MODULE TEST REPORT
UL 9540A
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)

Project Number. ..... :	**4791237445**
Date of issue ..... :	**2024.05.31**
Total number of pages ..... :	**30**
UL Report Office ..... :	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name ..... :	**Rubix Battery LLC**
Address ..... :	**2310 Township Road 444 Sugarcreek, OH 44681**
Test specification:	4th Edition, Section 8, November 12, 2019
Standard ..... :	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure ..... :	8.1 – 8.4
Non-standard test method ..... :	N/A

General disclaimer:

The test results presented in this report relate only to the sample tested in the test configuration noted on the list of the attachments.

UL LLC did not select the sample(s), determine whether the sample(s) was representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation or identification of component materials used in the test sample(s).

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Cell level information	
Cells in Module:	
●Manufacturer Name	REPT BATTERO Energy Co., Ltd.
●Part Number	CB56
●Chemistry	Lithium iron phosphate
●Format	Prismatic
Ratings (Vdc, Ah) :	3.2 Vdc, 100 Ah
Was the cell certified? :	Yes
Standard the cell was certified to:	UL 1973
Organization that certified the cell:	UL (MH64238)
Average cell surface temperature at gas venting, °C:	166
Average cell surface temperature at thermal runaway, °C:	210
Gas Volume:	58.9L
Lower flammability limit (LFL), % volume in air at the ambient temperature:	6.95
Lower flammability limit (LFL), % volume in air at the venting temperature:	5.95
Burning velocity (S_u) cm/s:	125
Maximum pressure (P_{max}) psig:	98.7

Cell Gas Composition:

Gas		Measured %
Carbon Monoxide	CO	9.302
Carbon Dioxide	CO_2	24.429
Hydrogen	H_2	57.227
Methane	CH_4	4.576
Acetylene	C_2H_2	0.164
Ethylene	C_2H_4	2.699
Ethane	C_2H_6	0.858
Propadiene (Allene)	C_3H_4	0.000
Propene	C_3H_6	0.264
Propane	C_3H_8	0.081
-	C4 (Total)	0.186
-	C5 (Total)	0.024
-	C6 (Total)	0.008
1-Heptene	C_7H_{14}	0.000
Benzene	C_6H_6	N.D
Toluene	C_7H_8	0.004
Dimethyl Carbonate	$C_3H_6O_3$	0.001
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.148
Total	-	100.0

Module level Information		
	Model No:	RS51100
	Ratings (Vdc, Ah):	51.2V, 100Ah
	Module cell configuration (xS/yP) ……:	16S/1P
	Module dimensions (W x D x H (mm)) :	520±1mm*575±1mm*165±1mm
	Module weight (kgs) :	49.3
	Module enclosure material:	Stainless steel
	Was the module certified? :	No
	Standard the module was certified to:	NA
	Organization that certified test item:	NA
	Cell failure test method performed for the module level (summary of method and test clause): ☒ External heating using thin film with 4°C to 7°C thermal ramp. ☐ Nail Penetration ☐ Overcharge ☐ External short circuit (***X*** Ω *external resistance*) ☐ Others	
	Description of method used to fail cells if other than external thin film heater with thermal ramp: **N/A**	
	Description of components employed within the module that serve to supress propagation (fire protection features). **N/A**	
	Number of initiating cells failed to achieve propagation.	1
	Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to at least seven adjacent cells
	Maximum Smoke Release Rate (m^2/s)	5.99
	Total Smoke Released: (m^2)	17078.83[1]
	Total smoke released duration	00:38:47 to 04:09:58
	Peak Chemical Heat Release Rate: (kW):	No flaming occurred
	External Flaming:	No external flaming occurred
	Location(s) of Flame Venting:	No flaming occurred
	Flying Debris:	No flying debris occurred
	Re-ignitions:	No further re-ignitions were observed during post test observation.

[1] The total smoke released information was affected by the equipment and for reference only.

Summary of Module level test Gas Analysis Data:

Gas Analysis:

☒ **Flame ionization detection**

☐ **Fourier-Transform infrared Spectrometer**

☒ **Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)**

☒ **White light source with photo detector (smoke release rate)**

- **Gas Composition & Volume for Each Compound (Pre-flaming and After flame):**

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	723.32	No flaming	0.05
Carbon Monoxide	Carbon Containing	89.27	No flaming	0.0
Carbon Dioxide	Carbon Containing	176.99	No flaming	1.24
Hydrogen	Hydrogen	326.29	No flaming	11.04

Summary of Module testing:

Performance Criteria in accordance with Clause 8.4 and Figure 1.1:

[X] The effects of thermal runaway was contained by the module design;

[ ] Cell vent gas (based upon the cell level test) was non-flammable

Necessity of a unit level test

[X] The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 4th edition has not been met, therefore unit level testing in accordance with UL 9540A will need to be conducted on a complete unit employing this module.

[ ] The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 4th edition has been met, therefore unit level testing in accordance with UL 9540A need not be conducted.

Testing Laboratory information

Testing Laboratory and testing location(s):

Testing Laboratory:	South Testing and Certification Co., LTD	
Testing location/ address .....:	Likou Road Section, Guangshan Road, Zengjiang Street, Zengcheng District, Guangzhou City, Guangdong Province, China	
Tested by (name, signature) .....:	Chen Shiyi, Olive Zhao	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) .....:	N/A	N/A
Project Handler (name, signature).....:	Gavin Chen	Gavin chen
Reviewer (name, signature) .....:	Benjamin Liu	Benjamin Liu

List of Attachments (including a total number of pages in each attachment):
Attachment A: Module Conditioning (Charge/discharge) Profiles **-** (*Pages **19** through **19***)
Attachment B: Module Construction Photos **-** (Pages ***20*** through ***20***)
Attachment C: Module Instrumentation Photos **-** (*Pages **21** through **22***)
Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing **-** (*Pages **23** through **23***)
Attachment E: Module Testing Photos **-** (*Pages **24** through **27***)
Attachment F: Module Gas Flow Rate and Heat Release Profiles **-** (*Pages **28** through **30***)

Photo(s) of module:

Test Item Charge/Discharge Specifications:	
• **Charge Current, A:**	**50**
• **Standard Full charge Voltage, Vdc:**	**58.4**
• **Charge temperature range, °C:**	**0-55**
• **End of charge Voltage, Vdc**	**N/A**
• **End of charge current, A:**	**5 or Any cell reaches 3.6V**
• **Discharge Current, A:**	**50**
• **End of discharge voltage, Vdc:**	**44.8**
• **Discharge temperature range, °C:**	**-20-55**

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Clause	Requirement + Test	Result - Remark	Verdict

Test item particulars..... :	
Possible test case verdicts:	
- test case does not apply to the test object.....:	N/A
- test object does meet the requirement.....:	P (Pass)
- test object does not meet the requirement.....:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Testing.....:	
Date of receipt of test item .....:	2024-04-26
Date (s) of performance of tests .....:	2024-05-08
General remarks:	
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report. **Throughout this report a point is used as the decimal separator.**	
Manufacturer's Declaration of samples submitted for test:	
The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided.....:	☐ **Yes** ☒ **Not applicable**
Name and address of factory (ies) .....:	Rubix Battery LLC 2310 Township Road 444 Sugarcreek, OH 44681
General product information and other remarks:	
Battery Module Model RS51100 employs cell Model CB56 100Ah manufactured by REPT BATTERO Energy Co., Ltd. Battery Module is manufactured by Rubix Battery LLC, rated 51.2V, 100Ah. This report was prepared for Rubix Battery LLC as requested by Shenzhen Tiansu Calibration and Testing Co., Ltd.	

