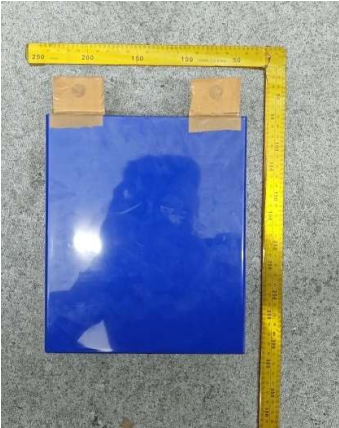


Prüfbericht-Nr.: <i>Test report no.:</i>	CN243TAR 001	Auftrags-Nr.: <i>Order no.:</i>	326009576	Seite 1 von 32 <i>Page 1 of 32</i>
Kunden-Referenz-Nr.: <i>Client reference no.:</i>	2371109	Auftragsdatum: <i>Order date:</i>	2024-03-26	
Auftraggeber: <i>Client:</i>	CSI Energy Storage Co., Ltd. No. 348 Lushan Road, SND, Suzhou City, 215000 Jiangsu, P.R. China			
Prüfgegenstand: <i>Test item:</i>	Battery Cell			
Bezeichnung / Typ-Nr.: <i>Identification / Type no.:</i>	CSI314			
Auftrags-Inhalt: <i>Order content:</i>	Test report			
Prüfgrundlage: <i>Test specification:</i>	UL 9540A: 2019 (Fourth Edition) Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems			
Wareneingangsdatum: <i>Date of sample receipt:</i>	2024-05-09			
Prüfmuster-Nr.: <i>Test sample no.:</i>	Engineering sample			
Prüfzeitraum: <i>Testing period:</i>	2024-06-04 - 2024-07-08			
Ort der Prüfung: <i>Place of testing:</i>	See page 5 Testing location			
Prüflaboratorium: <i>Testing laboratory:</i>	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüfergebnis*: <i>Test result*:</i>	See main report			
geprüft von: tested by: Minhao Hu&Yichen Zhao	genehmigt von: authorized by: Simon Wang			
Datum: <i>Date:</i> 2024-08-06	Minhao Hu Yichen		Ausstellungsdatum: <i>Issue date:</i> 2024-08-06	
Stellung / Position:	Project Engineer/Trainee	Stellung / Position:	Authorizer	
Sonstiges / <i>Other:</i>	N/A			
Zustand des Prüfgegenstandes bei Anlieferung: <i>Condition of the test item at delivery:</i>	Prüfmuster vollständig und unbeschädigt <i>Test item complete and undamaged</i>			
* Legende:	P(ass) = entspricht o.g. Prüfgrundlage(n)	F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
* Legend:	P(ass) = passed a.m. test specification(s)	F(ail) = failed a.m. test specification(s)	N/A = not applicable	N/T = not tested
Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht auszugsweise vervielfältigt werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens. <i>This test report only relates to the above mentioned test sample. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.</i>				

Prüfbericht-Nr.: CN243TAR 001
Test report no.:

Seite 2 von 32
Page 2 of 32

Anmerkungen
Remarks

1	Alle eingesetzten Prüfmittel waren zum angegebenen Prüfzeitraum gemäß eines festgelegten Kalibrierungsprogramms unseres Prüfhauses kalibriert. Sie entsprechen den in den Prüfprogrammen hinterlegten Anforderungen. Die Rückverfolgbarkeit der eingesetzten Prüfmittel ist durch die Einhaltung der Regelungen unseres Managementsystems gegeben. Detaillierte Informationen bezüglich Prüfkonditionen, Prüfequipment und Messunsicherheiten sind im Prüflabor vorhanden und können auf Wunsch bereitgestellt werden. <i>The equipment used during the specified testing period was calibrated according to our test laboratory calibration program. The equipment fulfils the requirements included in the relevant standards. The traceability of the test equipment used is ensured by compliance with the regulations of our management system. Detailed information regarding test conditions, equipment and measurement uncertainty is available in the test laboratory and could be provided on request.</i>
2	Wie vertraglich vereinbart, wurde dieses Dokument nur digital unterzeichnet. Der TÜV Rheinland hat nicht überprüft, welche rechtlichen oder sonstigen diesbezüglichen Anforderungen für dieses Dokument gelten. Diese Überprüfung liegt in der Verantwortung des Benutzers dieses Dokuments. Auf Verlangen des Kunden kann der TÜV Rheinland die Gültigkeit der digitalen Signatur durch ein gesondertes Dokument bestätigen. Diese Anfrage ist an unseren Vertrieb zu richten. Eine Umweltgebühr für einen solchen zusätzlichen Service wird erhoben. Informationen zur Verifizierung der Authentizität unserer Dokumente erhalten Sie auf folgender Webseite: go.tuv.com/digital-signature <i>As contractually agreed, this document has been signed digitally only. TUV Rheinland has not verified and unable to verify which legal or other pertaining requirements are applicable for this document. Such verification is within the responsibility of the user of this document. Upon request by its client, TUV Rheinland can confirm the validity of the digital signature by a separate document. Such request shall be addressed to our Sales department. An environmental fee for such additional service will be charged. For information on verifying the authenticity of our documents, please visit the following website: go.tuv.com/digital-signature</i>
3	Prüfklausel mit der Note * wurden an qualifizierte Unterauftragnehmer vergeben und sind unter der jeweiligen Prüfklausel des Berichts beschrieben. Abweichungen von Prüfspezifikation(en) oder Kundenanforderungen sind in der jeweiligen Prüfklausel im Bericht aufgeführt. <i>Test clauses with remark of * are subcontracted to qualified subcontractors and described under the respective test clause in the report.</i> <i>Deviations of testing specification(s) or customer requirements are listed in specific test clause in the report.</i>
4	Die Entscheidungsregel für Konformitätserklärungen basierend auf numerischen Messergebnissen in diesem Prüfbericht basiert auf der "Null-Grenzwert-Regel" und der "Einfachen Akzeptanz" gemäß ILAC G8:2019 und IEC Guide 115:2021, es sei denn, in der auf Seite 1 dieses Berichts genannten angewandten Norm ist etwas anderes festgelegt oder vom Kunden gewünscht. Dies bedeutet, dass die Messunsicherheit nicht berücksichtigt wird und daher auch nicht im Prüfbericht angegeben wird. Zu weiteren Informationen bezüglich des Risikos durch diese Entscheidungsregel siehe ILAC G8:2019. <i>The decision rule for statements of conformity, based on numerical measurement results, in this test report is based on the "Zero Guard Band Rule" and "Simple Acceptance" in accordance with ILAC G8:2019 and IEC Guide 115:2021, unless otherwise specified in the applied standard mentioned on Page 1 of this report or requested by the customer. This means that measurement uncertainty is not taken in account and hence also not declared in the test report. For additional information to the resulting risk based of this decision rule please refer to ILAC G8:2019.</i>

