CSA GROUP
Laboratory Test Data – UL 9540A

Master Contract:*302680*
Report*: 80204927*
Project: *80204927*

Apr.16, 2024

Mr. Yong Zhou
Project manager
FOXESS CO., LTD.
No.939,Jinhai Third Road,
New Airport Industry Area
Longwan District
Wenzhou,Zhejiang 325025
China

Subject: *Lithium-ion Rechargeable battery module, model EQ4000 (UL 9540A Test Report)*

Dear *Mr. Yong Zhou*

We are pleased to inform you that testing of your product per UL 9540A has been completed. Applicable test(s) was witnessed at ChuWeiNeng Testing Technology (Shanghai) Co.Ltd, and witnessed by CSA Group – Kunshan. Module level of test was conducted on the sample provided and the results are enclosed in the test report.

> Note: This Test Report is not an Authorization to apply the CSA Mark to the product. The results contained in the report(s) provided are contingent upon the characteristics of the actual sample(s) used in the investigation. In the absence of a continuing inspection service, CSA provides no assurance, expressed or implied, that the contents of the report are applicable to reproductions of the sample(s). Use or reproduction of the CSA name, logo, or trademark is not permitted without the prior written consent of CSA. No references can be made to this report when using the results of this investigation for the purposes of advertising, promotion or litigation, without the prior written consent of CSA.

Please examine the enclosed documents and contact me if you have any questions or would like us to make any changes.

On behalf of CSA, I would like to thank you for your business and offer our services for your future needs.

Yours truly,

Evan Zhang
CSA –*CCIC-CSA International Certification Co., Ltd. Kunshan Branch*
Building 8, Tsinghua Science Park, No. 1666 Zu chongzhi Rd (S), Kunshan, Jiangsu (215347)

Encl. [*UL 9540A Test Report*]
Att.1 - Module charge/discharge conditioning graphs
Att.2 - Photos
Att.3 - Cell temperature/voltage graph during testing
Att.4 - Heat Release Rate graphs
Att.5 - Gas generation graphs
Att.6 - Smoke release graph
Att.7 - Notable observation during test
Att.8 - Video (separated file)

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Laboratory Test Data - UL 9540A Checklist and Test Result (Module Level)

ORIGINAL TEST DATA

The results relate only to the items tested.
This report shall not be reproduced, except in full, without the approval of CSA Group Testing & Certification Inc.

Master Contract:	302680	Model:	EQ4000	Page number 1 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Standard(s): ANSI/CAN/UL 9540A:2019 Fourth Edition, Dated November 12, 2019 - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Testing Laboratory Name:	CCIC-CSA International Certification Co.,Ltd. Kunshan Branch
Address:	Building 8, Tsinghua Science Park, No. 1666 Zu chongzhi Rd(S), Kunshan, Jiangsu(215347)
Testing Program:	**Custom Test** : Cover Latter ☒, Testing Only ☐

If tests were performed at another facility, then described below:

Testing Laboratory Name:	ChuWeiNeng Testing Technology (Shanghai) Co.Ltd
Address:	Building 3, No.1065 Beihe Road, Jiading District, Shanghai
Facility Qualification Number:	N/A

	As above / or describe otherwise
Customer:	FOXESS CO., LTD.
Address:	No.939,Jinhai Third Road,New Airport Industry Area,Longwan District, Wenzhou,Zhejiang 325025,China

Tested By: Jiaming Huang, Technician
Name, Title

Jiaming Huang — 2024-03-19
Signature — *Date (YYYY-MM-DD)*

☒ **Reviewed by:** Jarvis Shen, Certifier
☒ **Witnessed by:**
Name, Title

Evan Zhang/Jarvis Shen — 2024-03-19
Signature — *Date (YYYY-MM-DD)*

Version6.2 : 2023-06-15

Master Contract:	302680	Model:	EQ4000	Page number 2 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Cell Level Test Summary	
Name of test laboratory perform cell level testing:	UL(Changzhou) Quality Technical Service Co.,LTD
Unique identification of test report:	UL, Project Number:4790517961
Standard and its edition used for testing:	UL9540A,4th edition
Manufacturer:	REPT BATTERO Energy Co.,Ltd
Brand name / Trademark:	N/A
Model number:	CB59
Nominal cell voltage, (V)	3.2
Cell capacity, (Ah)	72
Cell chemistry:	LFP
Physical format of cell:	Prismatic
Approximate dimension, (mm)	Depth:39.72±1;Width:148.66±1;Height:110.01±1
Mass, (g)	1380±150
Method used to initiate thermal runaway:	External heating
Average temperature at which cell first vented excluding gas collection sample, (°C)	154
Average temperature prior to thermal runaway excluding gas collection sample, (°C)	211
Flammable gas generation, (Liter)	---
Total gas generation, (Liter)	41.8
Lower flammability limit (LFL) at ambient temperature (25 ± 5°C), (%)	7.95
Lower flammability limit (LFL) at average gas vent temperature, (%)	6.95
Burning velocity, (Cm/Sec)	125.8
Maximum pressure P_{max}, (psig)	94.8
Gas composition:	