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5.0	**CONSTRUCTION**		**Verdict**
5.2	**Module Construction**		—
5.2.1, 5.2.3	Construction information	See Test Item Description at the beginning of this report	—
	General layout of module contents	See Attachment B	—
5.2.2	Module certified to UL 1973	No	
	Organization that certified module:	N/A	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		
8.1	**Samples**		
8.1.1	Samples conditioned through charge discharge cycling a minimum of 2 cycles.	See Attachment A for profiles See Table 1 for specifications See also Table 2 The module voltage was checked before the test, and the voltage did not drop further compared to 1h to 8h after cycles, which was judged acceptable.	M
8.1.2	100% SOC and stabilize from 1h to 8 h before testing		
8.1.3	Electronic controls such as BMS not relied upon during testing.		C
8.2	**Test Method**		
8.2.1	Ambient indoor laboratory conditions: 25 ±5°C (77 ±9°F) ≤50 ±25% RH at the initiation of the test.	See Table 3 The Ambient temperature 26.4°C, 85%RH at the initiation of the test. The engineering judgment found it acceptable.	M
8.2.2	Test conducted under a smoke collection hood appropriately sized for the module		C
8.2.3	The weight of the module was recorded before and after testing, (kg)	See Table 11	C
8,2,4	A sufficient number of cells were forced into thermal runaway to create a condition of cell to cell propagation within the module.	See Attachment C and F See Tables 4 and 5	C
	The location of the cell(s) forced into thermal runaway were selected to present the greatest thermal exposure to adjacent cells	See Attachment C for figures showing location within the module of the cell(s) forced into thermal runaway	C

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8.2.5	The method used to initiating thermal runaway in the cell(s) were in accordance with 7.2	See Summary of Cell Testing at the beginning of this report.	C
8.2.6	The occurrence of thermal runaway was verified	See Test Results from Cell Level Test from the beginning of this report See Attachments D and F	C
8.2.7	The module was placed on top of a non-combustible horizontal surface with the module orientation representative of its intended final installation.	See Attachment E	C
8.2.8	The chemical heat release rate of the module was measured with oxygen consumption calorimetry	See Table 10 See Attachment F	C
8.2.9	The chemical heat relate rate was measured for the duration of the test	See Attachment F	C
8.2.10	The chemical heat release rate was measured using the following equipment: ● Paramagnetic oxygen analyser ● Non-dispersive infrared carbon dioxide and carbon monoxide analyser ● Velocity probe ● Type K thermocouple	See Attachment F	C
	The instrumentation was located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influences of bends or exhaust devices.		C
8.2.11	The chemical heat release rate at each of the flows was calculated in accordance with 8.2.11.	See Attachment F	C
8.2.12	The hydrocarbon content of the vent gas was measured using flame ionization detection.	See Table 8 and 9	C
	Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.	See Table 9	C

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8.2.13	The hydrocarbon content of the vent gas may also 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 equivalent gas analyzer.	FTIR analysis was not used in accordance with the Certification Requirement Decision: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test. FTIR was considered redundant to the other gas measurement methods used.	N/A
	Vent gas velocity and temperature measurements respectively were obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.		C
8.2.14	The light transmission in the exhaust duct of the heat release rate calorimeter was measured using a white light source and photo detector for the duration of the test.		C
8.2.15	Smoke release rate was calculated as outlined in 8.2.15	See Table 10 See Attachment F	C
8.3	**Module level test report**		
	a. Module manufacturer and model number; b. Number of cells in module; c. Module configuration;	See Test Item Description in beginning of this report.	C
	d. Module construction features;	See Attachment C See Critical Components Table	C
	e. Module voltage corresponding to the tested SOC;	See Table 3	C
	f. Thermal runaway initiation method used;	See Attachment C	C
	g. Heat release rate versus time data;	See Table 10 See Attachment F	C
	h. Flammable gas generation and composition data;	See Attachment F See Tables 8 and 9	C
	i. Peak smoke release rate and total smoke release data.	See Table 10	C
	j. Observation(s) of flying debris or explosive discharge of gases;	See Table 12	C
	k. Observation(s) of sparks, electrical arcs, or other electrical events;	See Table 12	C

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	l. Identification/location of cells(s) that exhibited thermal runaway within the module;	See Tables 4 and 5	C
	m. Locations and visual estimations of flame extension and duration from the module;	See Attachments E and F See Table 7	C
	n. Module weight loss;	See Table 11	C
	o. Video of the test.		
8.4	**Performance – Module level**		
8.4.1	The following performance conditions are met during the module level test: a) Thermal runaway is contained by module design;		P
	b) Cell vent gas is nonflammable as determined by the cell level test	Cell gas report show the cell gases are flammable. See Cell Gas Composition Table.	F

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Table 1 – Specified conditioning parameters			
Charging:		**Discharging:**	
Current (CC), A	50	Current (CC), A	50
Standard full Charge Voltage, Vdc	58.4	End of discharge voltage, Vdc	44.8
End of charge current, A	5A or 3.6V/cell	Discharging Test Ambient, °C	-20~55
Charging Test Ambient, °C	0~55		
Refer to Attachment A for charge/discharge profiles for the module.			

Table 2 – Charge completion and module test initiation times	
Charge Completion Date and Time	**Module Test Date and Time**
2024-05-08 00:44 AM	2024-05-08 09:24 PM
Note: The voltage was checked before the test, and the voltage was consistent with the voltage within 8 hours after the cycle, which was judged acceptable by the engineer.	

Table 3 - Test Initiation Details	
Module No.	WT5100S
Test Date	2024-05-08
Test Start Time	09:24 PM
Initial Lab Temperature	26.4
Initial Relative Humidity	85%
Module OCV at Start of Test, Vdc	53.5

Table 4 – Approximate time of thermal runaway propagation through module	
Time to thermal runaway	**Location**
00:51:58	Cell 09 TR
00:53:58	Cell 12 TR
00:54:16	Cell 08 TR
00:58:33	Cell 05 TR
01:01:07	Cell 13 TR
02:21:20	Cell 07 TR
02:24:53	Cell 10 TR
02:27:20	Cell 11 TR
02:28:42~04:09:58	*Other Cells TR
*Note: Suspect there is one thermal runaway based on the video, as there is no more TC in the module, cannot determine the cell location.	

