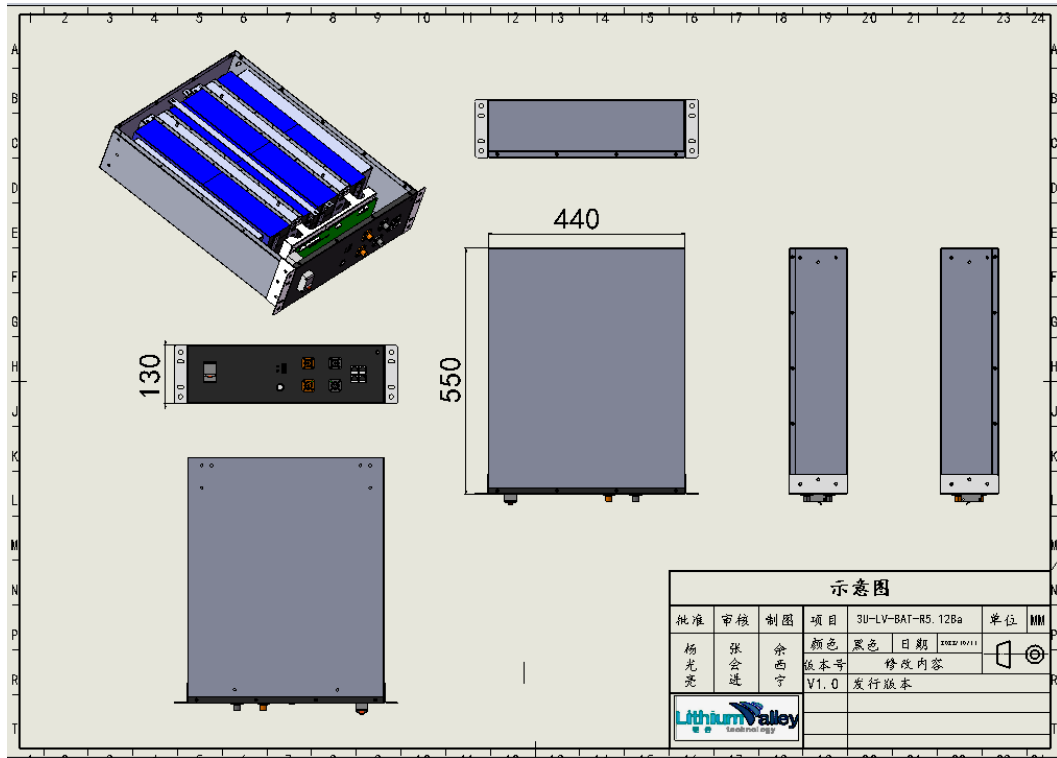
Standard charge method

Charge current.....: 33 A
 End of charge voltage.....: 56.16 V

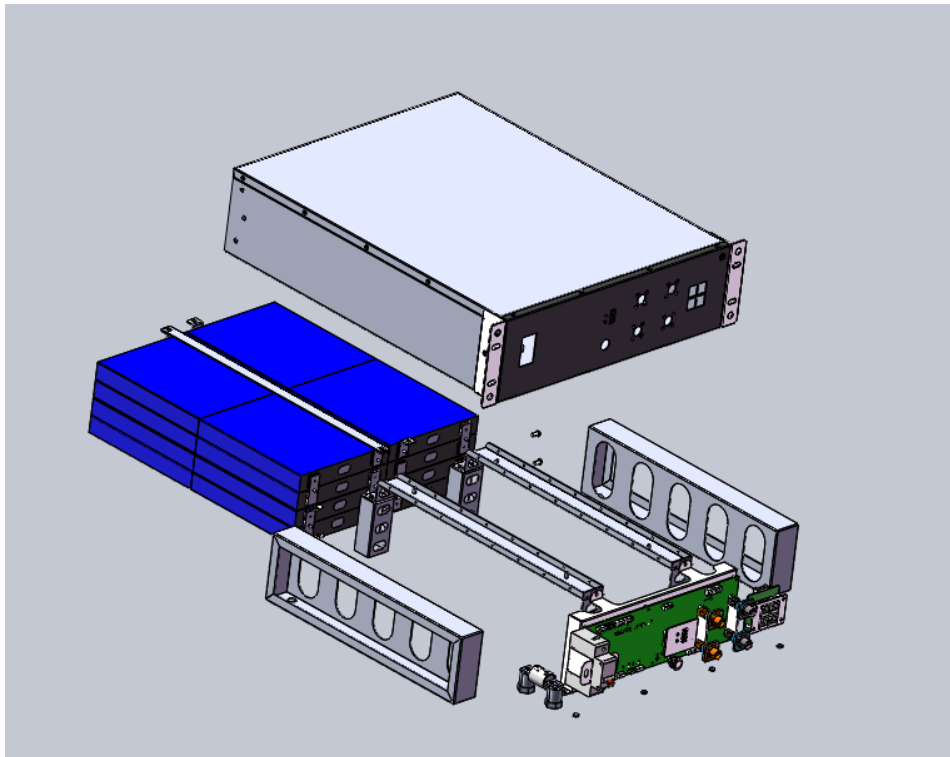
Standard discharge method

Discharge current: 33 A
 End of discharge voltage: 44.8 V
 If the module compliance with UL 1973: Certificate not provided.

Diagram of module with overall dimension



Contents (main components) of the module



Layout of the module contents

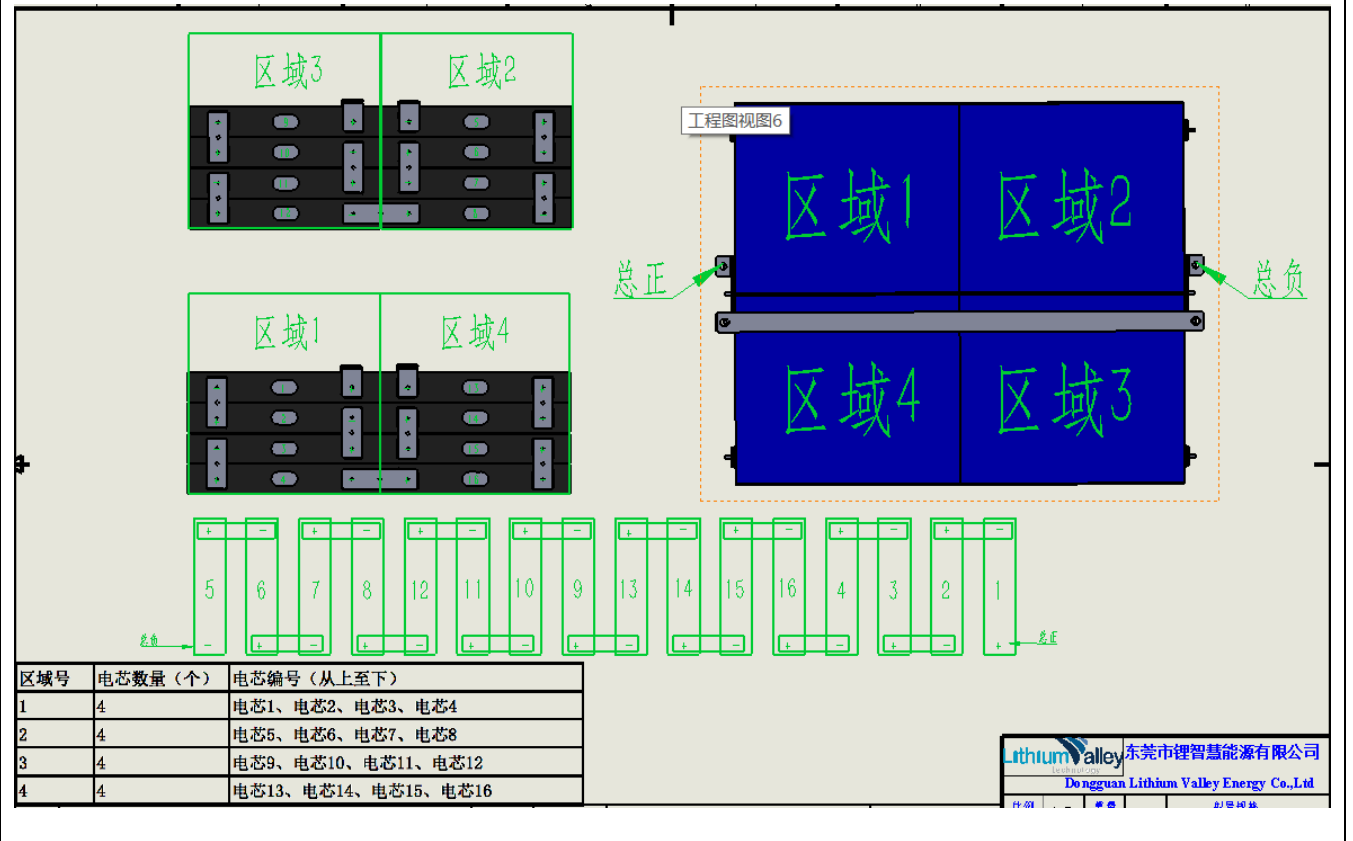


Photo of the module



ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
5	Construction – 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.		Pass
5.1.2	The cells associated with the BESS comply with ANSI/CAN/UL 1973 or not.	Report No. CN212RU5 001	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.	Certificate not provided.	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
	<ul style="list-style-type: none"> the chemistry; 		N/A
	<ul style="list-style-type: none"> a generic description of the electrolyte (s); 		N/A
	<ul style="list-style-type: none"> the overall dimensions of the individual stack; 		N/A
	<ul style="list-style-type: none"> 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
	<ul style="list-style-type: none"> the manufacturer's name and model number of the system; 		N/A
	<ul style="list-style-type: none"> the electrical rating in volts and rated storage capacity in Ah or Wh; 		N/A
	<ul style="list-style-type: none"> the number of cells and stacks in the system; 		N/A
	<ul style="list-style-type: none"> 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	Module 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