TEST REPORT	
ANSI/CAN/UL 9540A:2019	
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	
Report Number.	CN243TAR 001
Date of issue	See Cover Page
Total number of pages	See Cover Page
Name of Testing Laboratory preparing the Report	TÜV Rheinland (Shanghai) Co., Ltd. No. 177, Lane 777, West Guangzhong Road, Jing'an District, Shanghai 200072, P. R. China
Applicant's name	CSI Energy Storage Co., Ltd.
Address	No. 348 Lushan Road, SND, Suzhou City, 215000 Jiangsu, P.R. China
Test specification:	
Standard	ANSI/CAN/UL 9540A:2019
Test procedure	TÜV Rheinland Test Report
Non-standard test method	N/A
Test Report Form No.	UL 9540A-C01
Test Report Form(s) Originator	TÜV Rheinland (Shanghai) Co., Ltd.
Master TRF	Dated 2023-12-25
General disclaimer:	
The test 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 Issuing Testing Laboratory. The authenticity of this Test Report and its contents can be verified by contacting the TÜV Rheinland (Shanghai) Co., Ltd., responsible for this Test Report.	
Other / Scope:	
This report presents the result of cell level tests of UL 9540A: 2019. All tests were conducted at TUV Rheinland (Shanghai) Co., Ltd. and TUV Rheinland's partner labs that were under supervision of TÜV Rheinland's engineer. All tests were under supervision of TÜV Rheinland's engineer.	

List of Attachments:
Attachment A: Cell Conditioning (Charge/discharge) Profiles

Attachment B: Test method and result

Attachment C: Temperature and voltage profile during the test

Attachment D: Cell vent gas composition, Lower flammability limit (LFL), Vent gas burning velocity (Su) and Vent gas maximum pressure (Pmax)

Attachment E: Sample Photos and Test Photos

Attachment F: List of Test and Measurement Instruments

Summary of testing:

Model No:	CSI314
Ratings (Vdc, Ah):	3.2 V, 314 Ah
Chemistry of test item:	LiFePO ₄
Compliance with UL1973:	☒ Yes <u>Report No.: CN24XEVJ 001</u> <u>Cert. No.: CU 72405509 0001</u> ☐ No
Average cell surface temperature at gas venting:	167.4 °C
Average cell surface temperature at thermal runaway:	238.5 °C
Gas Volume:	180.7 L (std)
Lower flammability limit (LFL), % volume in air at the ambient temperature:	8.3%
Lower flammability limits (LFL), % volume in air at the venting temperature:	7.3%
Burning velocity (Su):	0.973 m/s
Maximum pressure (Pmax):	0.760 MPa

Cell Gas composition

Gas component		Concentration % (v/v)
Methane	CH ₄	4.495
Acetylene	C ₂ H ₂	0.157
Ethylene	C ₂ H ₄	2.299
Ethane	C ₂ H ₆	0.729
Propyne	C ₃ H ₄	0.012
Propylene	C ₃ H ₆	0.952
Propane	C ₃ H ₈	0.211
Butylene	C ₄ H ₈	0.616
Butane	C ₄ H ₁₀	0.080

Hydrogen	H ₂	49.725
Carbon Monoxide	CO	13.898
Carbon Dioxide	CO ₂	26.826
Total	-	100

Cell failure test method performed (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	☐
Others	☐

Result of testing:
Performance Criteria in accordance with Clause 7.7 and Figure 1.1:

Thermal runaway was not induced in the cell; and	☐
The cell vent gas did not present a flammability hazard when mixed with any volume of air, as determined in accordance with ASTM E918 at both ambient and vent temperatures.	☐

Necessity of a module level test

The performance criteria of the cell level test as indicated in 7.7 of UL 9540A 4th edition has not been met, therefore a module level testing in accordance with UL 9540A will need to be conducted on a complete module employing this cell.	☒
The performance criteria of the cell level tests as indicated in 7.7 of UL 9540A 4th edition has been met, therefore a module level testing in accordance with UL 9540A need not be conducted.	☐

Tests performed (name of test and test clause): UL 9540A cl 7. Cell Level	Testing location: National Center of Inspection and Testing on Advanced Energy Storage Products Quality (Jiangsu) 101 xinjin Road, xinwu, Wuxi, Jiangsu
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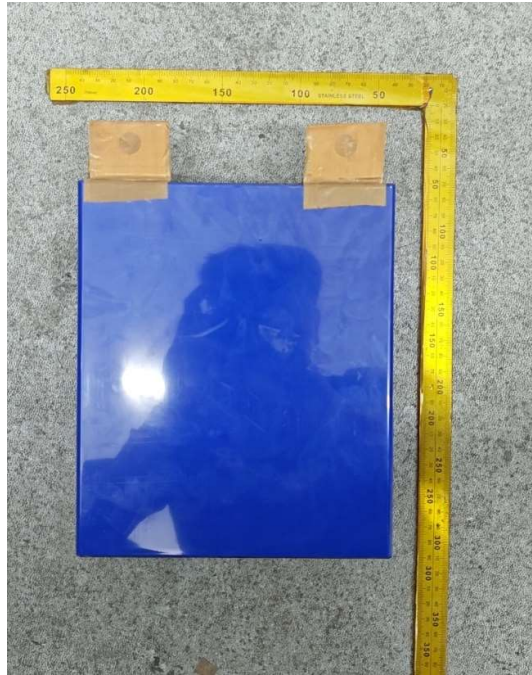
Possible test case verdicts:

- 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)

Testing:	
Date of receipt of test item	2024-05-09
Date (s) of performance of tests	2024-06-04 to 2024-07-08
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 ☐ comma / ☒ point is used as the decimal separator.	
Name and address of factory (ies)	Same as applicant
Other: N/A	

General product information :

Photo of cell:



Manufacturer..... :	CSI Energy Storage Co., Ltd.	
Model number..... :	CSI314	
Chemistry..... :	☒ LiFePO ₄ ☐ NMC ☐ NCA ☐ LTO ☐ Other:	
Physical configuration..... :	☒ Prismatic ☐ Cylindrical ☐ Pouch Weight(g): 5600±200	
Electrical rating	Rated capacity (Ah):	314
	Nominal voltage (V):	3.2
	Charge current (A):	157
Standard charge method	End of charge voltage(V):	3.65
	Charge temperature range(°C):	0~60
	Discharge current (A):	157
Standard discharge method	End of discharge voltage(V):	2.5
	Discharge temperature range(°C):	-20~60
Compliance with UL 1973..... :	☒ Yes Report No.: CN24XEVJ 001 Cert. No.: CU 72405509 0001	
Diagram with overall dimension(W*H*T) :	(173.7±0.5)mm * (207.2±0.5)mm * (71.5±0.5)mm	