Table 5 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	The test was started and the heater was turned on to heat the initiating cell (Cell 09) at a ratio of 4 ~ 7 °C/min.
00:38:47	Venting of initiating Cell 09	Initiating cell (Cell 09) vented at around 153°C measured through TC-09-3 by an indication of sudden dip in cell's

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		temperature curve and the bulge of top enclosure. See Figure (b)
00:51:58	Thermal runaway of initiating Cell 09	Initiating cell (Cell 09) was at around 201°C. The temperature of cell 09 began to increase in an uncontrollable manner, Gas venting observed from all sides with no flame observed. See Figure (c)
00:53:58	Thermal runaway of adjacent Cell 12	Thermal runaway propagated to nearby cell (cell 12). More Gas released, no ignition, no flame. See Figure (d)
00:54:16	Thermal runaway of adjacent Cell 08	Thermal runaway propagated to nearby cell (cell 08), More Gas released, no ignition, no flame. See Figure (e)
00:58:33	Thermal runaway of adjacent Cell 05	Thermal runaway propagated to nearby cell (cell 05). More Gas released, no ignition, no flame. See Figure (f)
01:01:07	Thermal runaway of adjacent Cell 13	Thermal runaway propagated to nearby cell (cell 13). More Gas released, no ignition, no flame. See Figure (g)
02:21:20	Thermal runaway of adjacent Cell 07	Thermal runaway propagated to nearby cell (cell 07). More Gas released, no ignition, no flame. See Figure (h)
02:24:53	Thermal runaway of Cell 10	Thermal runaway propagated to nearby cell (cell 10). More Gas released, no ignition, no flame. See Figure (i)
02:27:20	Thermal runaway of Cell 11	Thermal runaway propagated to nearby cell (cell 11). More Gas released, no ignition, no flame. See Figure (j)
02:28:42	Thermal runaway of other Cells	Thermal runaway propagated to nearby cells. More Gas released, no ignition, no flame. See Figure (k)
04:09:58	Test Termination	Propagation through complete module, no further thermal runaway observed after this time. Data collection stopped. See Figure (l).

Table 6 – Gases measured and measurement methods used in unit level testing

Measurement Method	Gases Measured	Chemical Formula	Gas Type
Flame Ionization Detection (FID)	Total Hydrocarbons	-	Hydrocarbons
Solid-state Hydrogen Sensor	Hydrogen	H_2	-
Non-dispersive infrared spectroscopy (NDIR)	Carbon Dioxide	CO_2	Carbon Containing
	Carbon Monoxide	CO	Carbon Containing
# - This table was modified to reflect the gases measured during testing.			

Table 7 - Gas generation periods

Time	Condition
00:51:58~04:09:58	No-Flaming

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N/A	Flaming
External Flaming of Gas	
Condition	**Duration (hh:mm:ss)**
External Flaming of Vent Gases:	N/A

Table 8– Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	Gas Type	During Pre-flaming (L)	During Flaming (L)	Minimum detectable flow rate (LPM)
See Table 9				

Table 9 – Summary of battery gas volumes identified during thermal runaway in module test				
Gas Component	Gas Type	During Pre-flaming (L)	Post-Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons	Hydrocarbons	723.32	No flaming	0.05
Carbon Monoxide	Carbon Containing	89.27	No flaming	0.0
Carbon Dioxide	Carbon Containing	176.99	No flaming	1.24
Hydrogen	Hydrogen	326.29	No flaming	11.04

Table 10 – Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR (kW)	0 (No flaming)	Maximum SRR (m^2/s)	5.99
		Total Smoke Released (m^2)	17078.83[2]

Table 11 – Module Weight During Test, kg	
Before Test:	47.66
After Test:	42.20
Weight Loss:	5.46

Table 12 – Other Observations during module test		
	Observed, Yes/No	Location
Flying debris	No	N/A
Explosive discharge of gas	No	N/A
Sparks or electrical arcs	No	N/A

[2] The total smoke released information was affected by the equipment and for reference only.

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	TABLE: Critical components information				
Object / Part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Metal Enclosure	Dongguan Xinmei Precision Hardware Co., LTD	WT5100S	Stainless steel, 575mm*520mm*148mm, Thickness: 1.5mm	--	--
Cells	REPT BATTERO Energy Co., Ltd.	CB56	3.2 Vdc, 100 Ah	UL 1973	UL MH64238
Epoxy board	Shenzhen Hecheng Fast Electronic Technology Co Ltd	3a	Min. 1.56mm, 125°C, V-1	UL 94 UL 796	UL E159194
Handle	Dongguan Xinmei Precision Hardware Co., LTD	LS537-1	ABS 110*63mm*28mm	--	--
Connector (+, -)	SHENZHEN CONNECTION ELECTRONIC CO LTD	DRTB35	150A, DC 600V	UL 60947-1	UL E304128
Breaker	SHANGHAI LIANGXIN ELECTRICAL CO LTD	NDB1-125 C125/1	125A	UL 1077	UL E300669
CAN USB	Zhejiang Gaotai Haoneng Technology Co., Ltd	RJ45-B	29*16mm	--	Tested with apparatus
Switch	DONGGUAN XKB ELECTRONIC TECHNOLOGY CO LTD	TGA0BP01A LAB00	10A, 500V	UL 94 UL 1694	UL E523734
Tubing	GUANGZHOU KAIHENG NEW MATERIAL CO LTD	K-102(CB)	125°C, 300V	UL 224	UL E321827
Positive copper bar	Wenzhou Dongyao Trading Co., LTD	Busbar-69X66X48mm	Cu, 66mm*49mm*47mm	--	--
Negative copper bar	Wenzhou Dongyao Trading Co., LTD	Busbar-307X106X62mm	Cu, 307mm*106mm*62mm	--	--
Red copper bar (+ Connector Connect to B+)	Wenzhou Dongyao Trading Co., LTD	Busbar-90X75X59mm	Cu, 90mm*75mm*50mm	--	--

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Black copper bar (- Connector Connect to B-)	Wenzhou Dongyao Trading Co., LTD	Busbar-334X60X28mm	Cu, 333mm*60mm*27mm	--	--
Cell Plate	Dongguan Xinmei Precision Hardware Co., LTD	Plate-152mm*138mm*70mm	Stainless steel 152mm*138mm*70mm Thickness：2.5mm	--	--
pulling plate	Dongguan Xinmei Precision Hardware Co., LTD	pulling plate-467mm*40mm*2.5mm	Stainless steel 467mm*40mm*2.5mm Thickness：2.5mm	--	--
Cell Busbar	Shenzhen Changxing New Energy Technology Co., Ltd	92*45*1.5mm	Al 1060 92*45*1.5mm	--	--
B+, B- Interconnecting conductor	DONGGUAN BOLI ELECTRONIC CO LTD	3135	600V, 200°C, 16AWG	UL 758	UL E305164
Internal acquisition cable	Kunshan Xinghongmeng Electronic Co Ltd	1007	300V, 80°C, 26AWG	UL 758	UL E315421
NTC (RVM69, RVM75, RVM77, RVM98)	SHENZHEN SUNLORD ELECTRONICS CO LTD	SDNT1608X103F3450FTF	10K ohm, Tmoa: 125°C	UL 1434	UL E352242
Protection IC (UVM2)	SINO WEALTH	SH367309	Overcharge Detection Voltage: 5000±10mV, Over-discharge Detection Voltage: 500±10mV, Operating temperature range: -40 to 85°C	--	--
MOSFET (QMS1 to QMS4, QMS9 to QMS11, QMS51 to QMS53)	Fullwin Technology Co., Ltd	FWE08N190RH	VDS: 80V ID: 120A VGS: 10V TJ, Tstg: -55°C to 175°C	--	--