Master Contract:	302680	Model:	EQ4000	Page number 3 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Cell Level Test Summary

Gas		Measured %
Carbon Monoxide	CO	8.949
Carbon Dioxide	CO2	31.946
Hydrogen	H2	51.599
Methane	CH4	4.029
Acetylene	C2H2	0.149
Ethylene	C2H4	2.120
Ethane	C2H6	0.693
Propadiene (Allene)	C3H4	N.D
Propylene	C3H6	0.232
Propane	C3H8	0.074
-	C4 (Total)	0.140
-	C5 (Total)	0.017
-	C6 (Total)	0.006
1-Heptene	C7H14	N.D
Styrene	C8H8	N.D
Benzene	C6H6	0.002
Toluene	C7H8	N.D
Dimethyl Carbonate	C3H6O3	0.035
Ethyl Methyl Carbonate	C4H8O3	0.007
Diethyl Carbonate	C5H10O3	N.D
Total	-	100

Master Contract:	302680	Model:	EQ4000	Page number 4 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Module Level Test Summary	
Manufacturer:	FOXESS CO., LTD.
Brand name / Trademark:	FOX ESS
Model number:	EQ4000
Nominal voltage rating, (V)	57.6
Nominal capacity rating, (Kwh)	3.97
Approximate dimension, (mm)	W×H×D:570mm×138 mm×380mm
Module certification available? (Yes/No)	Yes
Module evaluated with its associated BESS? (Yes/No)	Yes
Standard(s) used to certify product:	UL 1973 3rd edition
Certification organization name and its certificate number:	CSA, Project No.80182814
Module enclosure material:	Metallic
Electrical configuration of cell in module:	18s-1p
Number of cells in module:	18
Method used to initiate thermal runaway:	External heating
Number of cells used for initiating thermal runaway:	1
Number of cells exhibited thermal runaway within module:	3
Cell to cell propagation condition:	Yes
Peak chemical heat release rate, (kW)	No flame observed
Flammable gas generation, (Liter)	97.6
Total gas generation, (Liter)	124.1
Weight loss, (%)	1.1
Gas composition:	CO_2 (21.35%); THC (70.99%);CO(7.65%); H_2(below detectable limit)
Additional Information:	The sample to be tested is provided by the customer.

Master Contract:	302680	Model:	EQ4000	Page number 5 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Performance Module Level Test		
Requirement	**Comments**	**Verdict**
Thermal runaway was contained by module design.	Thermal runaway was contained by module design with no fire or explosion observed during test	P
Cell vent gas was nonflammable as determined by the cell level test.	Cell vent gas was flammable as determined by the cell level test	F
Summary of Result: Unit level testing is required based on above performance condition indicated in Section 8.4 of UL 9540A 4th Edition.		

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)

Master Contract:	302680	Model:	EQ4000	Page number 6 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Clause	Requirement + Test	Result - Remark	Verdict
	Construction		
5	**General**	---	---
5.2	**Module**	---	---
5.2.1	Enclosure material:	Metallic	---
	General layout of module contents:	See attachment 2 for details	---
	Electrical configuration of cell in module:	18s-1p	---
	Number of cells in module:	18	---
5.2.2	Module certification available? (Yes/No)	Yes, Project No.80182814	---
	Module evaluated with its associated BESS? (Yes/No)	Yes	---
	Standard(s) used to certify product:	UL 1973, 3rd edition	
5.2.3	Module Level Test Report	See below	---
	Performance		
8	**Module Level**	---	---
8.1	**Sample**	---	---
8.1.1	Prior to testing, module sample was conditioned for minimum 2 charge (100% SOC) - discharge (Specified end of discharge voltage) cycle as per manufacturer specified method.	See attachment 1 for details	P
	Module was functional after minimum 2 charge discharge cycle.	See attachment 1 for details	P
	Ambient temperature during module conditioning.	See table 2 for details	P
8.1.2	The tested module had 100% SOC at the start of the test. The samples were allowed to rest for a minimum of one hour and a maximum of 8 h before the start of the test.	See table 2 for details	P
8.1.3	Electronics and software controls such as BMS were not relied upon for this testing.	Confirmed	P
8.2	**Test method**	---	---
8.2.1	Ambient temperature during module testing.	19.4°C~25.7°C	P
8.2.2	Test was conducted under smoke collection hood	Confirmed	P
8.2.3	Weight of module was recorded before and after testing	See table 3 for details	P
8.2.4	Number of cells forced into thermal runaway inside module:	See below	P
	Number of cells forced into thermal runaway were able to create condition of cell-to-cell propagation	Total 3 cells exhibited thermal runaway due to 1 initiating cell failed	P