ANSI/CAN/UL 9540A:2019			
Clause	Requirement - Test	Result - Remark	Verdict
CONSTRUCTION			--
5	General		--
5.1	Cell		P
5.1.1	The cells info associated with the BESS include:		P
	Cell chemistry (e.g. NMC, LFP);	See page 7 "General product information "	P
	The physical format of the cell;	See page 7 "General product information "	P
	The cell electrical rating in capacity and nominal voltage;	See page 7 "General product information "	P
	Overall Dimensions, mm	See page 7 "General product information "	P
	Cell Weight, g	See page 7 "General product information "	P
5.1.2	The cells associated with the BESS comply with ANSI/CAN/UL 1973 or not.	See page 7 "General product information "	P
5.1.3	Further details included in the cell level test report.	Refer to 7.6.1	N/A
5.2	Module	Cell only	N/A
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report		N/A
5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973		N/A
5.2.3	Refer to 8.3 for further details		N/A
5.3	Battery energy storage system unit		N/A
5.3.1	The BESS unit documentation included in the test report shall indicate the units that comply with UL 9540		N/A
5.3.2	For BESS units for which UL 9540 compliance cannot be determined,		N/A
5.3.3	If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report		N/A
5.3.4	Refer to 9.7, 10.4 and 10.7 for further details		N/A
5.4	Flow Batteries		N/A
5.4.1	For flow batteries, the report will cover the chemistry, as well as the electrical rating in capacity and nominal voltage of the cell stack		N/A
5.4.2	The flow battery documentation included in the test report shall indicate if the flow battery system complies with UL 1973		N/A
5.4.3	See 7.6.2 for further details		N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement - Test	Result - Remark	Verdict
PERFORMANCE			--
6	General		--
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires		P
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications		P
7	Cell Level		--
7.1	General		P
7.1.1	Effective methods for forcing a cell into thermal runaway in a repeatable manner.	Two external film heaters (size 200mm*150mm)	P
7.2	Sample		P
7.2.1	Cell samples conditioned, prior to testing, through charge and discharge cycles for a minimum of 2 cycles using a manufacturer specified methodology to verify that the cells are functional.	See Attachment A	P
7.2.2	The cells charged to 100% SOC and allowed to stabilize for 1 to 8 h before testing.	See Attachment A	P
7.2.3	Cells with flexible laminate casings be constrained during the test to simulates the constraint in the BESS module to prevent excessive swelling.	Two metal plate (size 227*200*1.5 mm) band on either side of the large surface of the prismatic cell surface	P
7.3	Determination of thermal runaway methodology		P
7.3.1	General		P
7.3.1.1	Ambient indoor laboratory conditions: 25±5°C and 50±25% RH at the initiation of the test.	External heating thin film used	P
7.3.1.2	The propensity of the cell to exhibit thermal runaway demonstrated by heating the cell with externally applied flexible film heaters that cover as much of the cell case as possible without covering safety features or terminals, for consistent heating of the internal cell electrode assembly.		P
	A surface heating rate of 4°C to 7°C per minute applied to the cell.		P
	Determination of a maximum surface temperature end point criteria shall be developed based upon a review of cell design and chemistry.	Not used, heated until thermal runaway achieved	N/A
	If external heating with a flexible film heater does not cause the cell to exhibit thermal runaway, one of the following methods shall be employed to cause thermal runaway: a) Mechanical (e.g. nail penetration); b) Electrical stresses in the form of overcharging, over discharging or external short-circuiting; or c) Use of alternate heating sources (e.g. oven).		N/A

ANSI/CAN/UL 9540A:2019			
Clause	Requirement - Test	Result - Remark	Verdict
7.3.1.3	When using another cell abuse method to initiate thermal runaway, document the details of it.		N/A
7.3.1.4	In the case of monobloc batteries such as lead acid or nickel cadmium, the monobloc battery can be treated as an individual cell for this testing.		N/A
7.3.1.5	Estimated surface temperature at which internal short circuiting within the cell will occur that could lead to a thermal runaway condition.	Not used, heated until thermal runaway achieved	N/A
7.3.1.6	If using another external heating method, the temperature ramp and max. surface temperature outlined in 7.3.1.2 and 7.3.1.5 shall be used.		N/A
7.3.1.7	The cell's exterior surface temperature was measured	See Attachment C	P
7.3.1.8	The temperature at which the cell case vents due to internal pressure rise was documented.	See Attachment B	P
7.3.1.9	The temperature at the onset of thermal runaway shall be documented.	See Attachment B	P
	If cell venting occurs first, the cell was heated continuously until thermal runaway occurs.	See Attachment C	P
7.3.1.10	When using methods other than the heater method, the stresses (i.e. electrical or mechanical) shall be applied to the cell until thermal runaway occurs.		N/A
7.3.1.11	If the cell exhibits thermal runaway behavior, 3 additional samples tested using the same method and exhibit thermal runaway to demonstrate repeatability	See Attachment B	P
7.3.2	Flow battery thermal runaway determination tests		N/A
7.4	Cell vent gas composition test		P
7.4.1	Cell vent gas shall be generated and captured by forcing a cell into thermal runaway inside a pressure vessel.	A 140 L pressure vessel used	P
	The test shall be initiated with an initial condition of atmospheric pressure and less than 1% oxygen by volume.		P
	The initial atmospheric conditions prior to testing.	Pressure inside: 101.3 kPa	P
7.4.2	Cell vent gas composition	See Attachment D	P
	Hydrocarbon gases that represent an ignition or explosion hazard as well as other additional gases.		P
	Hydrogen gas shall be measured with a sensor capable of measuring in excess of 30% by volume.		P
7.4.3	The lower flammability limit of the cell vent gas, samples of the synthetically replicated gas mixture in accordance with ASTM E918.	See Attachment D	P
7.4.4	The synthetically replicated gas mixture used to determine gas burning velocity in accordance with the Method of Test for Burning Velocity Measurement of Flammable Gases.	See Attachment D	P
7.4.5	The synthetically replicated gas mixture used to determine Pmax in accordance with EN 15967.	See Attachment D	P

ANSI/CAN/UL 9540A:2019			
Clause	Requirement - Test	Result - Remark	Verdict
7.5	Off gas composition for flow battery systems	Li-ion cell	N/A
7.5.1	The off gas composition from the flow battery testing in a closed container and capturing the off gasses generated, and by collecting the off gasses generated at vent openings and vent ducts during the overcharge and short circuit testing.		N/A
	Composition of these captured gases and their flammability limit.		N/A
7.5.2	The volume of flammable gases measured during the testing shall be scaled to the maximum energy reservoir for the intended flow battery system in order to determine the potential total flammable gas that can be produced by the system under a fault condition that leads to off gassing.		N/A
7.6	Cell level test report		P
7.6.1	The report on cell level testing shall include the following:		P
	a) Cell manufacturer name and cell model number;	See production information	P
	b) Cell details per 5.1 (and whether UL 1973 compliant);	See production information	P
	c) Energy storage technology (and whether UL 9540 compliant);	UL 9540 certificate not provided	P
	d) The rated energy storage capacity of the cell;	See production information	P
	e) Voltage and current obtained during conditioning of the cell;	See Attachment A	P
	f) Open-circuit voltage of the cell at initiation of test;	See Attachment B	P
	g) Methods attempted and used to initiate thermal runaway;	See Attachment B	P
	h) Surface temperature at which gases are first vented and the average temperature of the samples tested excluding the gas collection sample;	See Attachment B	P
	i) Surface temperature (and location of maximum temperature) prior to thermal runaway and average temperature of the samples tested excluding the gas collection sample;	See Attachment B	P
	j) Flammable gas generation and composition measurements;	See Attachment D and E	P
	k) The lower flammability limit of the cell vent gas;	See Attachment D	P
	l) Burning velocity of the cell vent gas; and	See Attachment D	P
	m) Pmax of the cell vent gas.	See Attachment D	P
7.6.2	Minimum information of items a) through k) was provided in the report for flow battery		N/A
7.7	Performance – cell level test		F
7.7.1	a) Thermal runaway cannot be induced in the cell; and	Thermal runaway induced	F
	b) The cell vent gas does not present a flammability hazard when mixed with any volume of air, as	Vent gas is flammable	F