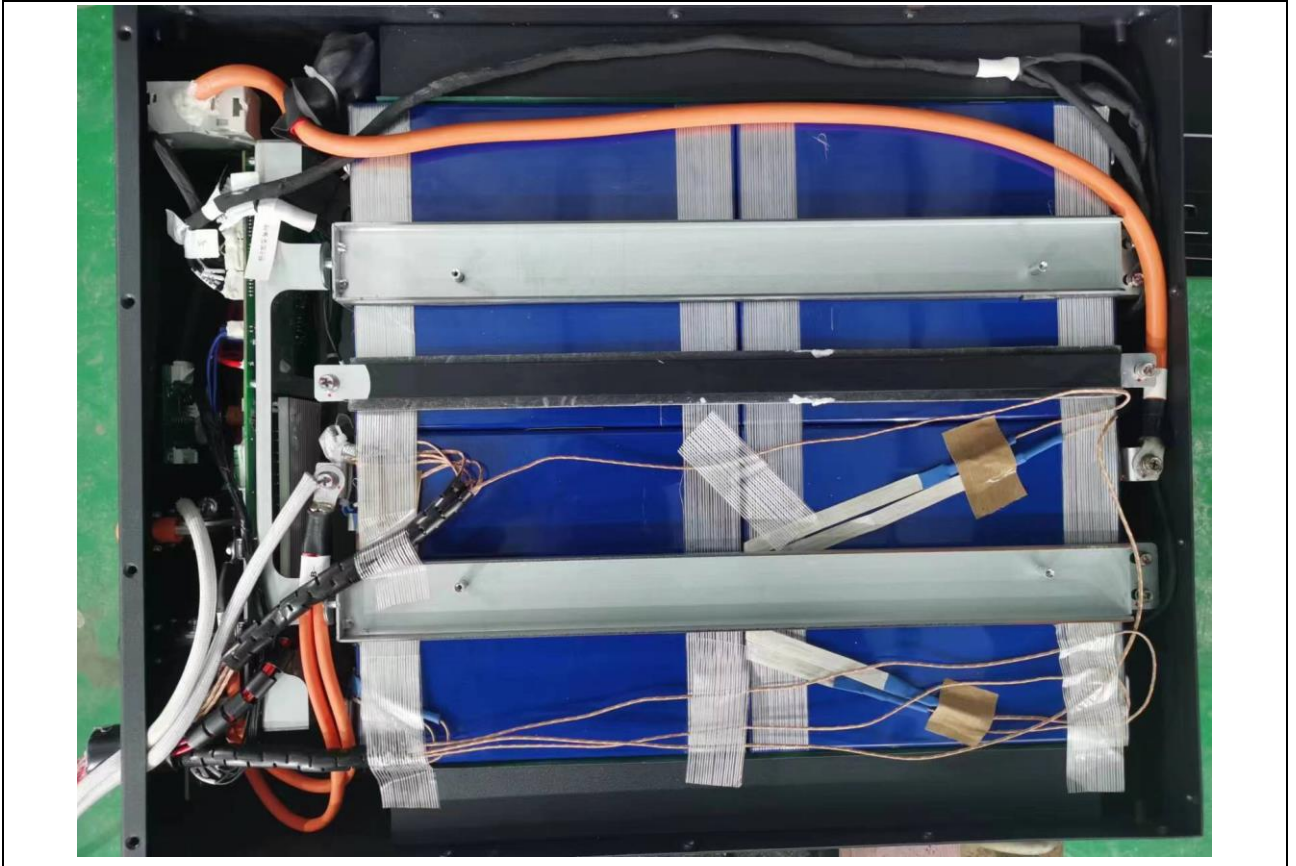
ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
8.2.2	The test conducted under a smoke collection hood sized appropriately to collect the gasses generated.		Pass
8.2.3	The weight of the module shall be recorded before and after testing is completed.	See attachment 3	Pass
8.2.4	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: $HRR_i = [E \times \varphi - (E_{CO} - E) \times \frac{1-\varphi}{2} \times \frac{X_{CO}}{X_{O_2}}] \times \frac{\dot{m}_e}{1+\varphi \times (\alpha-1)} \times \frac{M_{O_2}}{M_a} \times (1-X_{H_2O}^e) \times X_{O_2}^e$	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	Three different kind of sensors were used. H ₂ was not detected by the palladium-nickel thin-film solid state sensor and heat conduction sensor. The value in attachment 6 was measured by electrochemistry 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 intergerated into the testing system	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
8.2.15	Smoke release rate shall be calculated as follows: $SRR = 2.303 \left(\frac{V}{D} \right) \text{Log}_{10} \left(\frac{I_o}{I} \right)$	See attachment 7	Pass
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;	7.6 kg	Pass
	o) Video of the test.	20221208-1.mp4 is provided	Pass