Master Contract:	302680	Model:	EQ4000	Page number 7 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Clause	Requirement + Test	Result - Remark	Verdict
	Location of cells forced into thermal runaway were selected to present greatest thermal exposure to adjacent cell.	See attachment 2 for details	P
	Factors consider when selecting location of cells inside module:	☒ Heat transfer was maximized to other cells. ☐ Cooling by ventilation was restricted or limited. ☐ Thermal sensors, detection and suppression discharge points were remote. ☐ Other(explain):	P
8.2.5	Method used to initiate thermal runaway during cell level was used at the module level of testing	Confirmed	P
8.2.6	Occurrence of thermal runaway was verified by sustained temperature above the cell surface temperature at the onset of thermal runaway.	Confirmed	P
8.2.7	Module was placed on top of a noncombustible horizontal surface	Confirmed	P
	Module orientation was representative of its intended final installation	Confirmed	P
8.2.8	Chemical heat release rate of the module in thermal runaway was measured with oxygen consumption calorimetry	Confirmed	P
8.2.9	Chemical heat release rate was measured for the duration of the test	Confirmed	P
8.2.10	Equipment used for chemical heat release rate measurement:	☒ Paramagnetic oxygen analyzer ☒ Non-dispersive infrared carbon dioxide analyzer ☒ Non-dispersive infrared carbon monoxide analyzer ☒ velocity probe ☒ Type K thermocouple ☐ Other(explain):	P
	The instrumentation was located in the exhaust duct.	Confirmed	P
8.2.11	Heat release rate was calculated as per following formula. $HRR_1 = \left[E \times \varphi - (E_{co} - E) \times \frac{1-\varphi}{2} \times \frac{X_{co}}{X_{O_2}}\right] \times \frac{\dot{m}_e}{1+\varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^o_{H_2O}) \times X^o_{O_2}$	Confirmed	P

Master Contract:	302680	Model:	EQ4000	Page number 8 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Clause	Requirement + Test	Result - Remark	Verdict
8.2.12	The hydrocarbon content of the vent gas was measured using flame ionization detection.	Confirmed	P
	Hydrogen gas was measured with a palladium-nickel thin-film solid state sensor.	Confirmed	P
8.2.13	The hydrocarbon components of the vent gas composition were additionally 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.	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
	Velocity and temperature measurements respectively was obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.	Confirmed	P
8.2.14	Light transmission in the exhaust duct was measured for the duration of the test.	Confirmed	P
8.2.15	Smoke release rate was calculated as per following formula. $SRR = 2.303\left(\frac{V}{D}\right) Log_{10}\left(\frac{I_o}{I}\right)$	Confirmed	P
8.3	**Module level test report**	**---**	**---**
8.3.1	Module level report include information indicated in item a) through o)	Confirmed	P

Master Contract:	302680	Model:	EQ4000	Page number 9 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Table 1 – Module charge/discharge specification			
Charging method	CC-CV	Discharging method	CC-CV
Charge current, (Adc)	36	Discharge current, (Adc)	36
Charge voltage, (Vdc)	65.7	Discharge voltage, (Vdc)	52.2
Charge end current, (Adc)	2	Discharge end current, (Adc)	2
Manufacturer recommended charge temperature, (°C)	0~+55	Manufacturer recommended discharge temperature, (°C)	-10~+55

Table 2 – Module rest duration				
Sample Number	Final charge end time		Test start time	
	Date (YYYY-MM-DD)	Time (HH:MM AM/PM)	Date (YYYY-MM-DD)	Time (HH:MM AM/PM)
202403028	2024-03-19	13:52 PM	2024-03-19	16:26 PM
Ambient temperature during Module conditioning				
Ambient Lab Temperature, (°C)		Relative Humidity, (%RH)		
22.0 to 25.4		45.0 to 50.0		

Table 3 – Module level test	
Sample Number:	202403028
Ambient Lab Temperature, (°C)	20.9
Relative Humidity, (%RH)	47.0
Number of cells used for initiating thermal runaway:	1
Weight of module before testing, (kg)	37.2
Weight of module after testing, (kg)	36.8
Weight loss, (%)	1.1
Open circuit voltage before test, (Vdc)	61.0
Module charge capacity after final charge cycle, (Ahr)	71.1
External film heater ramp rate, (°C/min)	4.5
Other method used to initiate thermal runaway:	N/A
Location of cell for initiating thermal runaway:	See attachment 2 for details
Number of cells exhibited thermal runaway within module:	3
Location of cell exhibited thermal runaway within module:	See attachment 2 for details
Cell to cell propagation condition:	Yes
Peak chemical heat release rate, (kW)	No flame observed
Flammable gas generation, (Liter)	Before Flaming: 97.6 After Flaming: ---

Table 3 – Module level test

Total gas generation, (Liter)	Before Flaming: 124.1 After Flaming: ---
Peak smoke release rate, (m^2/sec)	0.25
Total smoke release, (m^2)	67.56