ANSI/CAN/UL 9540A:2019			
Clause	Requirement - Test	Result - Remark	Verdict
	determined in accordance with ASTM E918 at both ambient and vent temperatures.		
7.7.2	BESS contain cells that all comply with the criteria in 7.7.1 shall be suitable for installation in residential dwelling units.		N/A
7.8	Performance – flow battery thermal runaway determination tests		N/A

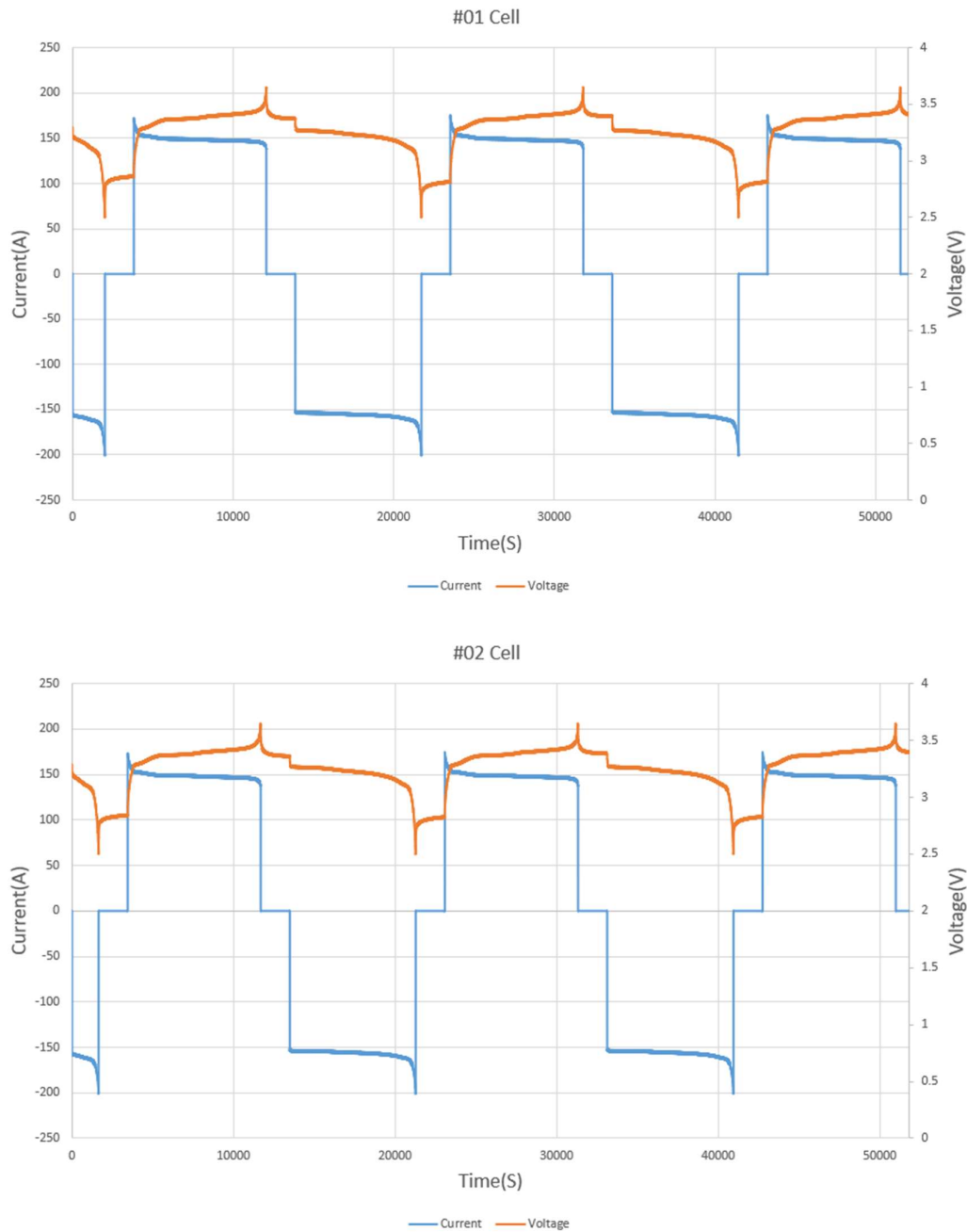
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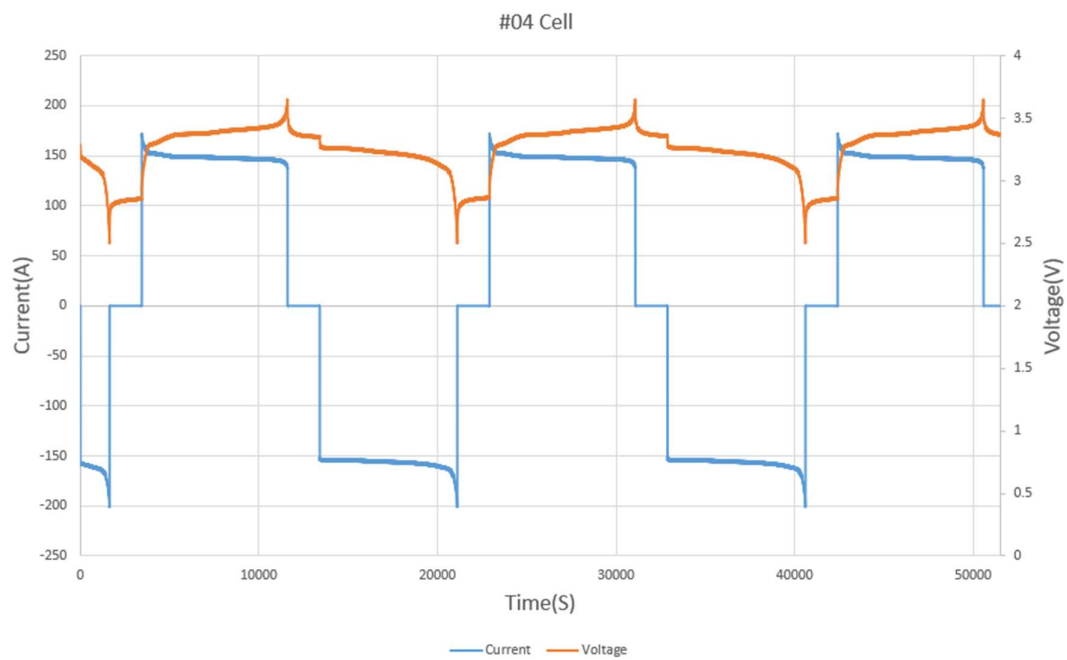
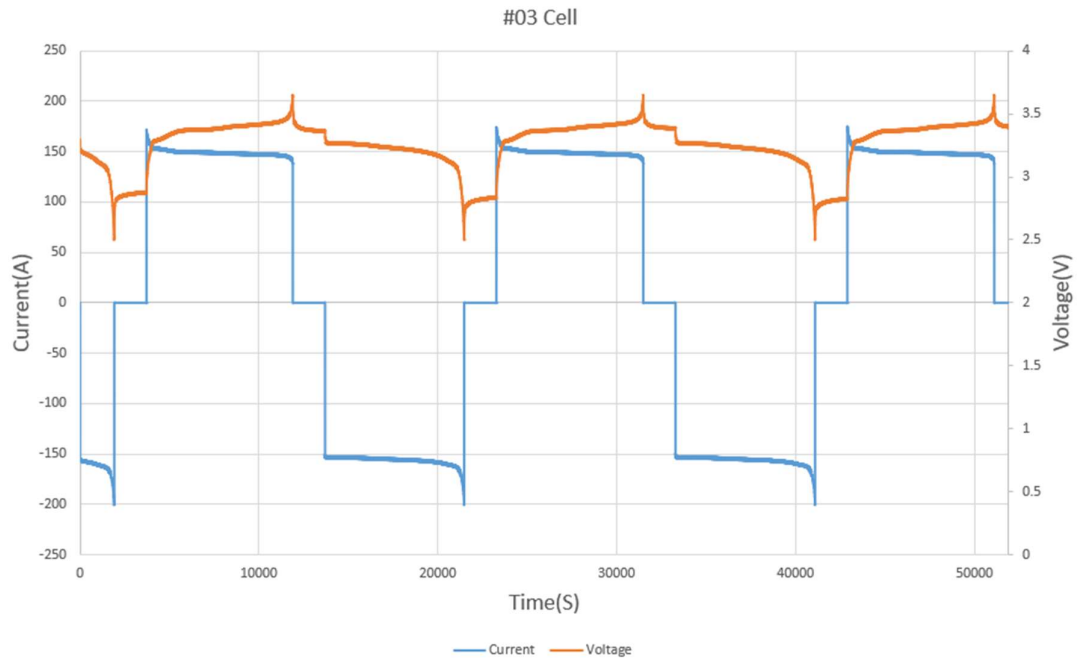
Attachment A: Cell Conditioning (Charge/discharge) Profiles