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MOSFET (QMS12 to QMS18, QMS57 to QMS59, QMSCL1)	Hangzhou Silan Microelectronics Co., Ltd.	SVG104R0NSTR	VDS: 100V, VGS: ±20V, ID: 120A, TJ:-55°C to 150°C	--	--
Current sensing resistor of BMS (RVM41, RVM42, RVM44, RVM60, RVM95, RVM99, RVM106, RVM108 to RVM110)	Shenzhen Hao Ou electronic Co., LTD	HoLR2512D	3W-2mR-1%-25ppm	--	--
MCU (U6)	Xinwang Microelectronics	KF32F330KQTT	Supply voltage: 1.8V to 3.6V, Operating temperature: -40°C to 105°C	--	--
IC (U4, U5)	3PEAK INCORPORATED	LMV331TP	Supply Voltage: 6.0V, Operating Temperature Range: -40°C to 85°C	--	--
Transformer (Transform1)	TNK Electronic Technology Co., Ltd.	TSA778	Operating temperature: -40°C to 130°C, Turns Ratio: 27:18:18:18±3%, Isolation Hipot: 1500VA, 5mA, 3s	--	--
IC (UCC1, UCC6)	WuXi Silicon Technology Co., Ltd	WS3085	Operating Voltage: 6V, Operating Temperature: -40°C to 125°C	--	--
IC (UCC3, UCC4, UCC8)	NOCOSENSE	NIRS21	Power Supply Voltage: -0.5V to 6.5V, Topr: -40°C to 125°C	--	--

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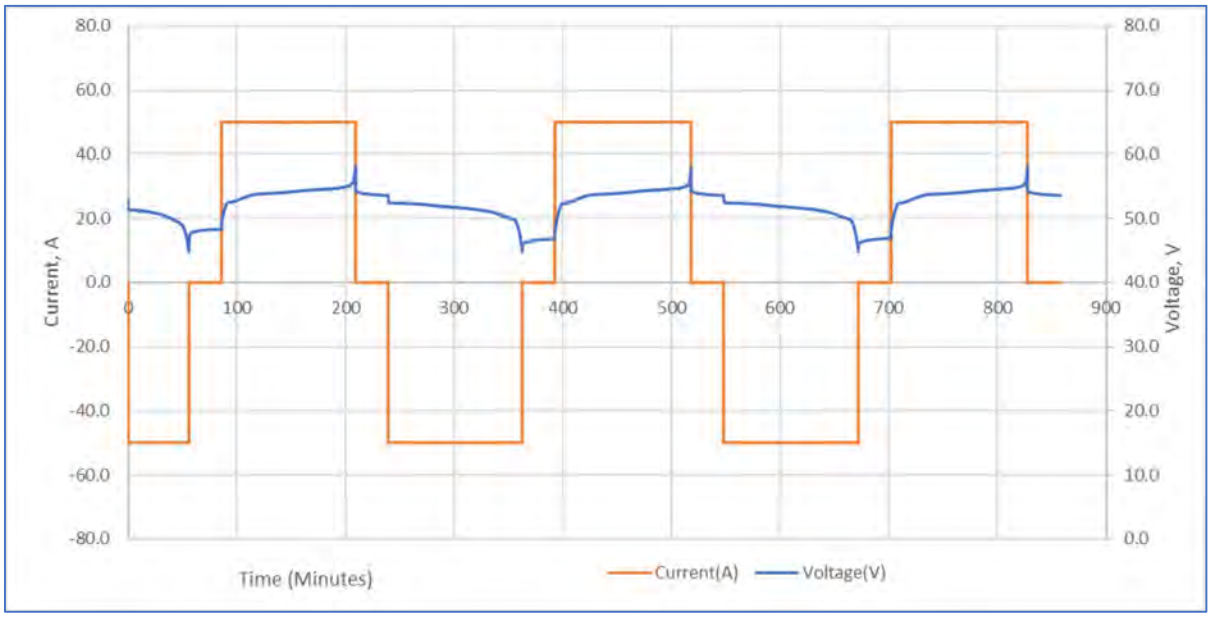
IC (U2)	Hangzhou Silan Microelectronics Co., Ltd.	SD4932BTR	VCC: -0.3V to 30V, Tamb: -40°C to 85°C	--	--
IC (UCC7)	3PEAK INCORPORATED	TPT3232E	VCC: -0.3V to 6V, TJ: 150°C	--	--
IC (U1)	Sillumin Semiconductor Co., Ltd.	SLM345	Output Supply Voltage: 10V to 40V, TA: -40°C to 125°C	--	--
IC (UPW1, UPW3)	3PEAK INCORPORATED	TPL820F50-89TR	VIN: 3.6V to 42V, Junction Temperature Range: -40°C to 125°C	--	--
IC (UPW2)	3PEAK INCORPORATED	TPL820F33-89TR	VIN: 3.6V to 42V, Junction Temperature Range: -40°C to 125°C	--	--
IC (UVM2)	SION WEALTH	SH367309	VBAT: 8.5V to 65V, TA: -40°C to 85°C	--	--
IC (UCAN3)	3PEAK INCORPORATED	TPT7721	VCC: -0.5V to 6.0V, TJ: 150°C	--	--
IC (UCAN4)	Silicon Internet of Things Technology Co., Ltd	SIT1050T	VCC: 4.5V to 5.5V, Tamb: -40°C to 125°C	--	--

Attachment A: Module Conditioning (Charge/discharge) Profiles - (*Pages **19** through **19**)*



Charge/Discharge Cycle

Attachment B: Module Construction Photos **-** (Pages ***20*** *through* ***20***)

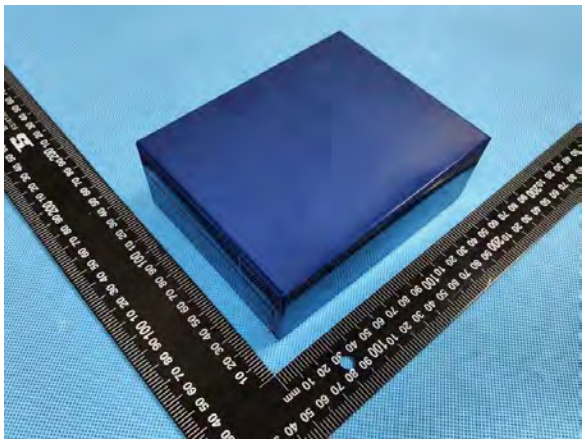


Figure 1 - Photo of cell – Wide side view

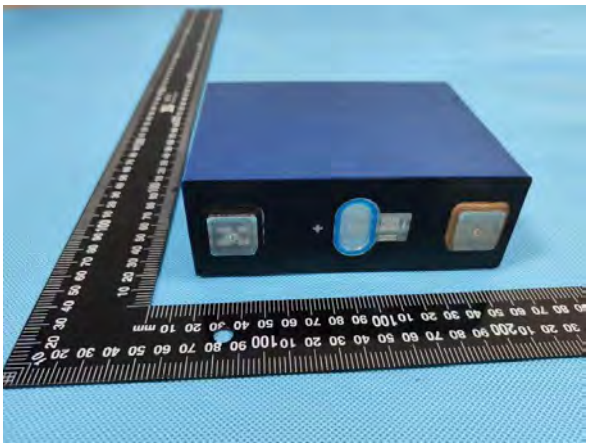


Figure 2 - Photo of cell – Top view

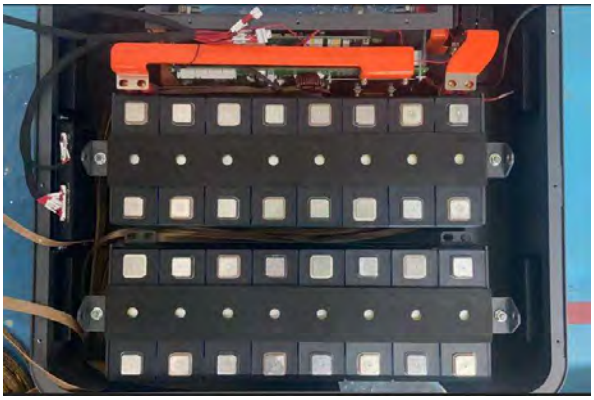


Figure 3 - Photo of module – Internal view

Figure 4 - Photo of module – Front view

Figure 5 – Photo of module – Rear view

Figure 6 - Photo of module – Side view

Attachment C: Module Instrumentation Photos - (*Pages **21** through **22***)