Gas composition

Gas Component		Volume Released (Before Flaming) (Liter)	Volume Released (After Flaming) (Liter)
Carbon Monoxide	CO	9.5	---
Carbon Dioxide	CO_2	26.5	---
Hydrogen(palladium-nickel thin-film solid state sensor)	H_2	Below detectable limit	---
Total hydrocarbons (equivalent to CH_4)	---	88.1	---

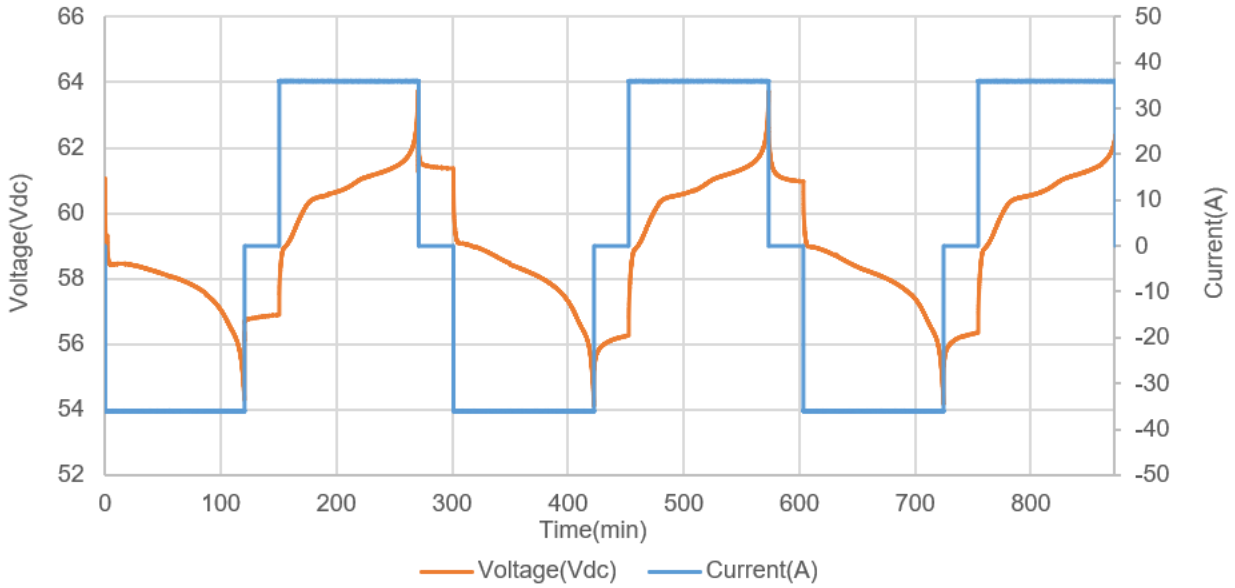
Master Contract:	302680	Model:	EQ4000	Page number 11 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Attachments

Index of Attachments		
No.	**Name**	**Page**
1	Module charge/discharge conditioning graphs	12
2	Photos	13~16
3	Cell temperature/voltage graph during testing	17~18
4	Heat Release Rate graphs	19
5	Gas generation graphs	20
6	Smoke release graph	21
7	Notable observation during test	22
8	Video (separate file)	MP4

Master Contract:	302680	Model:	EQ4000	Page number 12 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Attachment 1 - Module charge/discharge conditioning graphs



Master Contract:	302680	Model:	EQ4000	Page number 13 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Attachment 2 – Photos

General sample photos

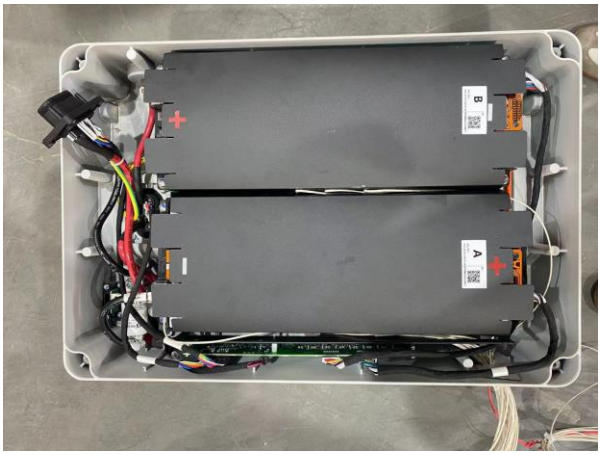
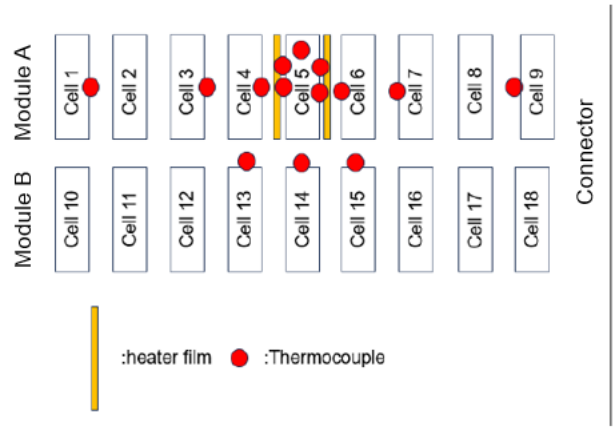