Attachment 1 Photos

Before test





During test



Test started

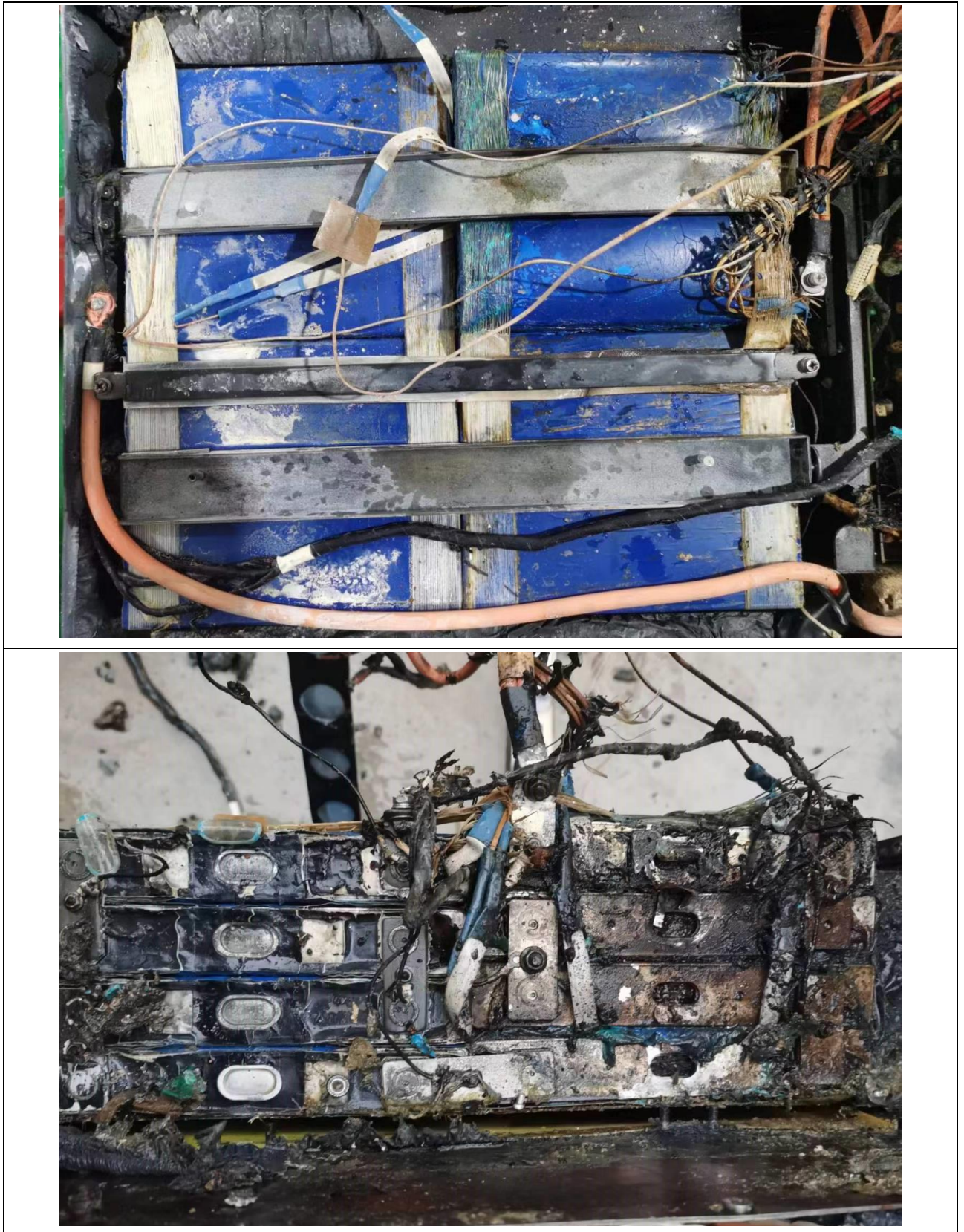


First vent observed



Thermal runaway observed
After test





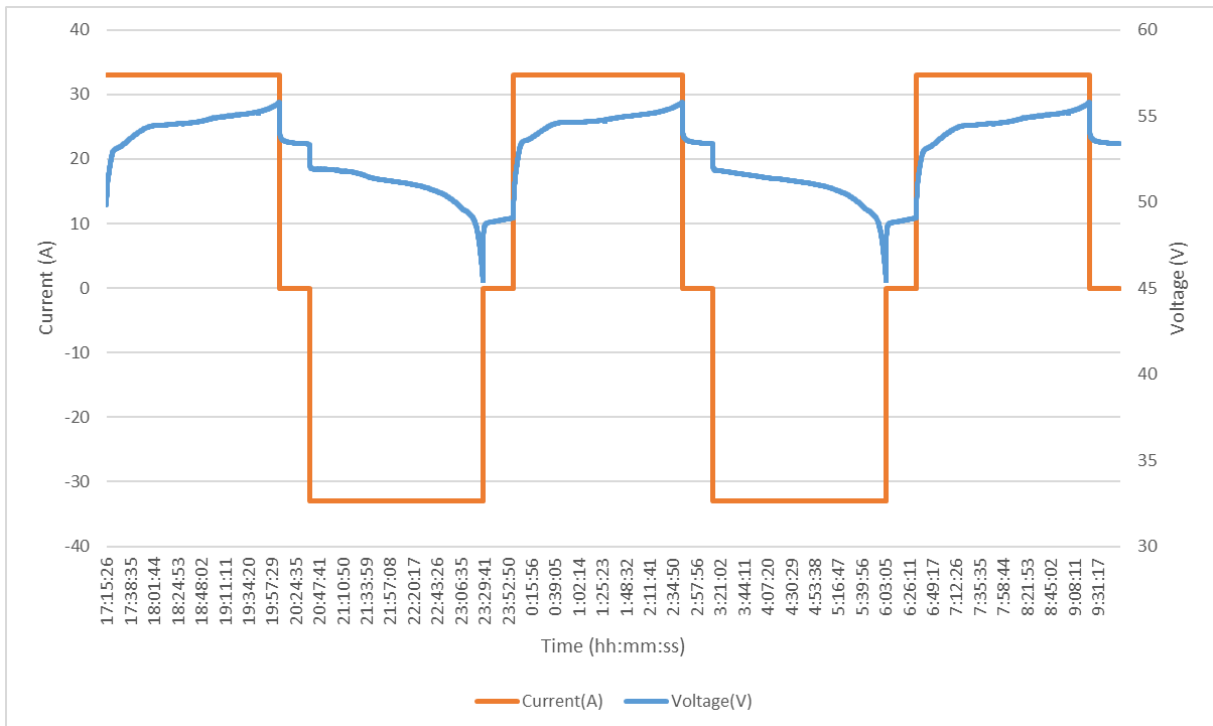


Attachment 2 Module Conditioning (charge/discharge) profiles

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 33A current to module end charge voltage 56.16 V, then keep the module stabilized for 30 minutes. After being stabilized, the module was discharged with 33A current to module end discharge voltage 44.8 V, then keep the module stabilized for 30 minutes.

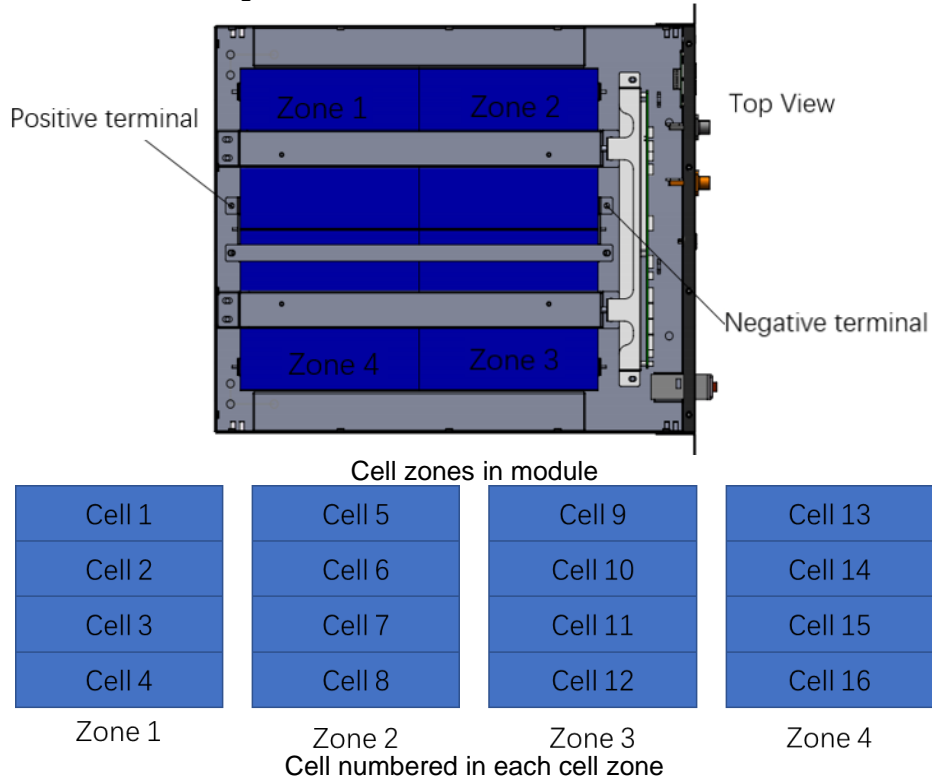
After repeat the cycle above twice and then module was fully charged with 33A current to module end charge voltage 56.16 V, and before testing, the module was stabilized for about 3 hours. During conditioning the ambient temperature was maintained in 25 ±5°C and 50 ±25% RH.



Module charge and discharge voltage/current profiles

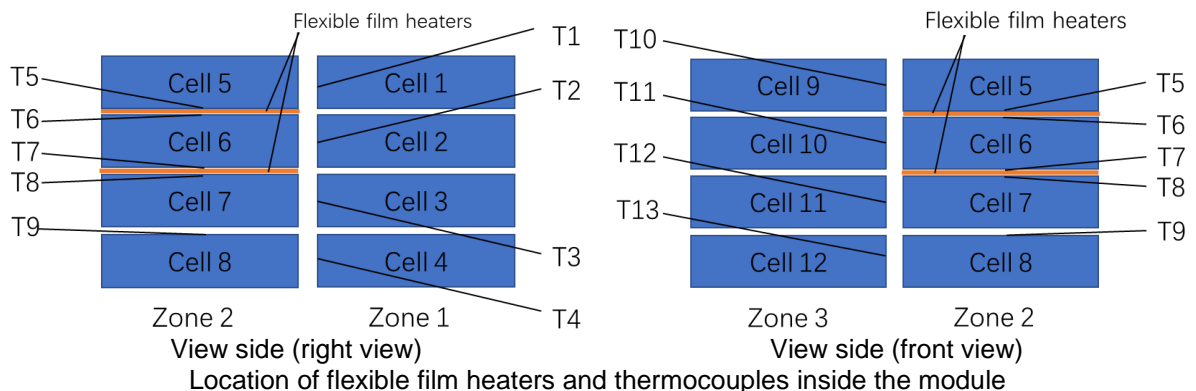
Attachment 3 Module thermal runaway record

There are 4 cell zones (zone 1 to zone 4) in module, every cell zone consists of 4 cells, the cell numbered in each cell zone is shown in below figure.



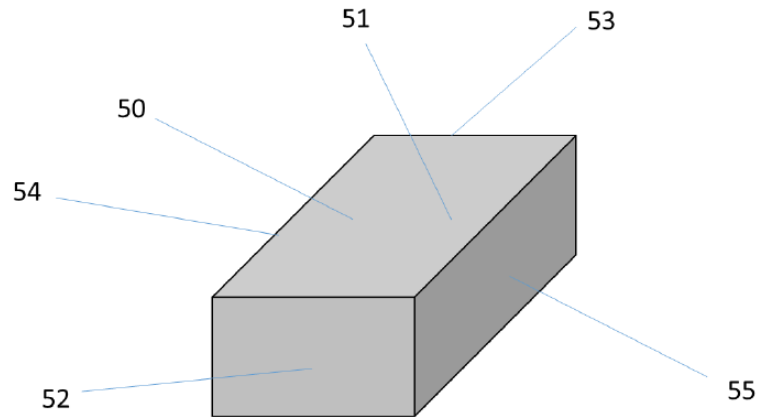
External heating method was used to initiate thermal runaway in the module. 2 flexible film heaters, rated 220VAC/500W, sized 170*200mm, were pasted on big sides of cell 6.

To monitor the cells temperature inside the module, 13 thermocouples, Type K, were used inside the module. See below figure and table for detail location of the film heaters and thermocouples.



Thermocouple No.	Location
T1-T4	Center of bottom narrow side of Cell 1 to Cell 4, facing Cell 5 to Cell 8
T5	Center of wide side of Cell 5, facing Cell 6.
T6	Center of wide side of Cell 6, facing Cell 5, under film heater.
T7	Center of wide side of Cell 6, facing Cell 7, under film heater.
T8	Center of wide side of Cell 7, facing Cell 6.
T9	Center of wide side of Cell 8, facing Cell 7.
T10-T13	Center of narrow side of Cell 9 to Cell 12, facing Cell 5 to 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

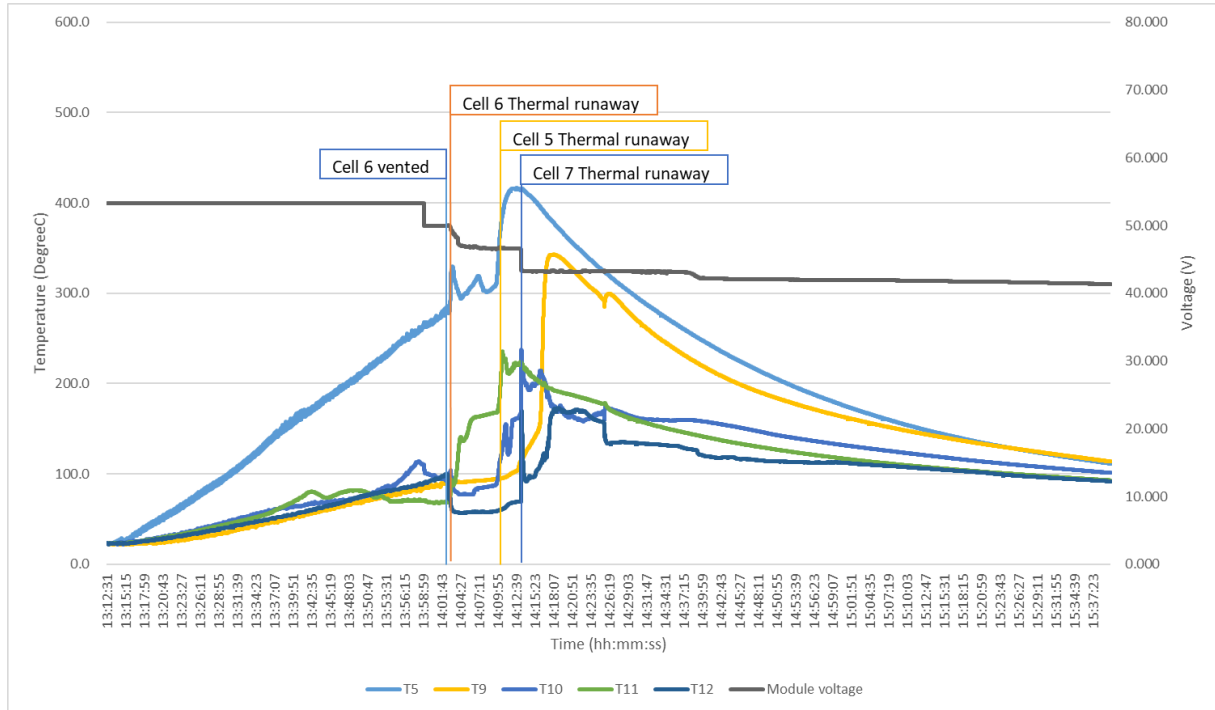
Thermocouple No.	Location
50	Enclosure top side, correspond to center of cell zone 3
51	Enclosure top side, correspond to center of cell zone 2
52	Centre of enclosure front side
53	Centre of enclosure back side
54	Centre of enclosure left side
55	Centre of enclosure right side