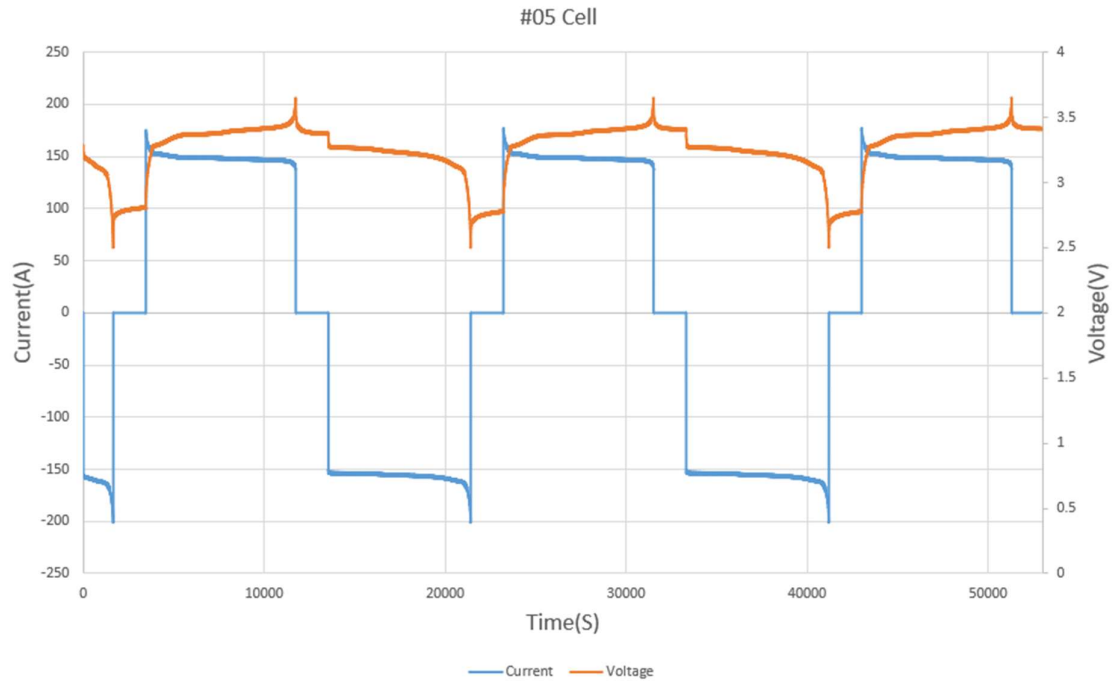
The cells were conditioned, prior to testing, through charge and discharge cycles for 2 cycles using a manufacturer specified methodology.

During the cycling, ambient condition is maintained within $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and R.H. $50 \pm 5\%$.