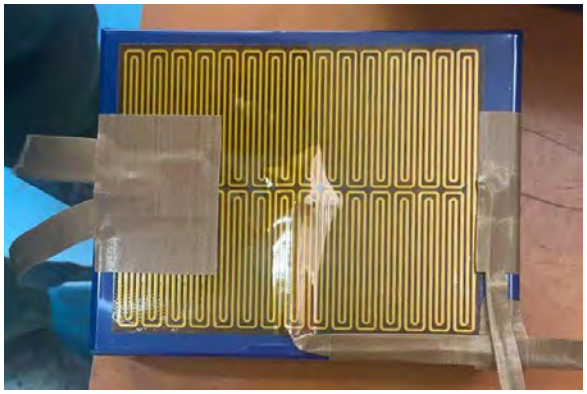


Figure 7 – Cell with heater. Two pieces of 101.6 mm by 127mm for each sample.

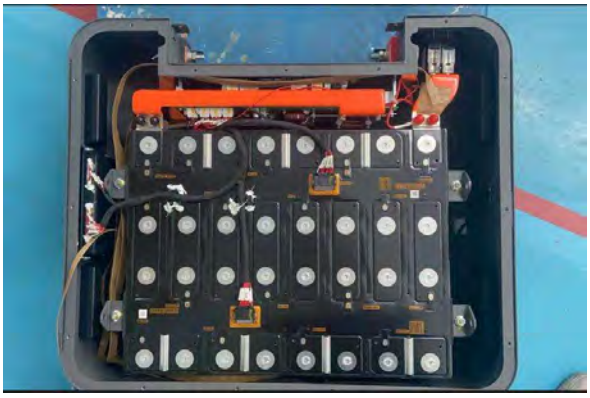
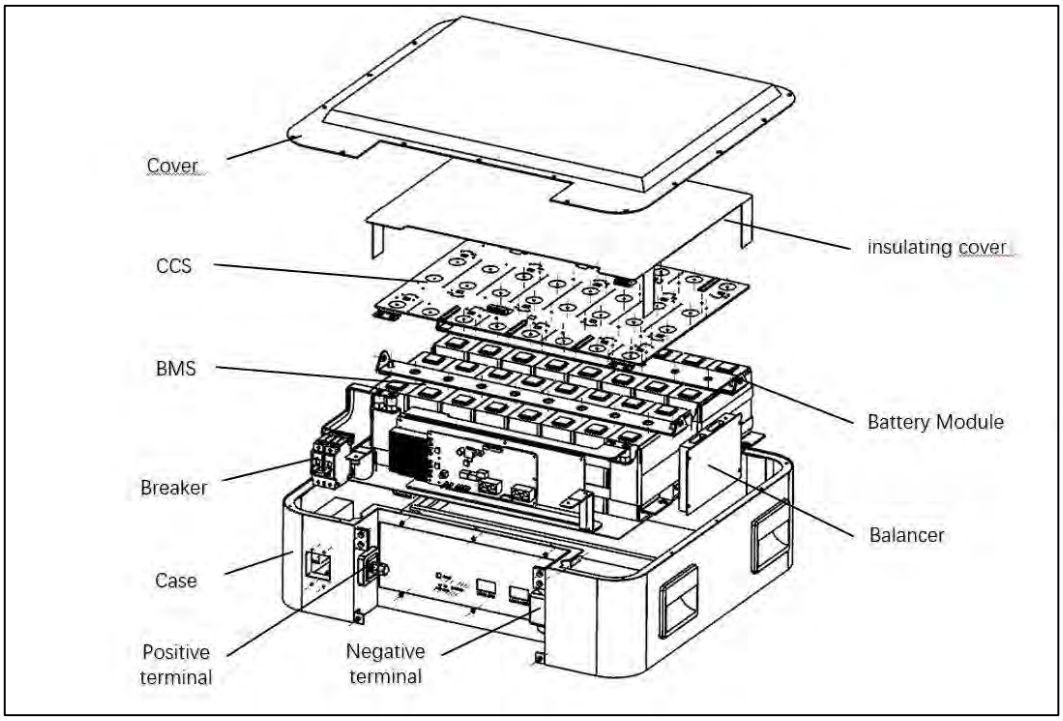
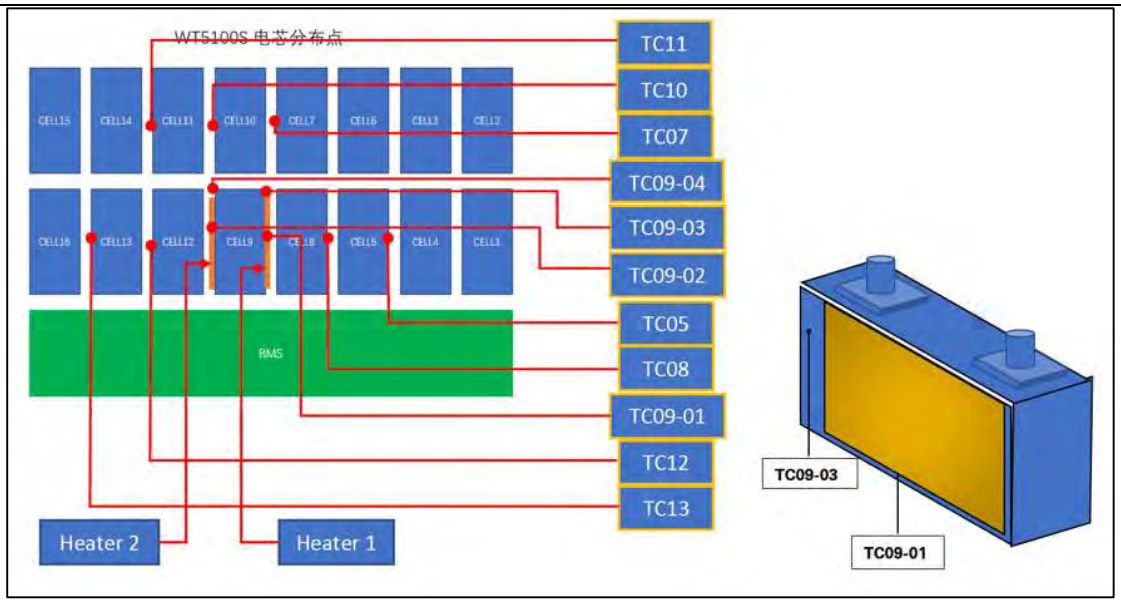


Figure 8 – Module with heater, TCs and Voltage Sampling wires.