Figure 1: Module overview

Photos with heater and thermocouple installation

Attachment 2 – Photos



T4:Cell 5 left side surface center(under heater)
T5:Cell 5 left side surface center not covered by heater film
T6:Cell 5 right side surface center(under heater)
T7: Cell 5 right side surface center not covered by heater film
T11:Cell 5 positive
T2:Cell 3 left side surface center
T3:Cell 4 left side surface center
T8:Cell 6 right side surface center
T9:Cell 7 right side surface center
T10:Cell 9 right side surface center
T1:Cell 1 left side surface center
T14:Cell 14 narrow side surface center
T13:Cell 13 narrow side surface center
T12:Cell 15 narrow side surface center

Figure 2: Heater film and TC location

Photos during test in progress

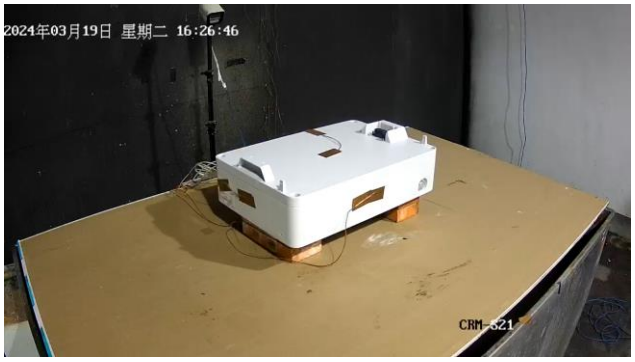


Figure 3: At test start (Time in 16:26)

Figure 4: During cell venting (Time in 17:01)

Figure 5: During thermal runaway (Time in 17:17)

Figure 6: During thermal runaway (Time in 17:19)

Attachment 2 – Photos

No Text on this Box

Figure 7: During thermal runaway (Time in 17:20)

No Text on this Box

Photos after test

Master Contract:	302680	Model:	EQ4000	Page number 16 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Attachment 2 – Photos

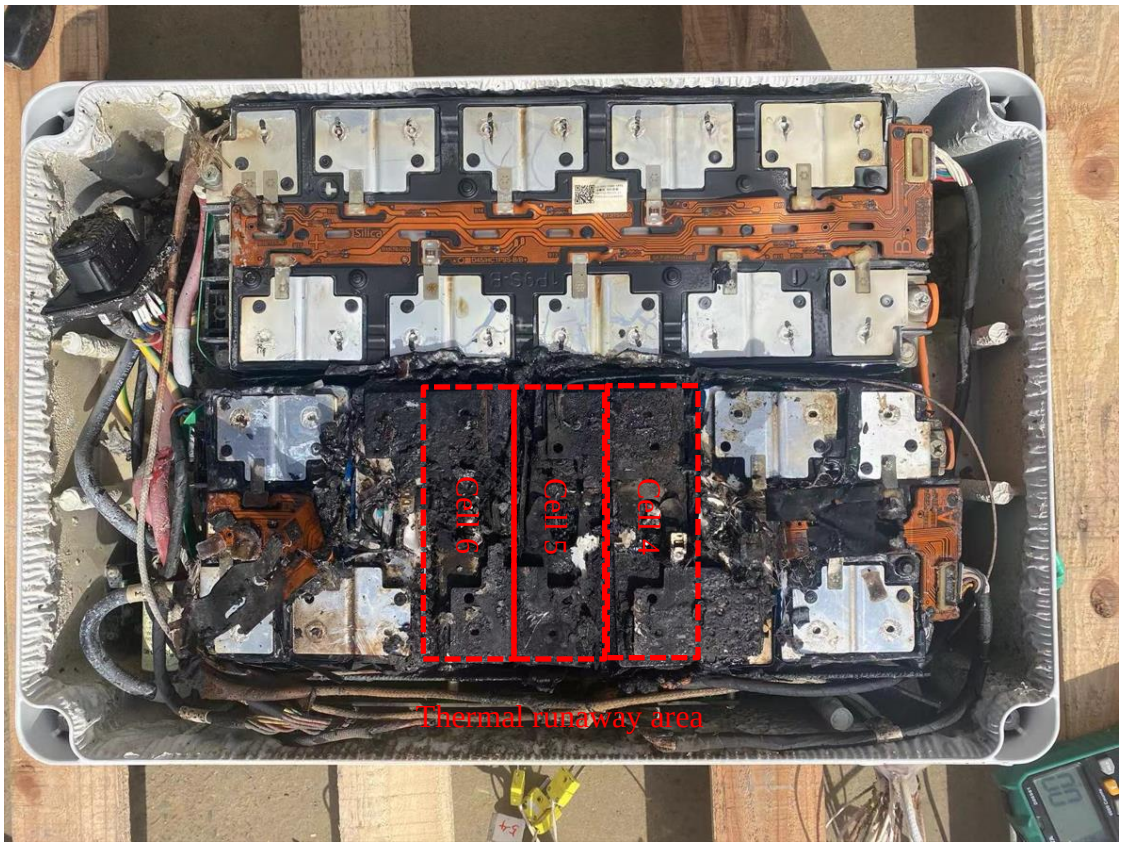


Figure 8: Module after test overview

Master Contract:	302680	Model:	EQ4000	Page number 17 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Attachment 3 - Cell temperature/voltage graph during testing