Figure 1. Cell charge and discharge voltage/current profiles

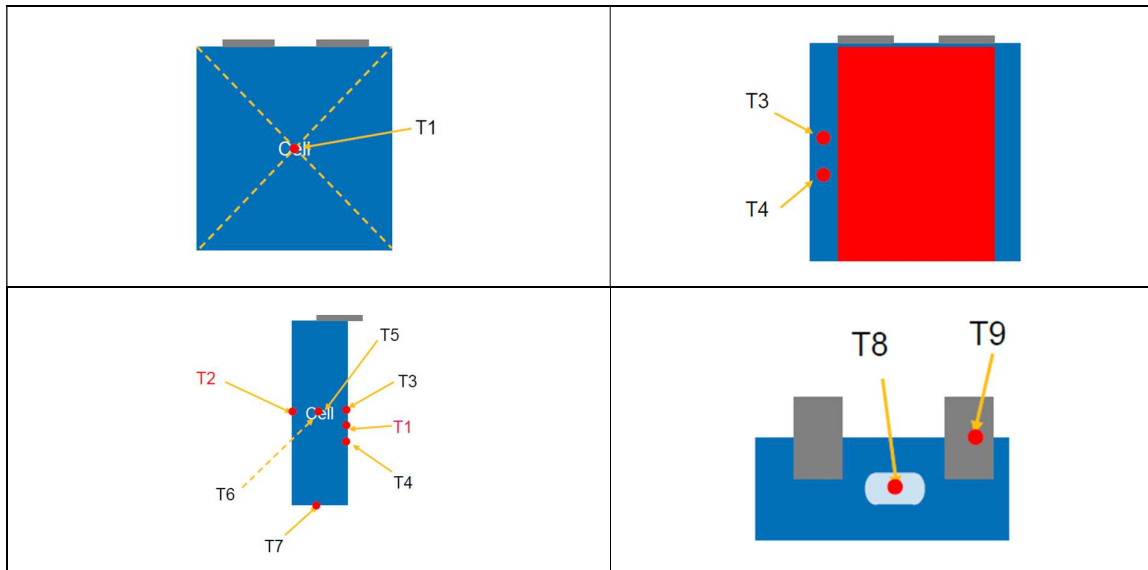






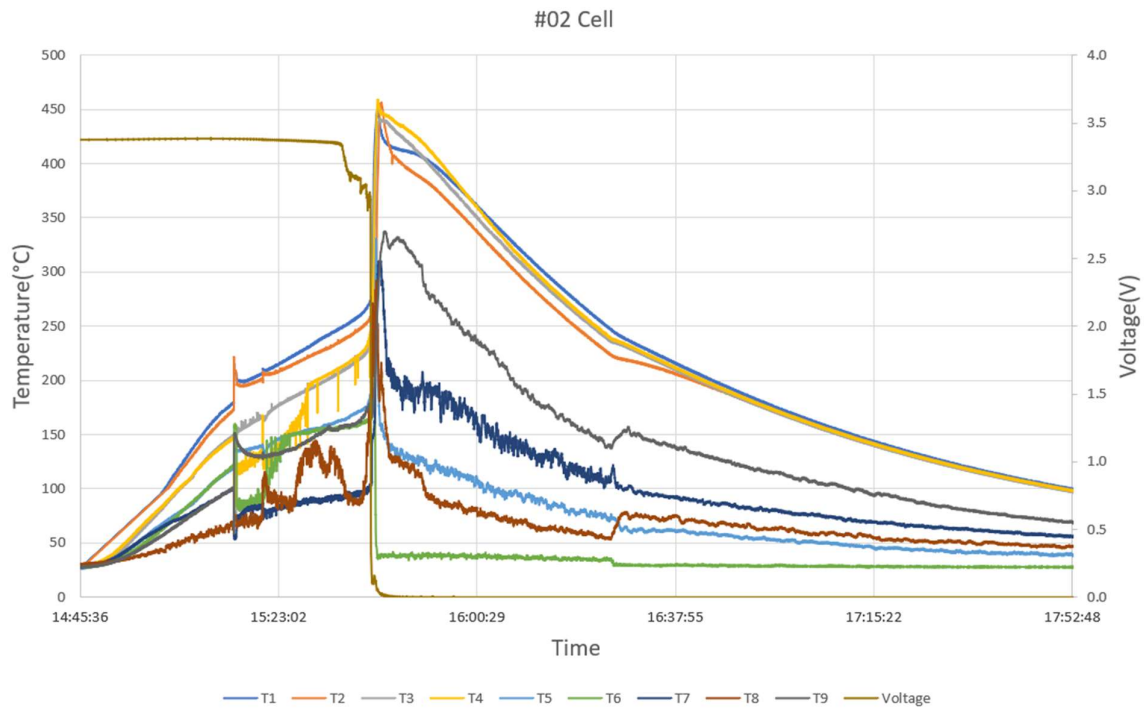
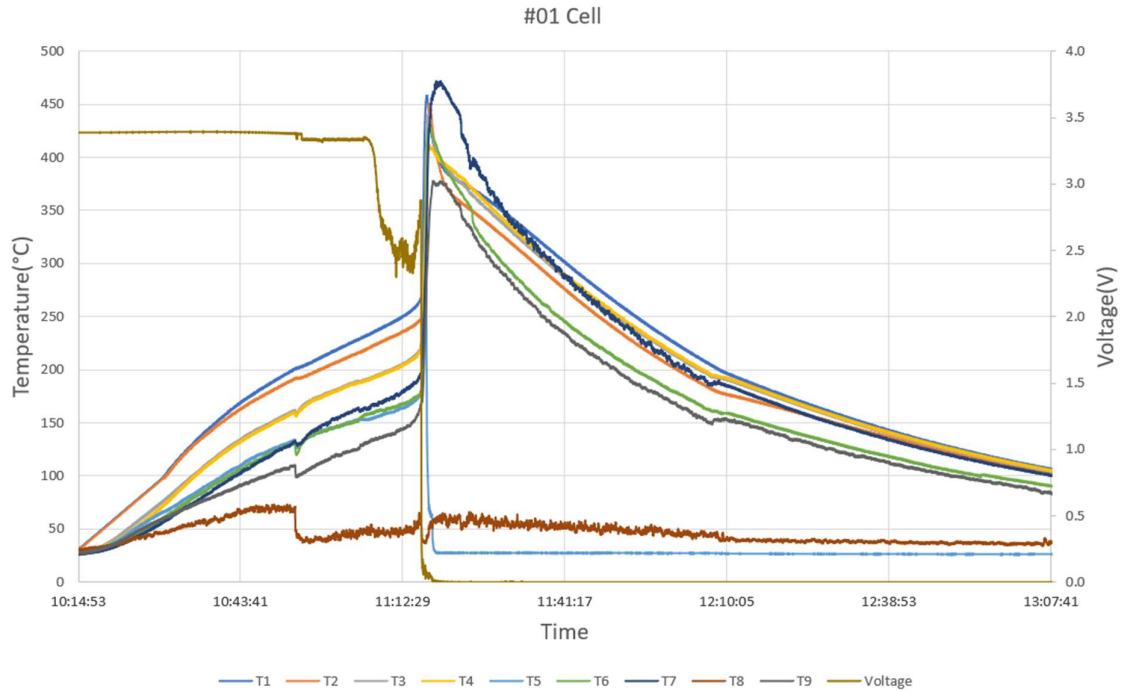
Attachment B: Test method and result