Note: The thermocouple TC-09-1 was used to control the supply power to the heater to keep the heating rate at 4 ~ 7 °C/min. TC-09-3 and TC-09-4 were used to represent the temperature of initiating cell.
TC-09-1, on the wide side surface center of cell 30, between the cell and heater 1.
TC-09-3 and TC-09-4, on each wide side surface center of cell 30, not covered by heater.
TC-05, TC-07, TC-08, TC-10, TC-11, TC-12 and TC-13 were attached on the wide surface center of cells shown in below illustration.





No.	TC No.	Thermocouples Position
1	TC-09-1	Cell-09 Wide side center surface, Under Heater 1
2	TC-09-2	Cell-09 Another wide side center surface. Under Heater 2
3	TC-09-3	Cell-09 Wide side center surface, Not covered by Heater 1
4	TC-09-4	Cell-09 Another wide center side surface, Not covered by Heater 2
5	TC-05	Cell-05 wide side center surface
6	TC-07	Cell-07 wide side center surface
7	TC-08	Cell-08 wide side center surface
8	TC-10	Cell-10 wide side center surface
9	TC-11	Cell-11 wide side center surface
10	TC-12	Cell-12 wide side center surface
11	TC-13	Cell-13 wide side center surface
12	TC-14	Module top enclosure near the Cell-09

Figure 9 – Locations of TCs

Figure 10 – Module on the test platform – Side view 1

Figure 11 – Module on the test platform – Side view 2

Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing **-** (*Pages **23** through **23***)

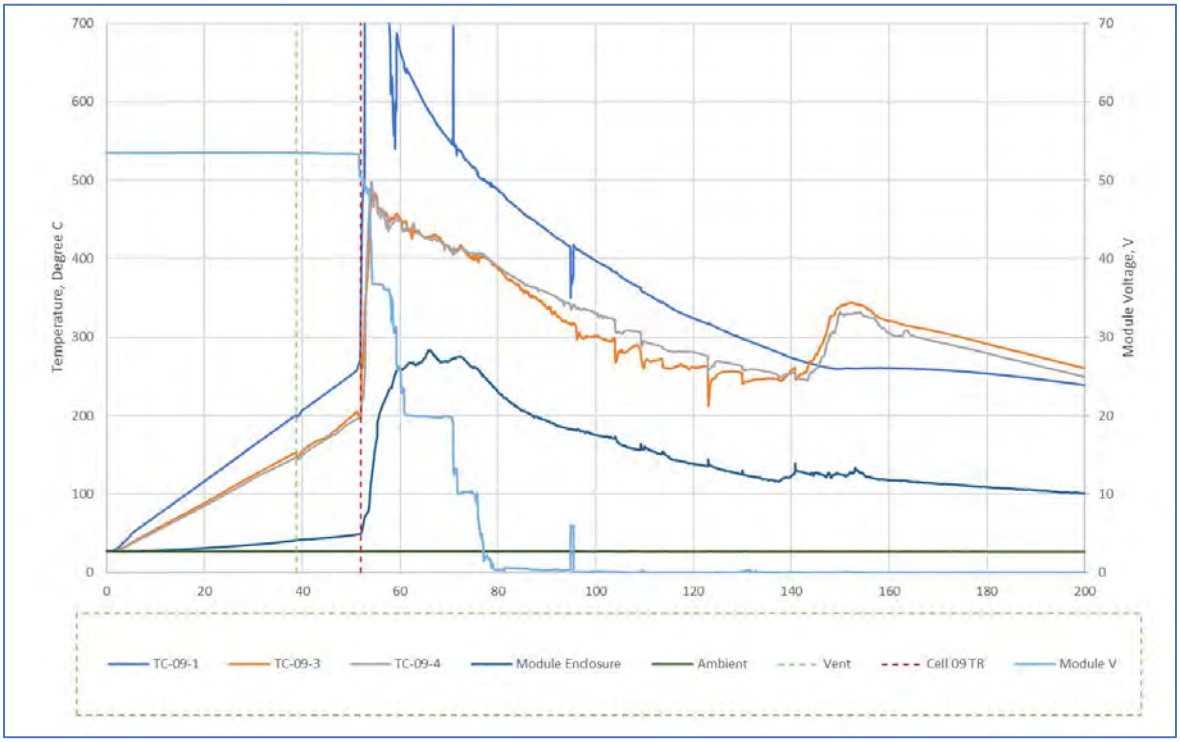


Figure 12 – Initiating cell Temperature Profiles During Testing

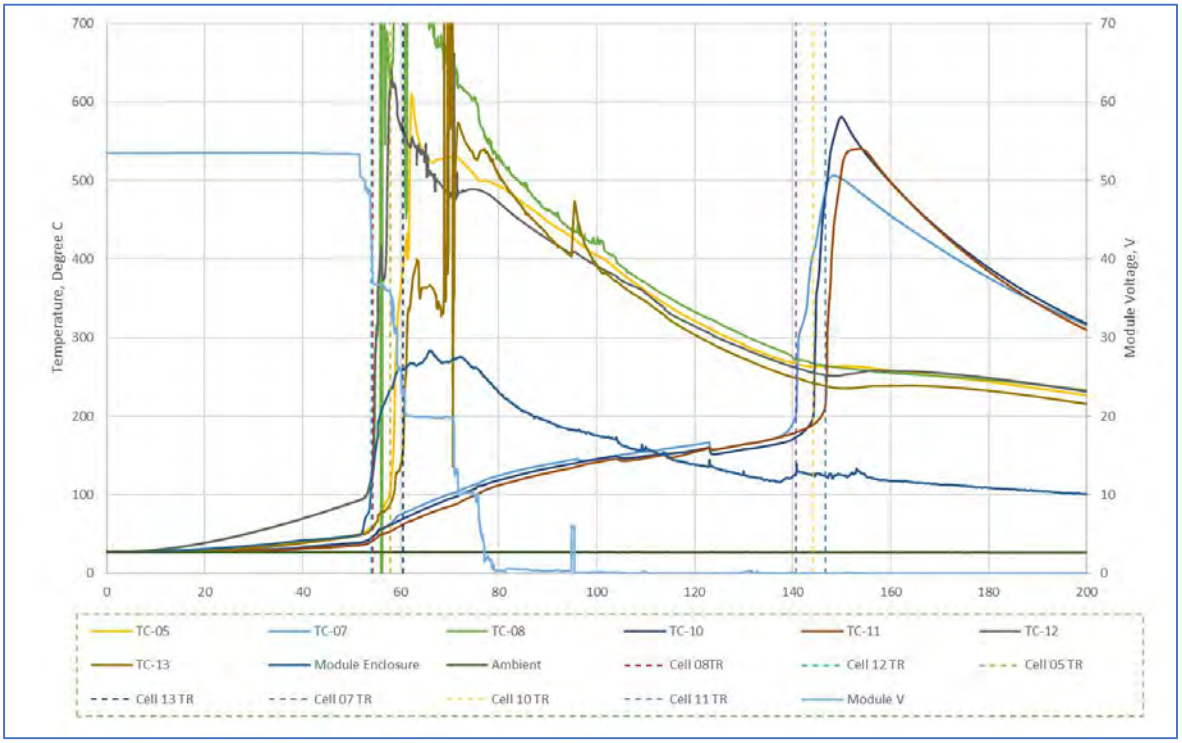
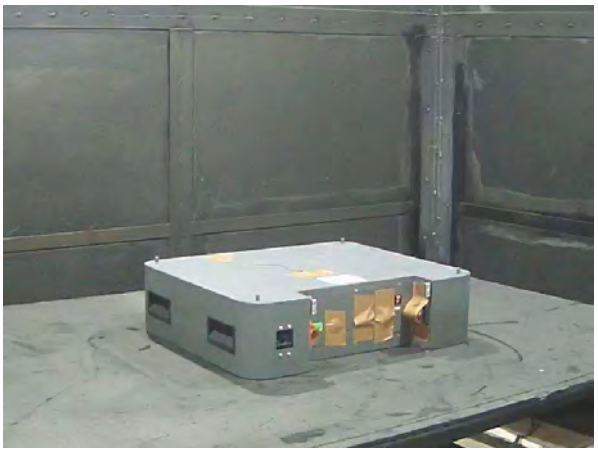