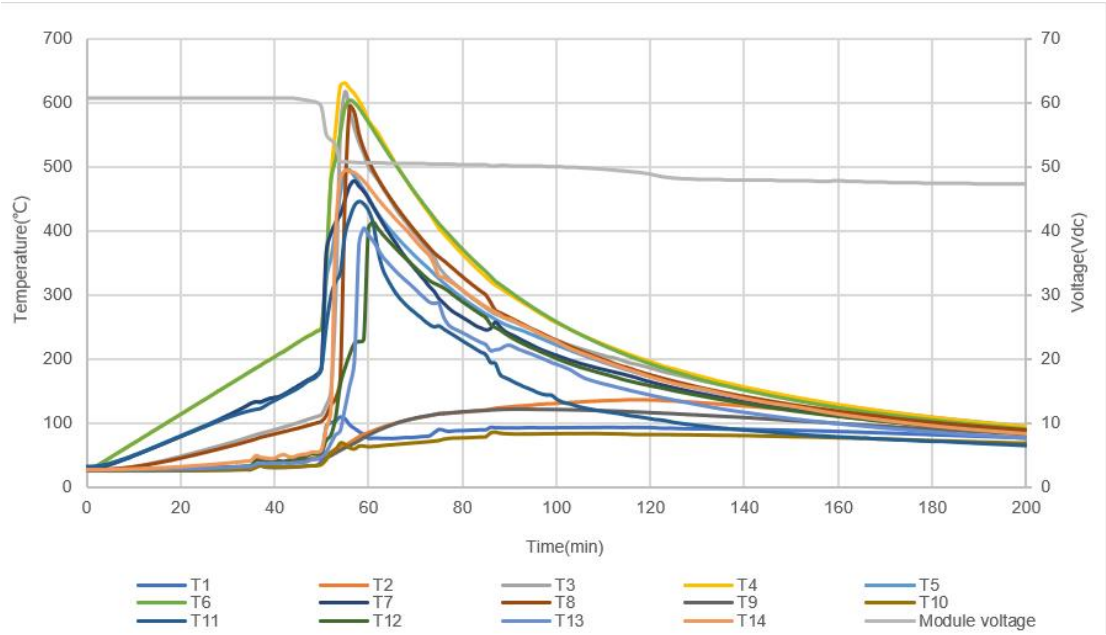


Figure 1: Initiating Cell temperature and module voltage

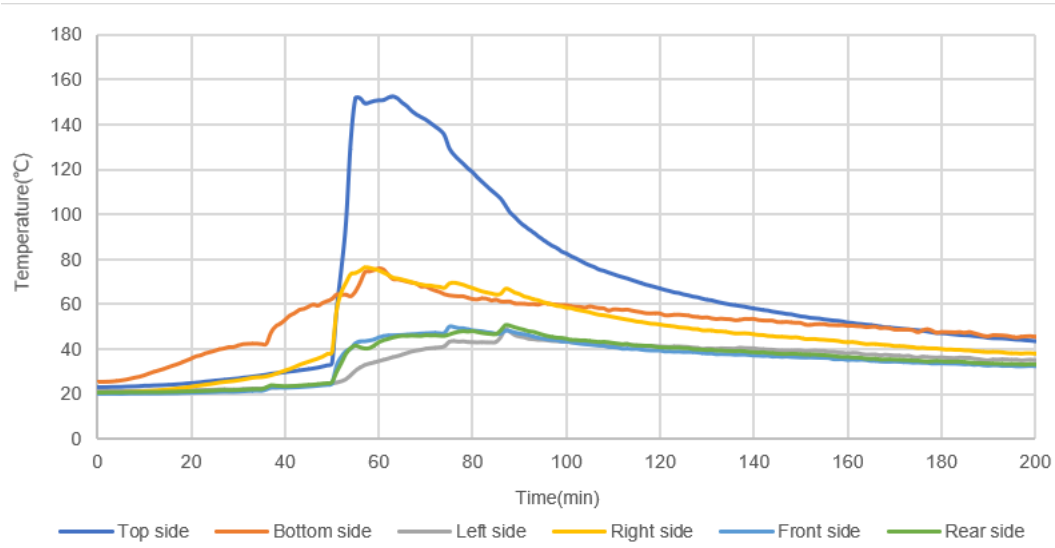


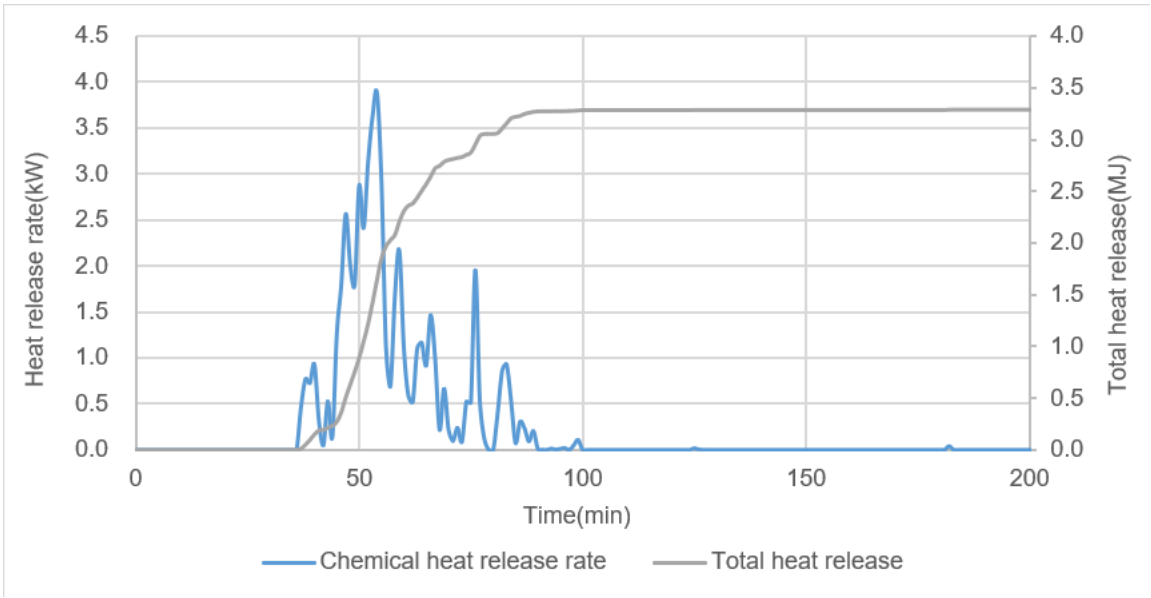
Figure 2: Module enclosure temperature

Attachment 3 - Cell temperature/voltage graph during testing

Maximum temperature measurement	
Location	**Measured maximum temperature (°C)**
Maximum temperature within module(Cell 5 left side under heater film)	630
Maximum temperature at Module enclosure (top surface)	152

Master Contract:	302680	Model:	EQ4000	Page number 19 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