Cell 6 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:

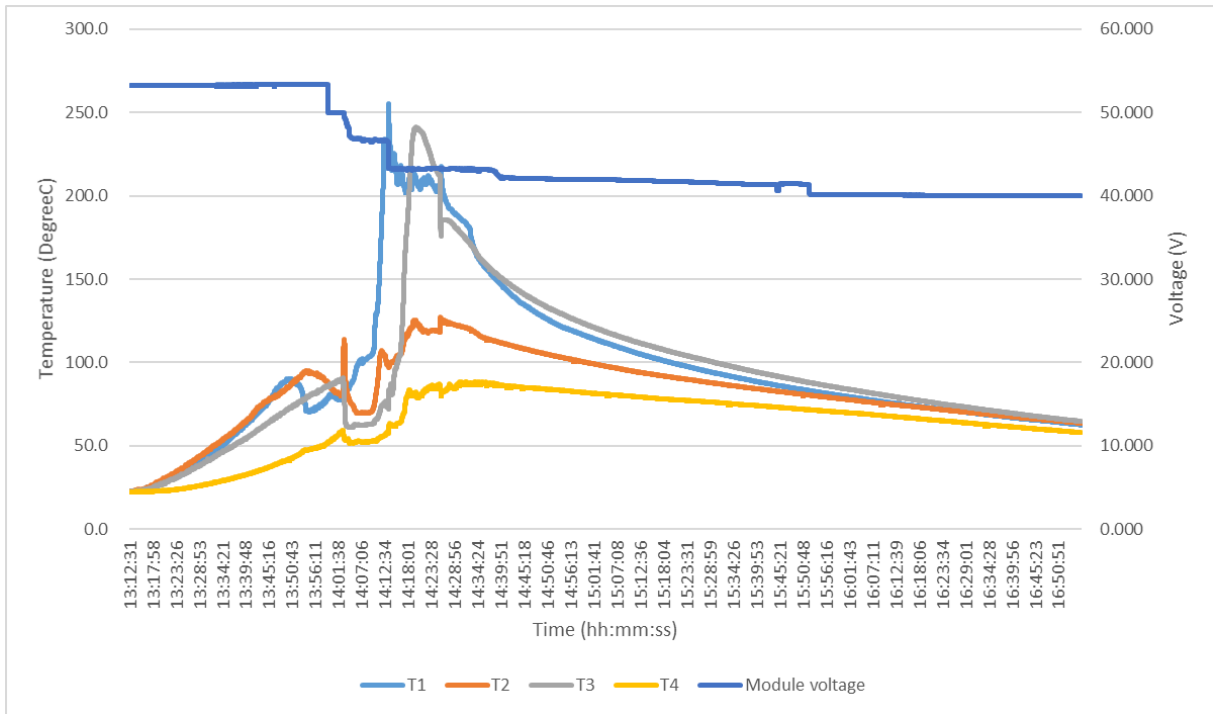
Ambient conditions at the initiation of the test:	25.1°C 35.1%RH			
Module voltage before test:	53.27 V			
Module voltage after test:	40.05 V			
Module weight before test	48.1 kg (with test auxiliary material)			
Time when test was initiated:	2022.12.08 13:12			
Observations during test:	1 st vented	14:02	1 st thermal runaway	14:03
	2 nd vented	14:03	2 nd thermal runaway	14:09
	3 rd vented	14:13	3 rd thermal runaway	14:13
	4 th vented	14:25	4 th thermal runaway	Not observed
	5 th vented	Not observed	5 th thermal runaway	
	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 6 went to thermal runaway due to external heating. Cell 5, cell 7 vented and went to thermal runaway due to thermal runaway propagation. Cell 8 vented due to thermal runaway propagation.			
Module weight after test	40.5 kg (with test auxiliary material)			
Module weight loss	7.6 kg			

Attachment 4 Temperature and voltage profile during test

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



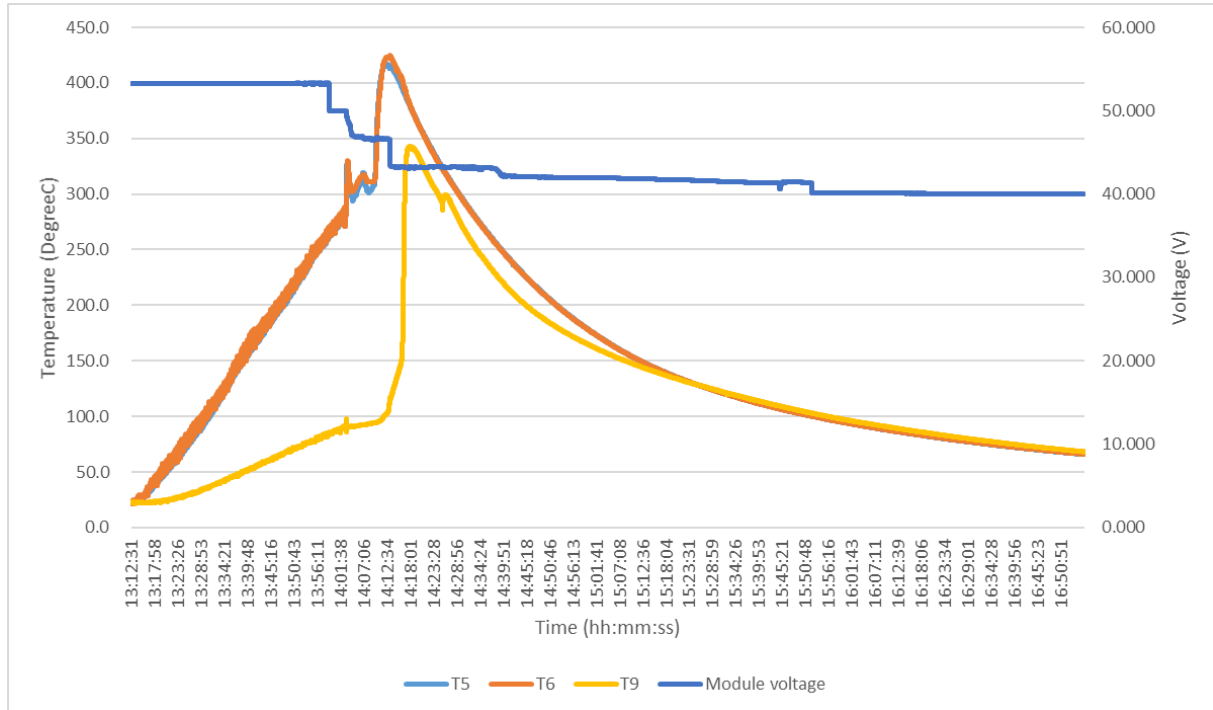
Measured temperature inside the module and module voltage during the test are shown in below figure.



Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
T1	Center of bottom narrow side of Cell 1, facing Cell 5.	255.1
T2	Center of bottom narrow side of Cell 2, facing Cell 6.	127.3
T3	Center of bottom narrow side of Cell 3, facing Cell 7	241.1
T4	Center of bottom narrow side of Cell 4, facing Cell 8.	88.5

Measured temperature inside the module and module voltage during the test are shown in below figure. Thermocouple No. T7 and T8 were broken during test and hence not shown in below figure.



Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
T5	Center of wide side of Cell 5, facing Cell 6.	416.4
T6	Center of wide side of Cell 6, facing Cell 5, under film heater.	424.5
T7	Center of wide side of Cell 6, facing Cell 7, under film heater.	Damaged
T8	Center of wide side of Cell 7, facing Cell 6.	Damaged
T9	Center of wide side of Cell 8, facing Cell 7.	342.8