Figure 13 – Temperature Profiles Describing Cell to Cell Propagation

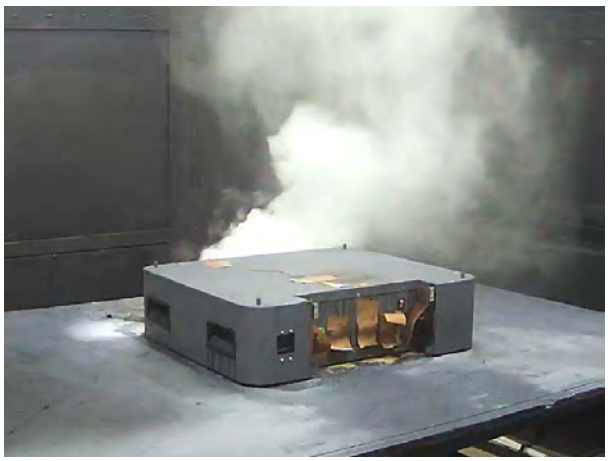
Attachment E: Module Testing Photos **-** (*Pages **24** through **277***)

	
(a) Test Start [00:00:00]	(b) Initiating cell Venting [00:38:47]
	
(c) Thermal runaway of initiating cell [00:51:58]	(d) Thermal runaway of adjacent cell12 [00:53:58]

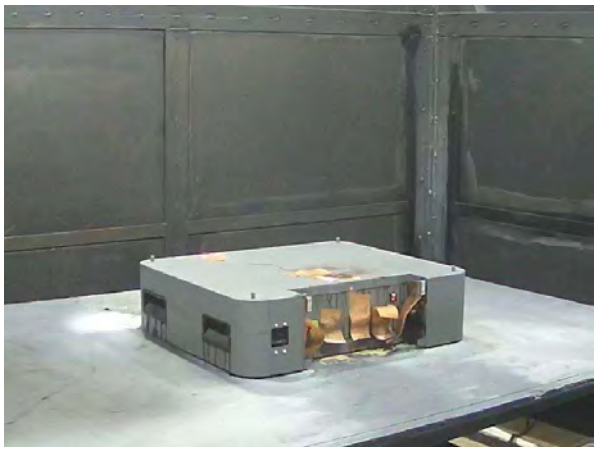
	
(e) Thermal runaway of adjacent cell 08 [00:54:16]	(f) Thermal runaway of adjacent cell 05 [00:58:33]
	
(g) Thermal runaway of adjacent cell 13 [01:01:07]	(h) Thermal runaway of adjacent cell 07 [02:21:20]

(i) Thermal runaway of adjacent cell 10
[02:24:53]

(j) Thermal runaway of adjacent cell 11
[02:27:20]



(k) Thermal runaway of other cells
[02:28:42]



(l) Test Termination
[04:09:58]

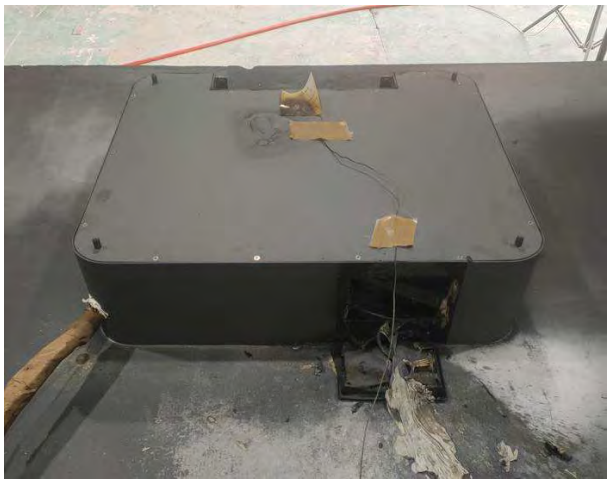


Figure 14 – Module Post Testing Photos

Attachment F: Module Gas Flow Rate and Heat Release Profiles - (*Pages **28** through **30***)