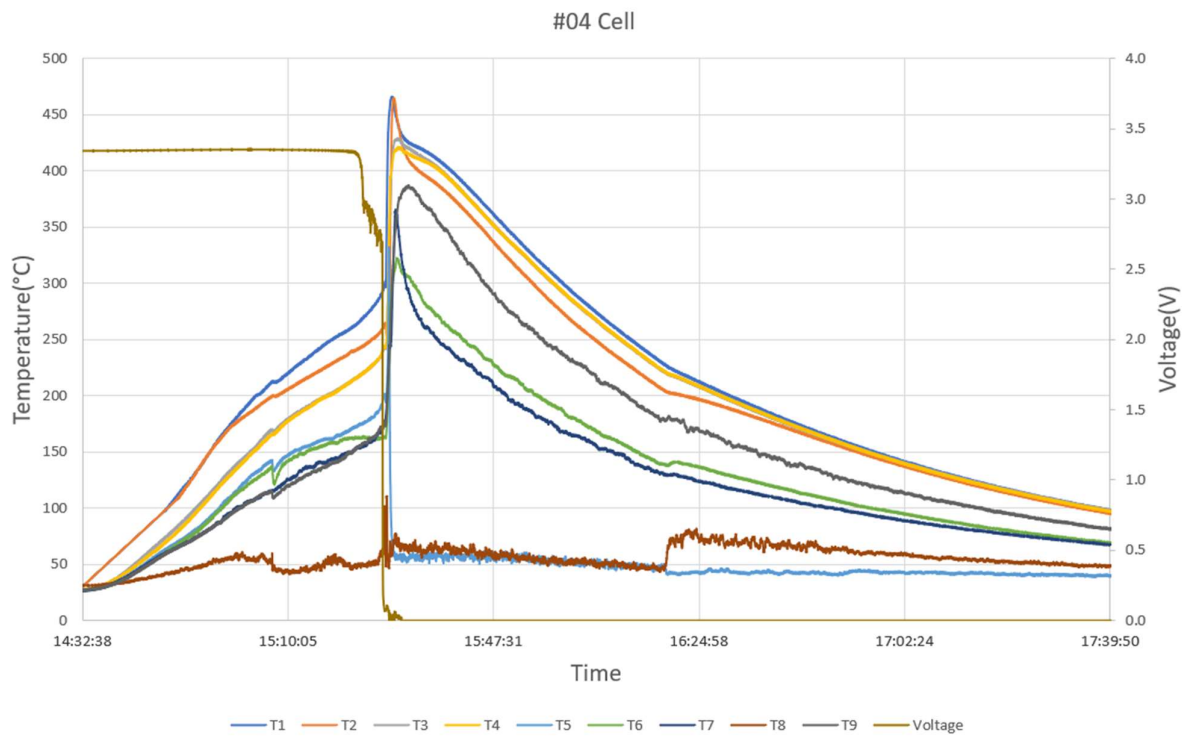
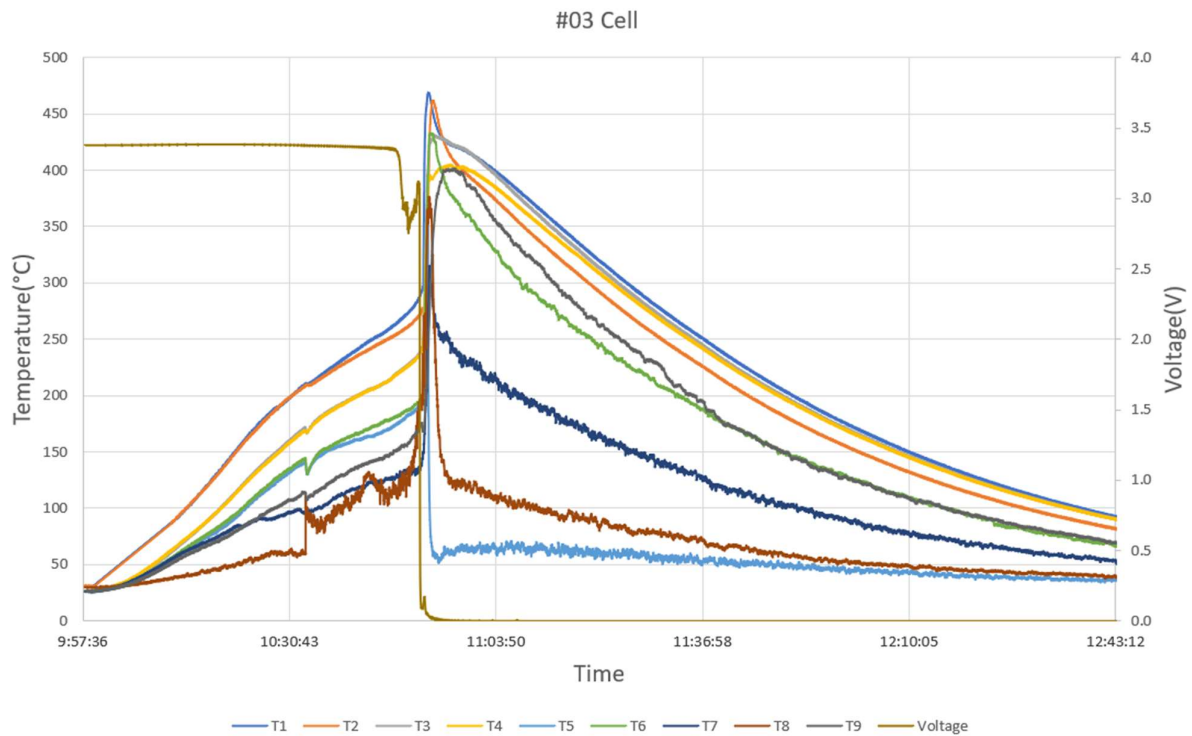
Thermocouple (type K, 24AWG), T1 and T2 were located below the heater, at the center of the cell surface used to record cell temperature. T3 and T4 were located on the side of the wide surface, near the heater to record cell temperature. T5 and T6 were located on the side of the narrow surface. T7 was located on bottom surface of cell. T8 was located on vent of cell. T9 was located on the positive electrode.