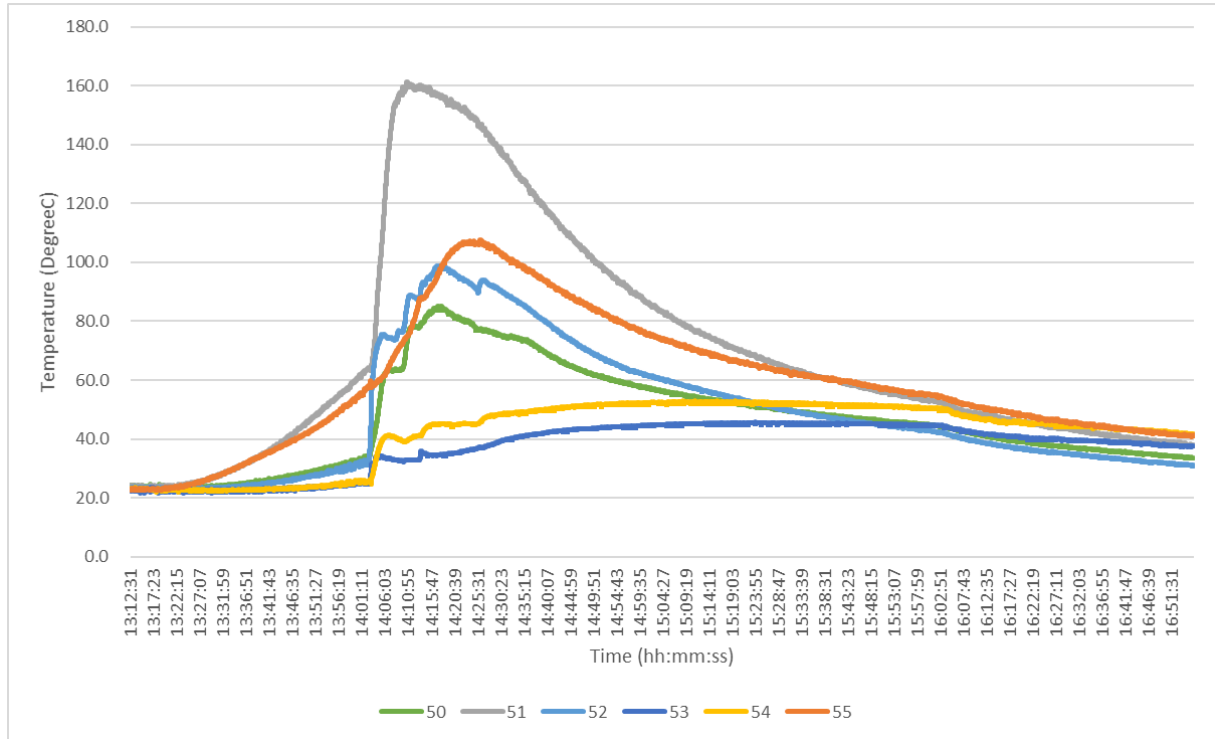
Measured temperature inside the module and module voltage during the test is shown in below figure.



Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
T10	Center of narrow side of Cell 9, facing Cell 5	237.8
T11	Center of narrow side of Cell 10, facing Cell 6	236.2
T12	Center of narrow side of Cell 11, facing Cell 7	172.8
T13	Center of narrow side of Cell 12, facing Cell 8	105.4

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



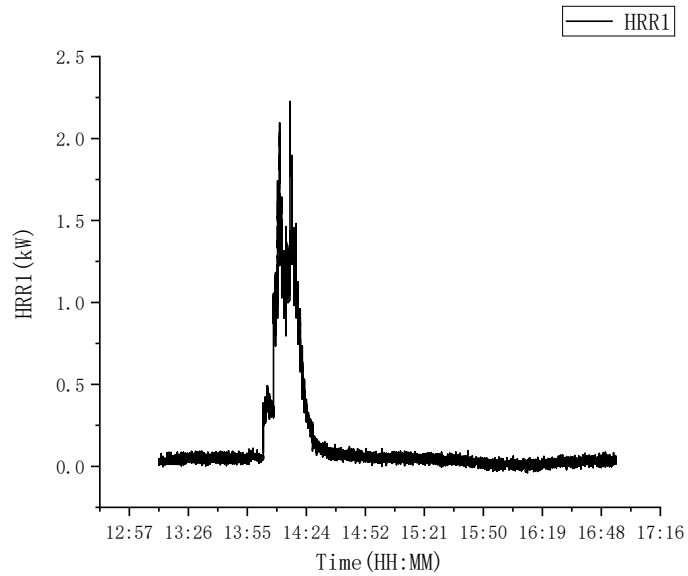
Maximum measured temperature of each location is shown in below table

Thermocouple No.	Location	Maximum measured temperature (°C)
50	Enclosure top side, correspond to center of cell zone 3	85.2
51	Enclosure top side, correspond to center of cell zone 2	161.3
52	Centre of enclosure front side	98.8
53	Centre of enclosure back side	45.7
54	Centre of enclosure left side	52.9
55	Centre of enclosure right side	107.6

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=2.23 kW



HRR Curve

Attachment 6 Gas generation measurement

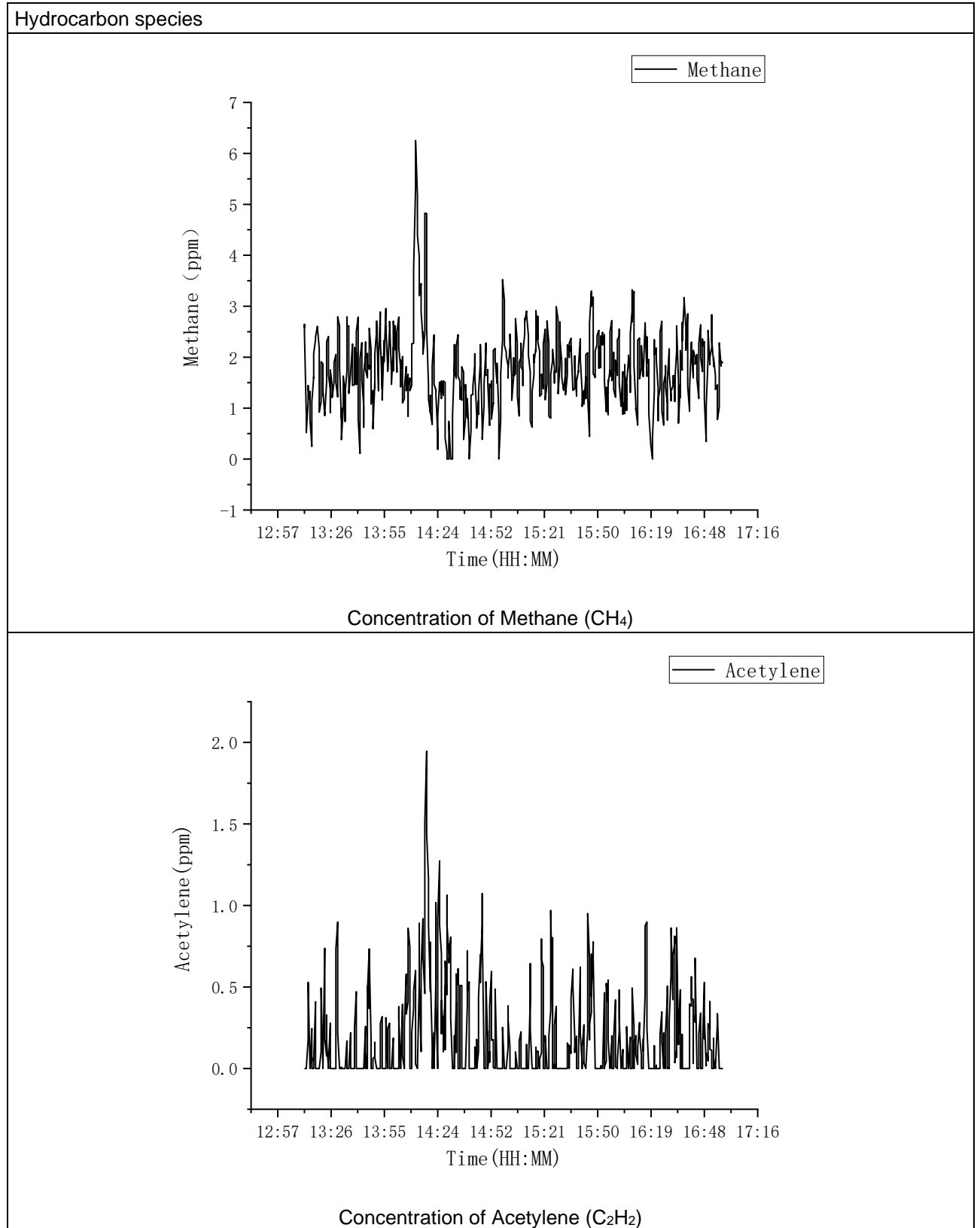
Vent gas compositions were measured using a Fourier-Transform Infrared Spectrometer within the calorimeter's exhaust duct. And the composition, velocity and temperature of the vent gases were measured within the calorimeter's exhaust duct.