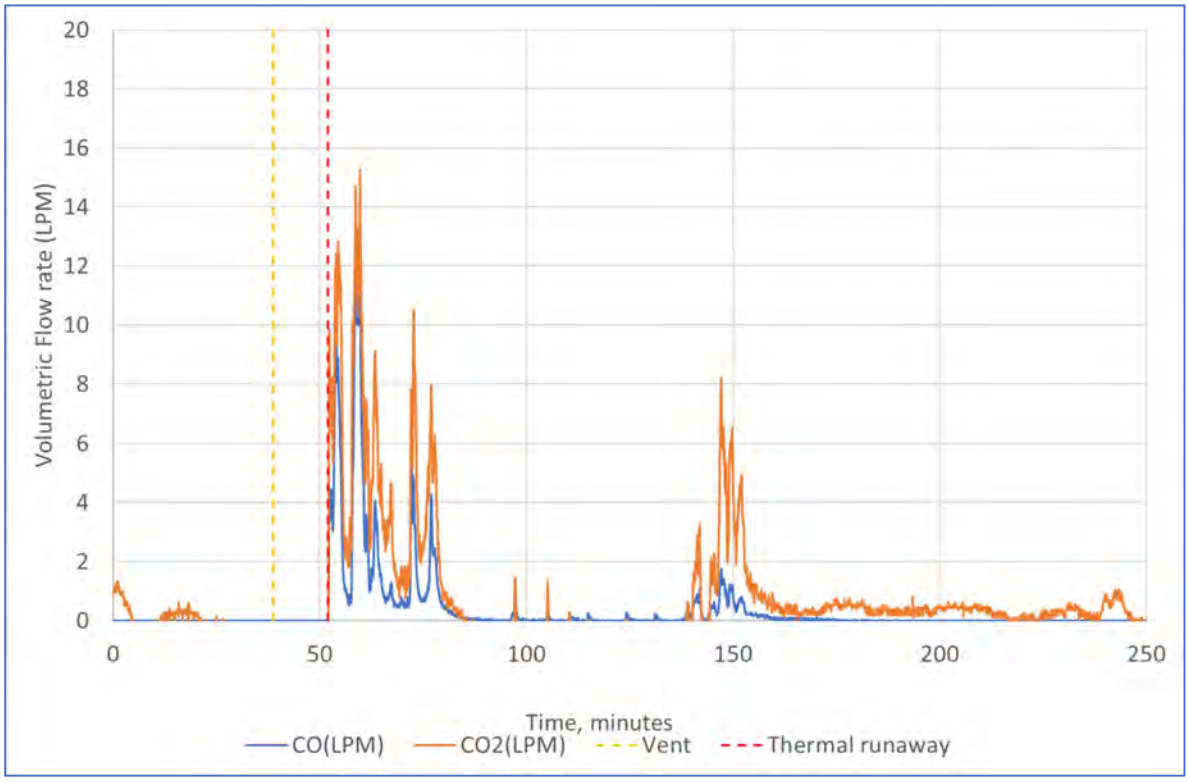


Figure 15 – CO, CO2 Volumetric flow rates

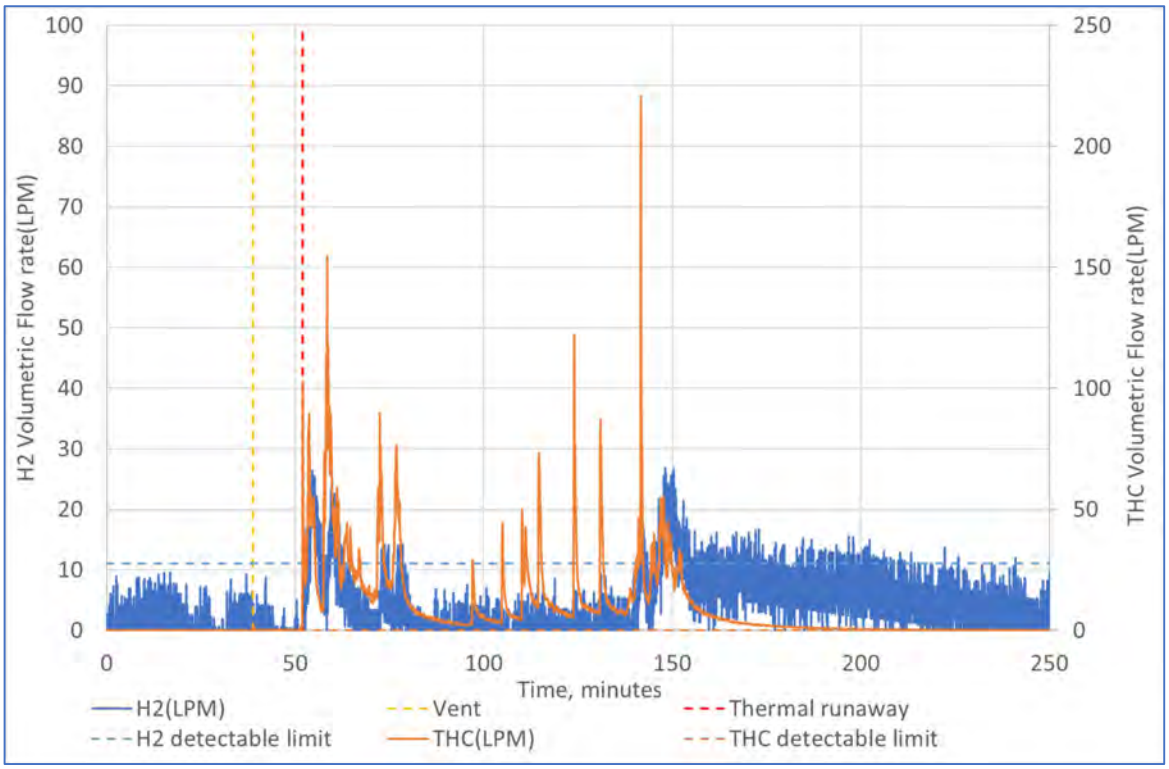


Figure 16 – THC, H2 Volumetric flow rates

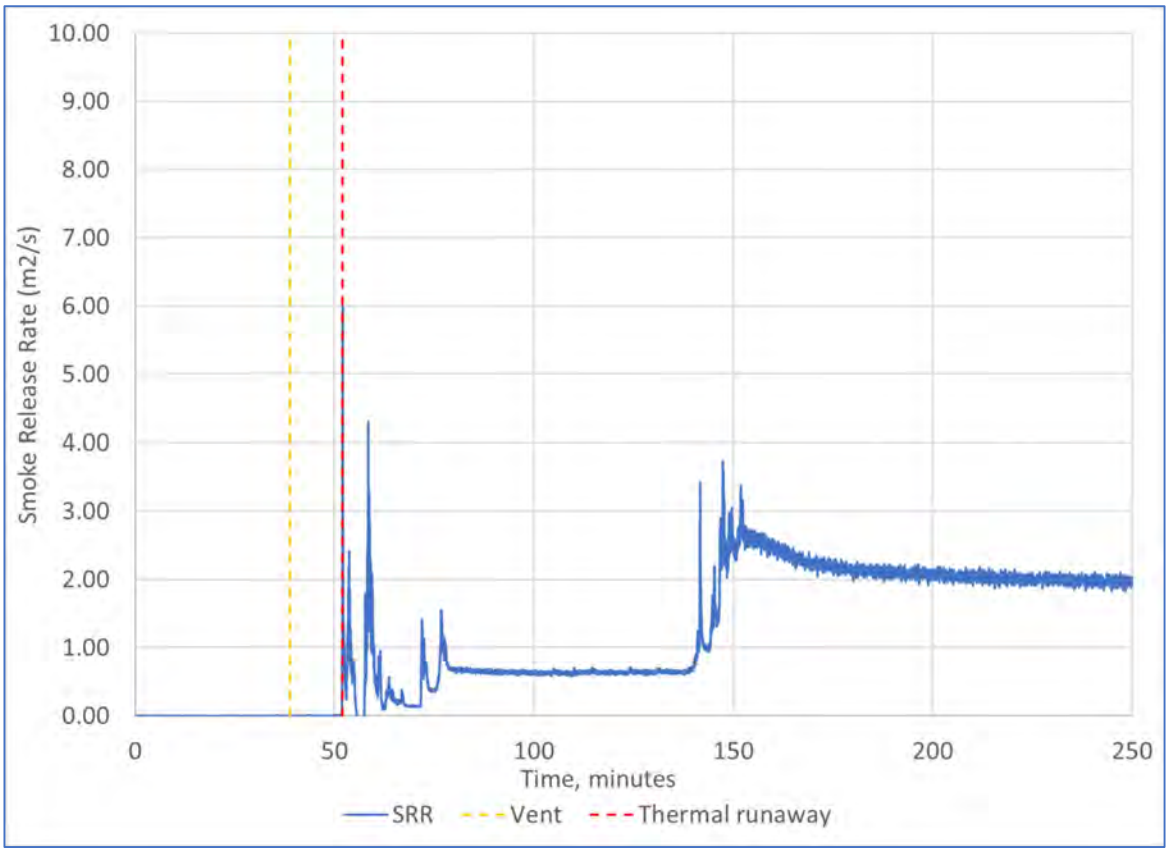


Figure 17 – Smoke release rate[3]

[3] The total smoke released information was affected by the equipment and for reference only.