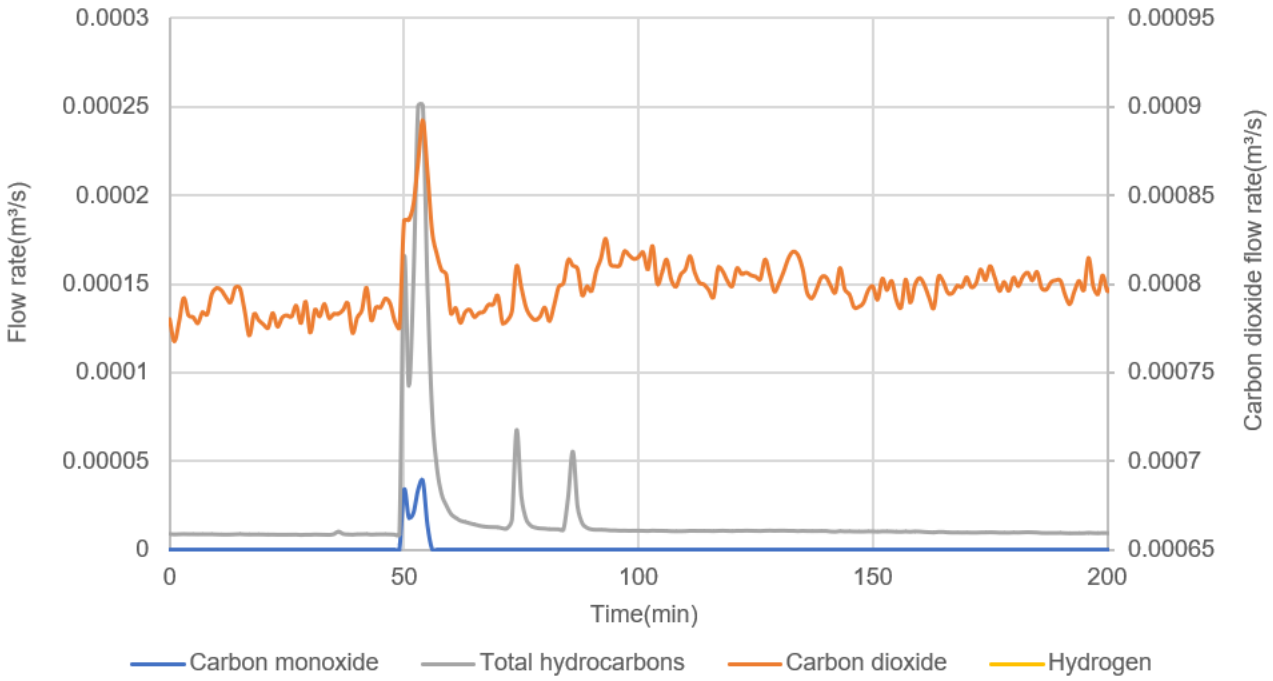
Attachment 4 - Heat Release Rate graphs



Note: No flame observed during test, so the heat release rate and Total Heat Release are identified as noise.

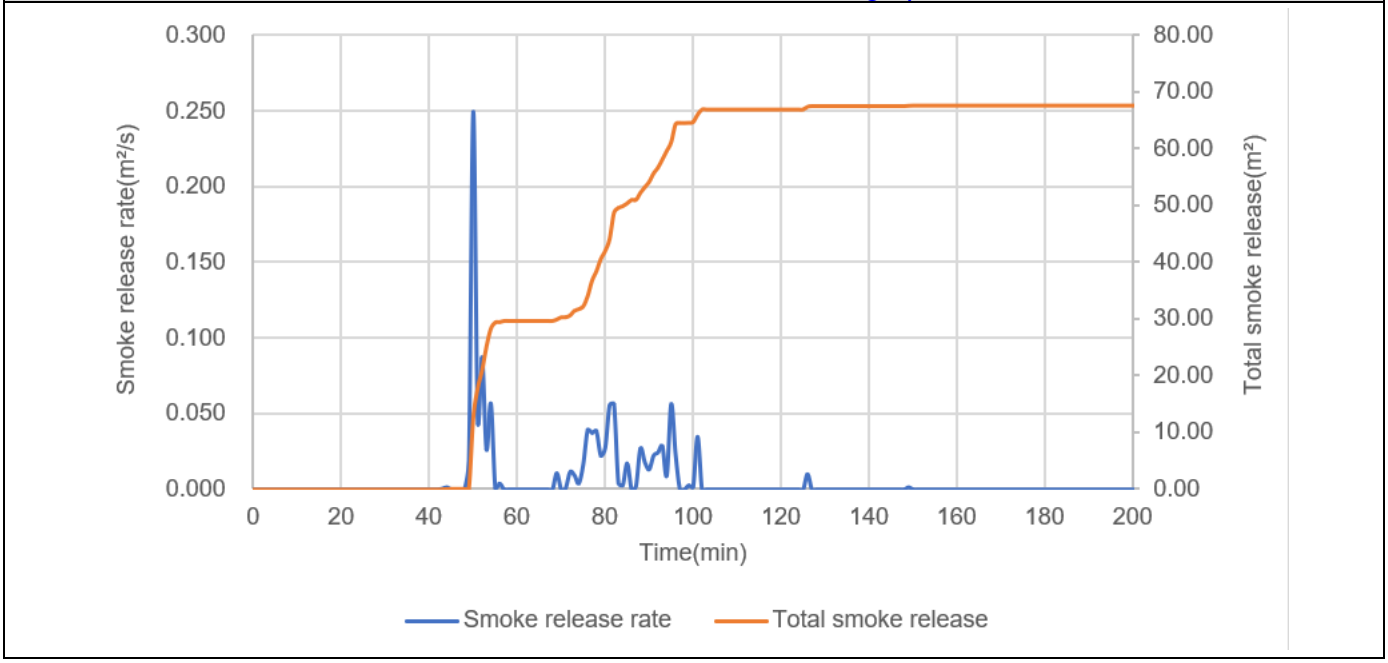
Master Contract:	302680	Model:	EQ4000	Page number 20 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Attachment 5 - Gas generation graphs



Master Contract:	302680	Model:	EQ4000	Page number 21 of 22
Project / Network:	80204927	Description:	Lithium-ion rechargeable battery module	

Attachment 6 - Smoke release graph



Attachment 7 - Notable observation during test

Observation	Time from test start (mm/dd HH:MM:SS)	Comment
Test start	03/19 16:26:39	Two pieces of heater film on cell 5 was energized with thermal ramp 4.5°C/min
Venting/Thermal runaway	03/19 17:01:10	Cell 5 was venting with temperature dropped
Venting/Thermal runaway	03/19 17:17:03	Cell 5 was thermal runaway with smoke released and all of heater film was deenergized
Venting/Thermal runaway	03/19 17:19:05	Cell 4 was thermal runaway with smoke released
Venting/Thermal runaway	03/19 17:20:33	Cell 6 was thermal runaway with smoke released
Test end	03/20 08:30:00	Data acquisition stopped

End of Report….