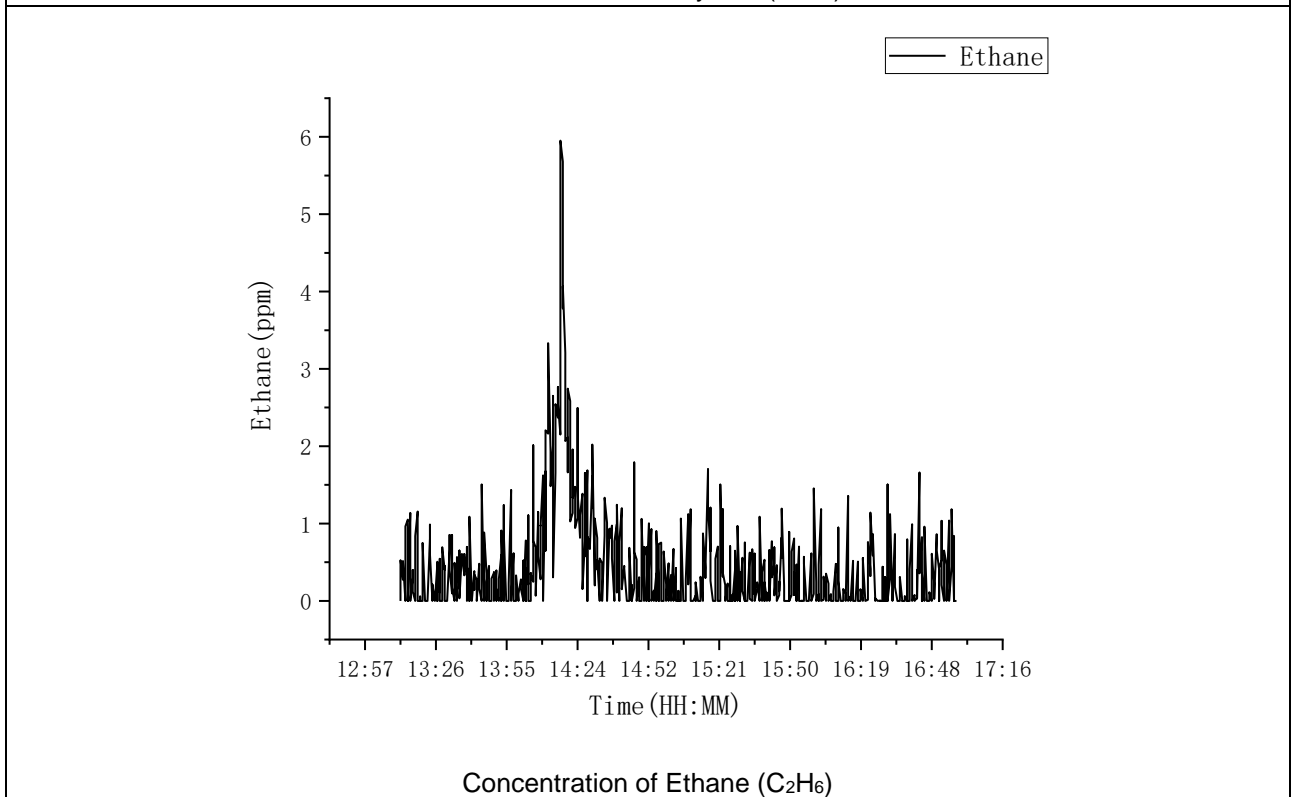
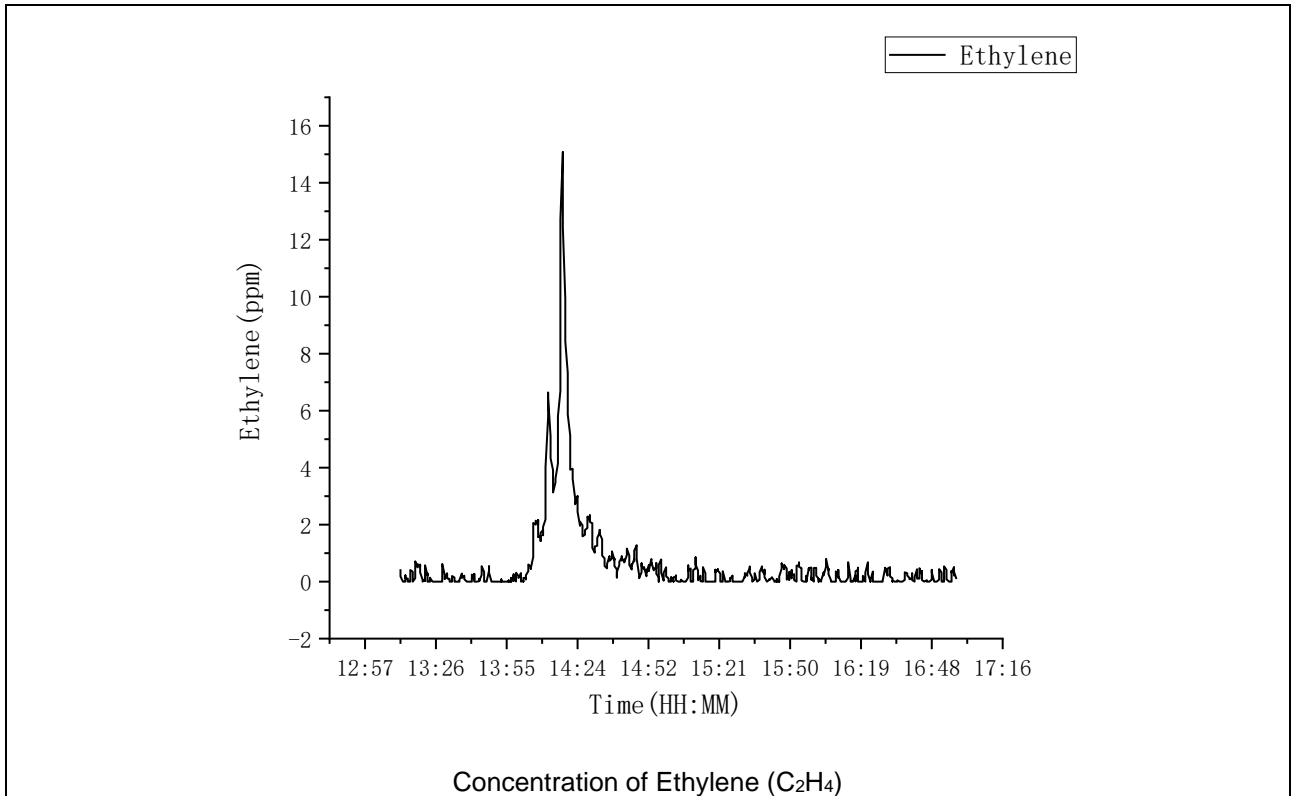
The hydrocarbon content of the vent gas was measured using flame ionization detection. The hydrogen content was measured with a palladium-nickel thin-film solid state sensor, a heat conduction sensor and an electrochemistry sensor. The hydrogen was not detected by the palladium-nickel thin-film solid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

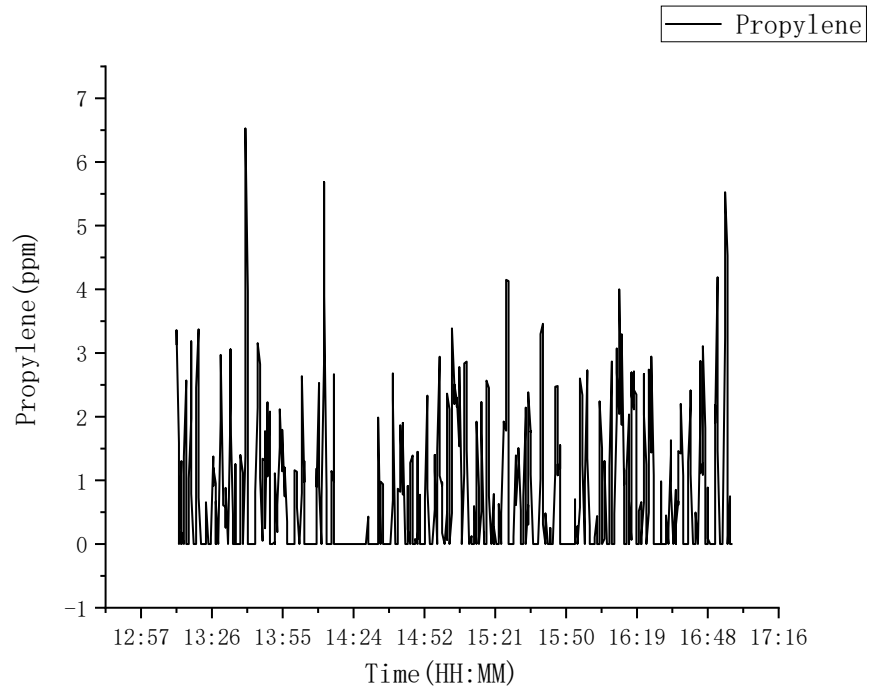
The gas composition and volume are shown in below table

Gas type	Gas components		Volume (L)
Hydrocarbon species	Methane	CH ₄	16.7
	Acetylene	C ₂ H ₂	1.8
	Ethylene	C ₂ H ₄	6.1
	Ethane	C ₂ H ₆	4.3
	Propylene	C ₃ H ₆	7.2
	Propane	C ₃ H ₈	4.4
Hydrogen halide species	Hydrogen Fluoride	HF	9.4
Nitrogen containing species	Nitrogen Monoxide	NO	4.7
Other species	Carbon Monoxide	CO	6.3
	Carbon Dioxide	CO ₂	22.8
	Hydrogen (Palladium nickel thin film solid state sensor)	H ₂	0
	Hydrogen (TCD sensor)	H ₂	0
	Hydrogen (Electrochemical sensor)	H ₂	181.1
Total Hydrocarbons (equivalent to C ₃ H ₈ , measured by FID)			74.7

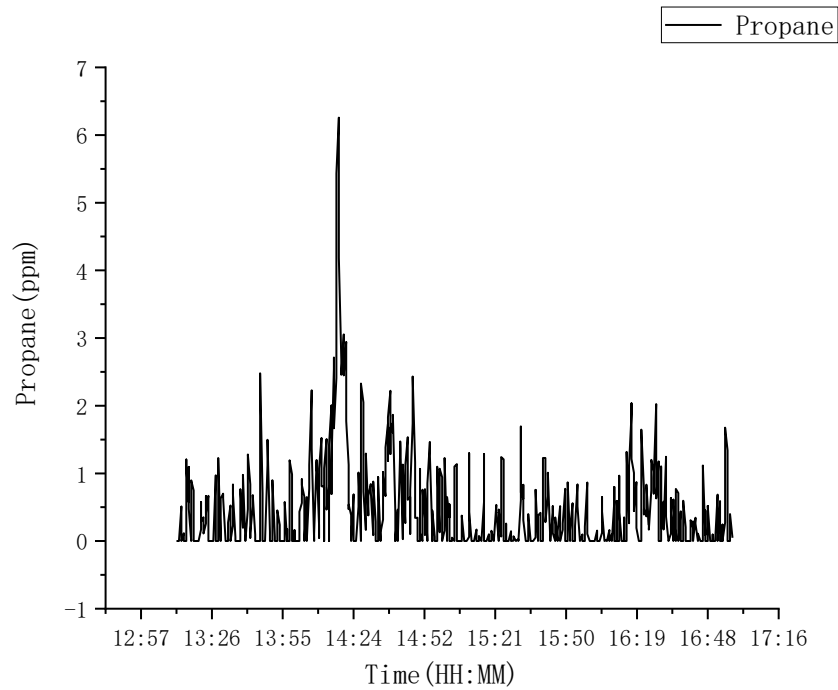
Concentration of different gas components according to gas species classification was displayed as following graphs





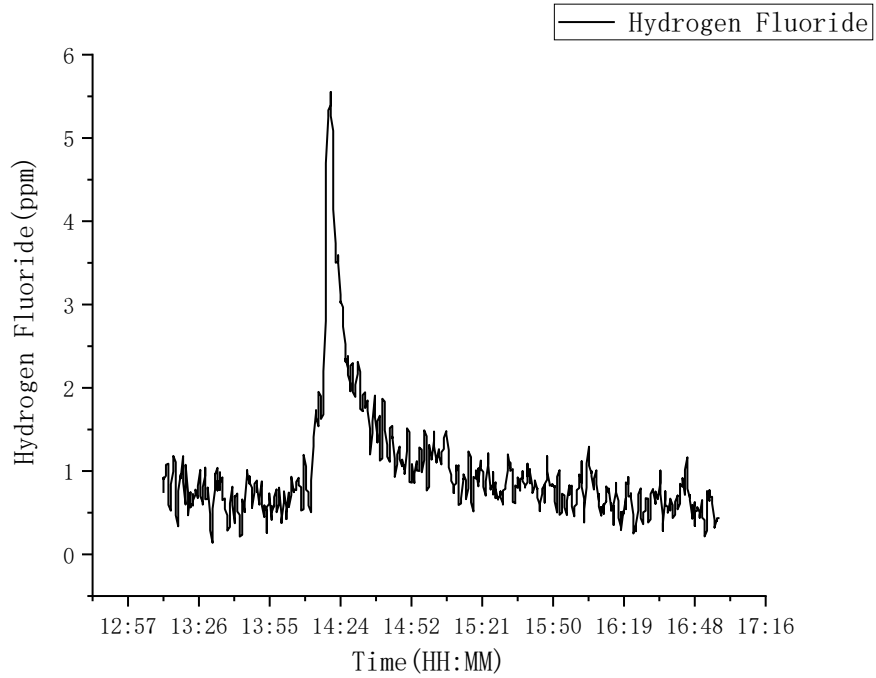


Concentration of Propylene (C₃H₆)



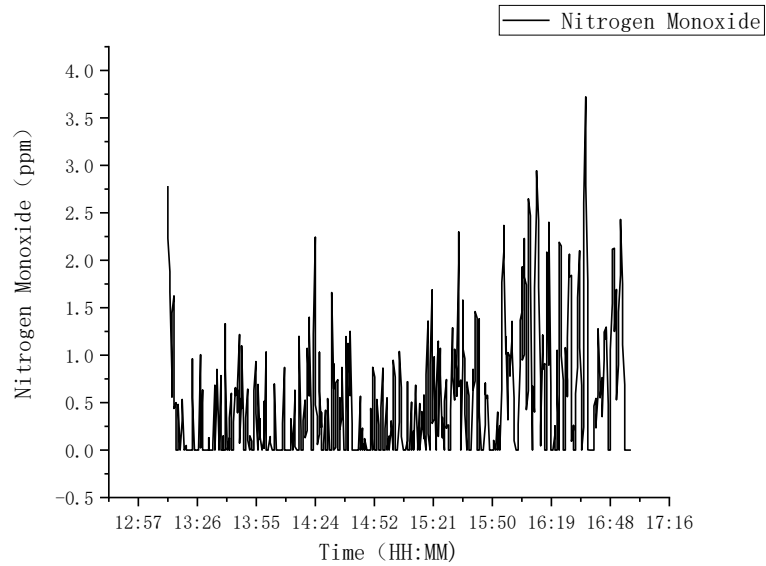
Concentration of Propane (C₃H₈)

Hydrogen halide species



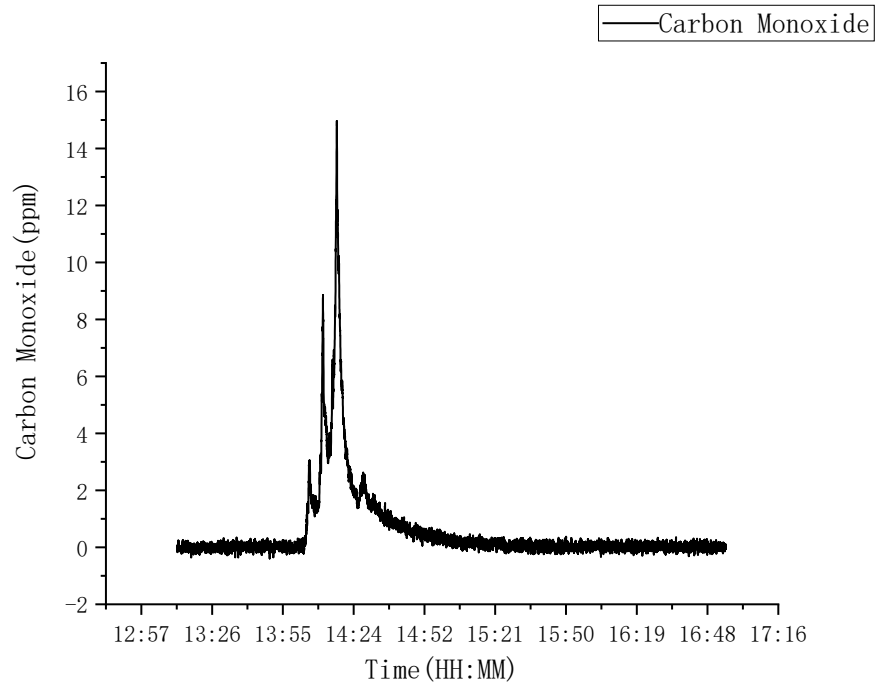
Concentration of Hydrogen Fluoride (HF)

Nitrogen containing species

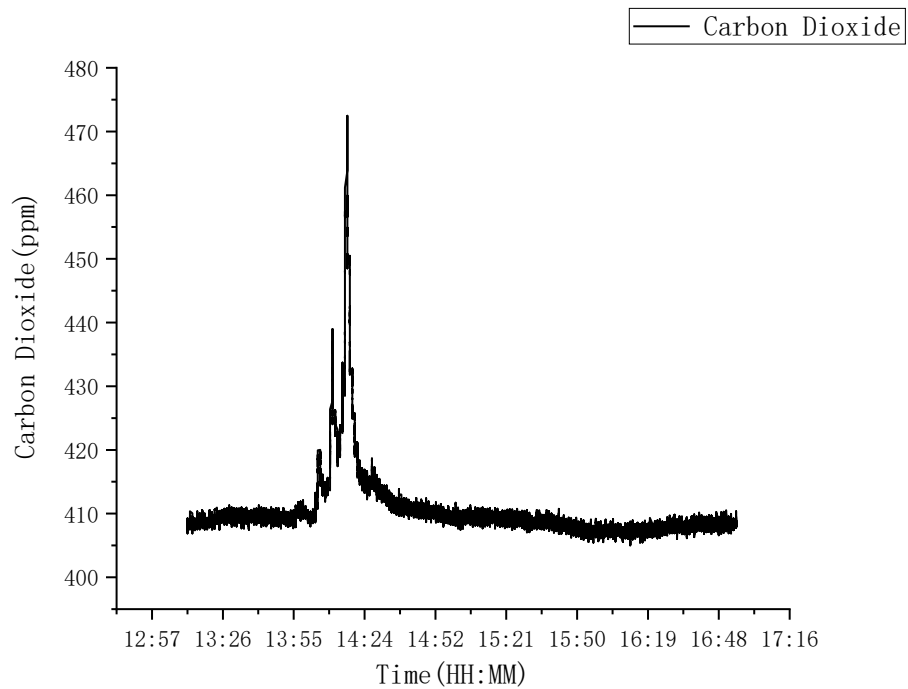


Concentration of Nitrogen Monoxide (NO)

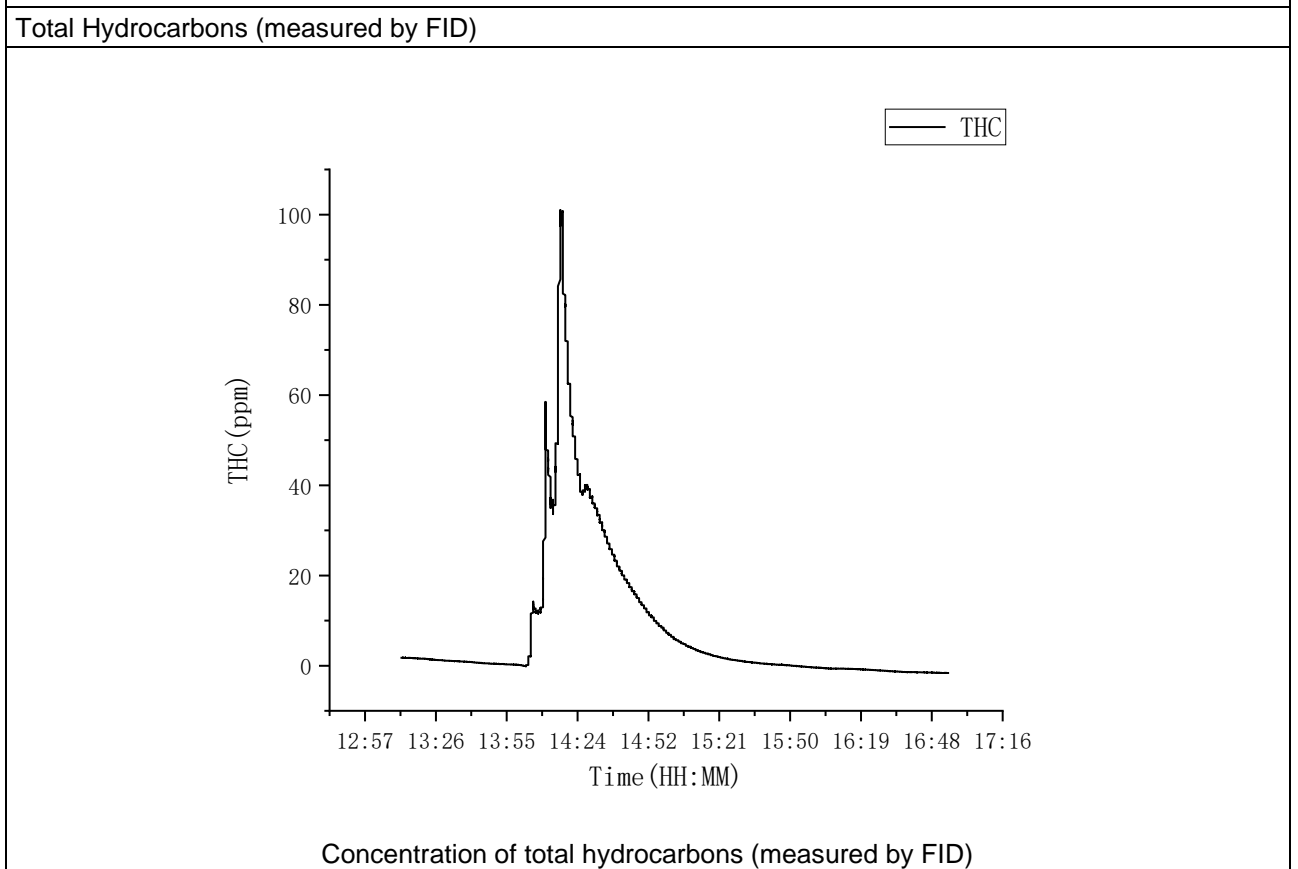
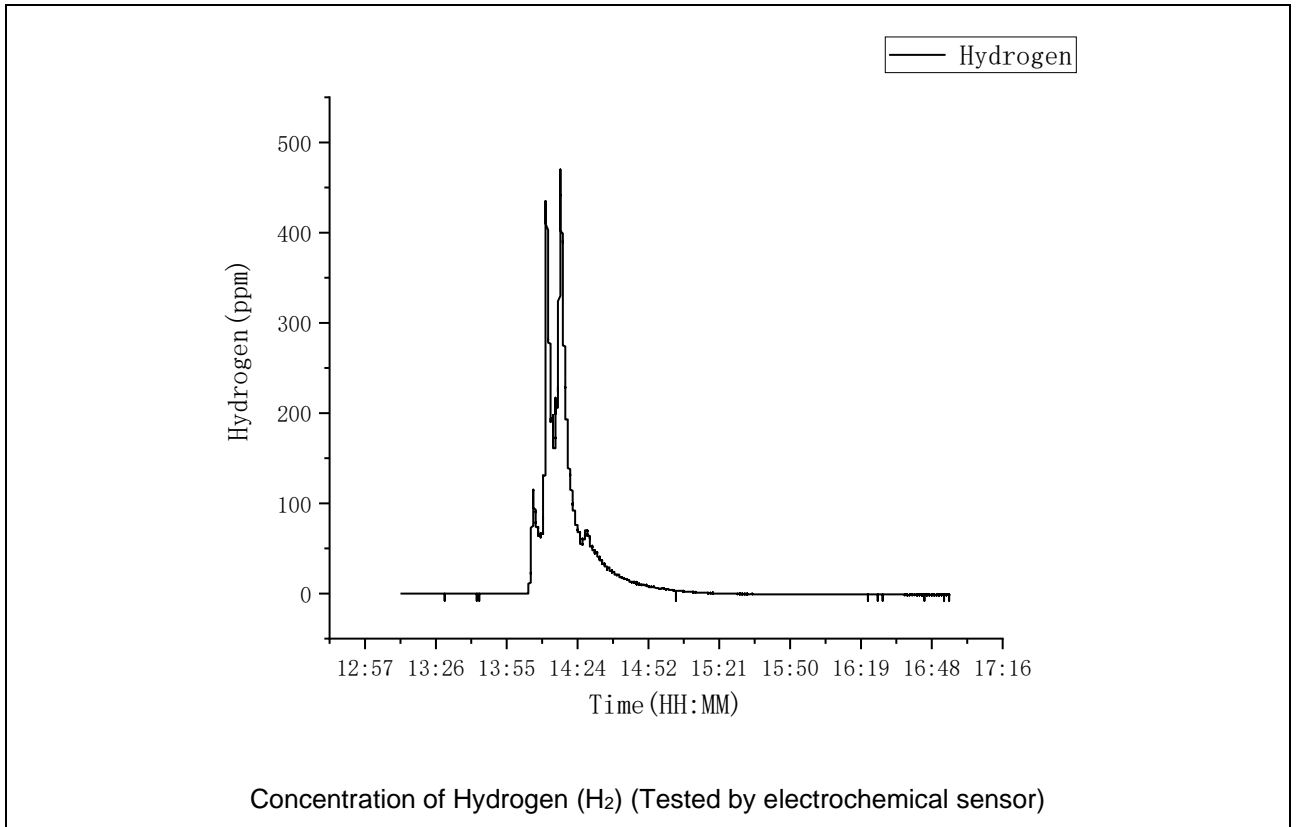
Other species



Concentration of Carbon Monoxide (CO)



Concentration of Carbon Dioxide (CO₂)



Attachment 7 Smoke release rate measurement

Smoke release rate shall be calculated as follows:

$$SRR = 2.303 \left(\frac{V}{D} \right) \text{Log}_{10} \left(\frac{I_0}{I} \right)$$

Where:

SRR = Smoke release rate (m²/s)

V = Volumetric exhaust duct flow rate (m³/s)

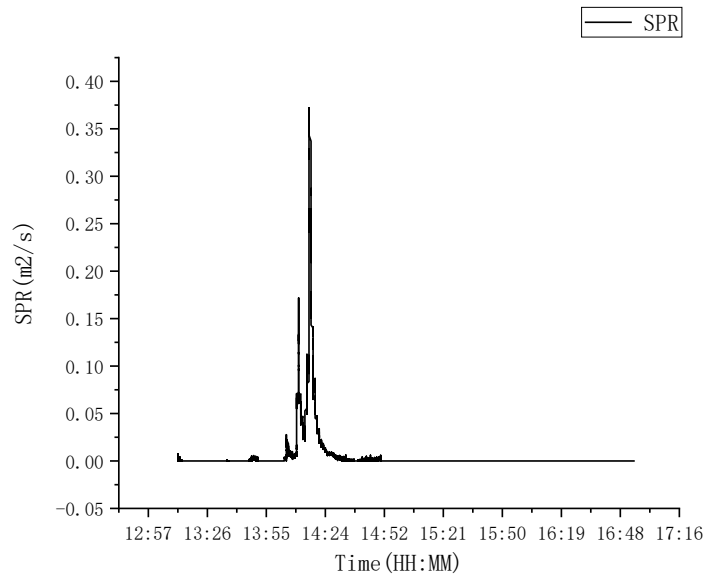
D = duct diameter (m)

I₀ = Light transmission signal of clear (pre-test) beam (V)

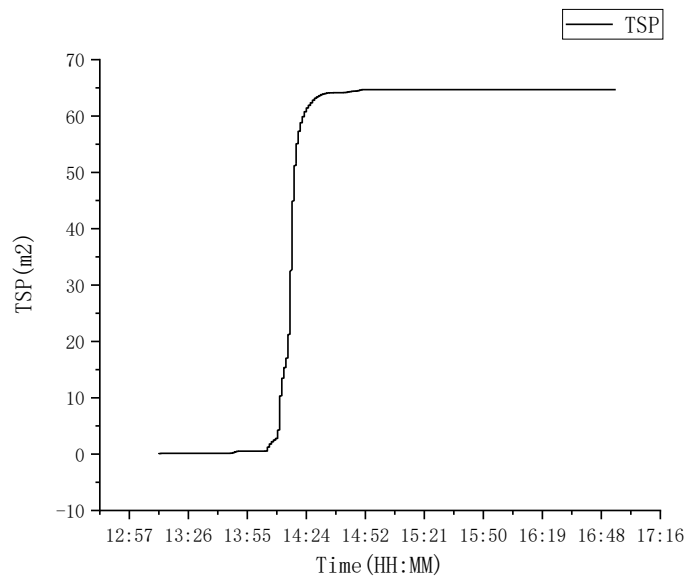
I = Light transmission signal during test (V)

Measured peak smoke release rate SRR: 0.37 m²/s

Measured total smoke release rate TSR: 64.67 m²



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	2022.02.25	
2	Digital multi-meter	FLUKE101	0-600V	S-038	2022.02.23	
3	Tape	1000mm 5000mm	0-1000mm 0-5000mm	S-040 S-042	2022.03.14 2022.03.14	
4	Electronic scale	TCS-500	0-500kg	S-039	2022.02.23	
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	2022.02.23 2022.02.23 2022.07.11 2022.02.23	
8	Oxygen consumption calorimeter measurement system	Paramagnetic oxygen analyzer	ABB AO2020	O2: 0-21% CO2:0-10% CO:0-1%	S-062-5~7	2022.08.11
		CO and CO2 sensor				
		Micro-differential pressure transmitter	DP101MD	-100~100Pa	S-024-4	2022.02.23
		Thermopile	TT I 20-CAXL-II 6U-10-SPW-M	0-1000°C	S-028-5~7	2022.02.26
		Light filter	—	25%, 50%, 75%	S-024-6 S-024-7 S-024-8	2022.03.07
		Gas mass flowmeter	Sevenstar D07-60G	0-8g/s	S-024-9	2022.03.29
9	Palladium-nickel thin-film solid state sensor	710B Model5000	1000ppm-100% 0-4%	S-023-5 S-023-2	2022.03.01	
10	Hydrogen sensor (TCD)	ABB AO2020	0-4%	S-62~8	2022.03.01	
11	Electrochemical hydrogen sensors	H ₂ 40000 H ₂ 1000	0-4% 0-0.1%	S-023-3~4	2022.03.01	
12	Fourier-Transform Infrared Spectrometer	MG6000	0.01ppm-100%	S-019	2022.03.01	
13	Flame Ionization Detector	ABB AO2020	0-30000ppm	S-062~10	2022.08.11	

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