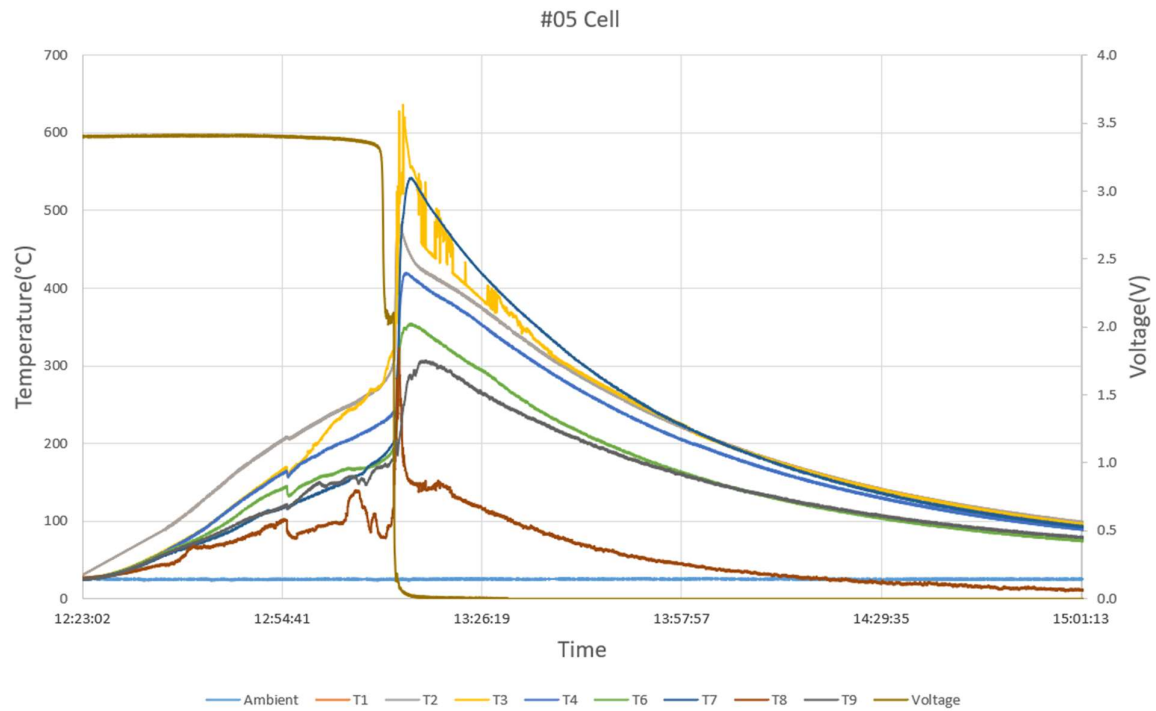


Ambient conditions at the initiation of the test	25.7°C 50% R.H.	24.1°C 55% R.H.	23.9°C 48% R.H.	24.3°C 48% R.H.	23.8°C 46% R.H.
Sample number	#01	#02	#03	#04	#05 ¹⁾
Open circuit voltage before test (V)	3.39	3.38	3.38	3.35	3.41
Cell vent temperature (°C)	162.0	166.0	171.7	169.9	169.7
Cell vent time (seconds)	2368	2061	2127	2114	2087
Thermal runaway onset temperature (°C)	224.1	242.1	242.1	245.9	240.0
Thermal runaway time (seconds)	3718	3313	3254	3362	3109
Maximum temperature (°C)	472.0	459.2	468.7	465.7	636.3
Average cell vent temperature (°C) ²⁾	167.4				
Average thermal runaway onset temperature (°C) ²⁾	238.5				
Note:					
1) The sample is for gas vent capture.					
2) The temperatures were averaged over the tested samples (#01, #02, #03, #04) excluding the gas vent capture sample (#05).					

Attachment C: Temperature and voltage profile during the test







Note: Thermocouple T5 was damaged during the test.

Attachment D: Cell vent gas composition, Lower flammability limit (LFL), Vent gas burning velocity (Su) and Vent gas maximum pressure (Pmax)

The cells to be tested were charged to 100% SOC and allowed to stabilize for a minimum of 1 h and a maximum of 8 h before the start of the test.

A cell was forced into thermal runaway by the external heating as determined in cell thermal runaway methodology test inside a 140L pressure vessel.

Test result

Room ambient condition.....:	23.8 °C, 46% R.H.
Sample number	#05
Open circuit voltage before test (V)	3.41
Pressure vessel size.....:	140 L
Initial oxygen content by volume (%):.....:	< 0.1 %
Cell weight before test (g):.....:	5720
Cell weight after test (g):.....:	4630
Total vent gas produced (L):.....:	180.7 (std)

Gas component		Concentration % (v/v)
Methane	CH ₄	4.495
Acetylene	C ₂ H ₂	0.157
Ethylene	C ₂ H ₄	2.299
Ethane	C ₂ H ₆	0.729
Propyne	C ₃ H ₄	0.012
Propylene	C ₃ H ₆	0.952
Propane	C ₃ H ₈	0.211
Butylene	C ₄ H ₈	0.616
Butane	C ₄ H ₁₀	0.080
Hydrogen	H ₂	49.725
Carbon Monoxide	CO	13.898
Carbon Dioxide	CO ₂	26.826
Total	-	100

Lower flammability level (LFL)

Test Method	ASTM E918-19 Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure	
Lower flammability level (LFL), % volume in air at the ambient temperature		8.3%
Lower flammability level (LFL), % volume in air at the venting temperature		7.3%

Vent gas maximum pressure (Pmax)

Test Method	BS EN 15967:2022 Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours	
Content of flammable substance		27.4% volume
Accuracy		0.2% absolute
Maximum explosion pressure		0.760 MPa

Vent gas burning velocity (Su)

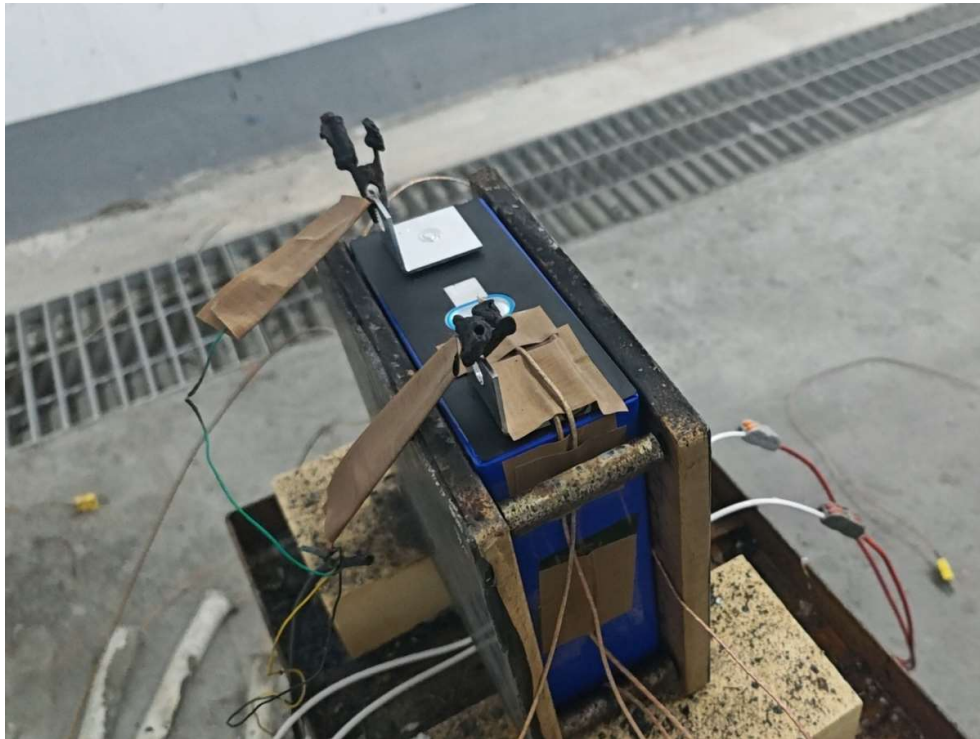
Test Method	ISO 817:2014 / Amd 2:2021 Refrigerants - Designation and safety classification	
Vent gas burning velocity (Su) at room temperature and atmosphere pressure		0.973 m/s

Attachment E: Sample Photos and Test Photos

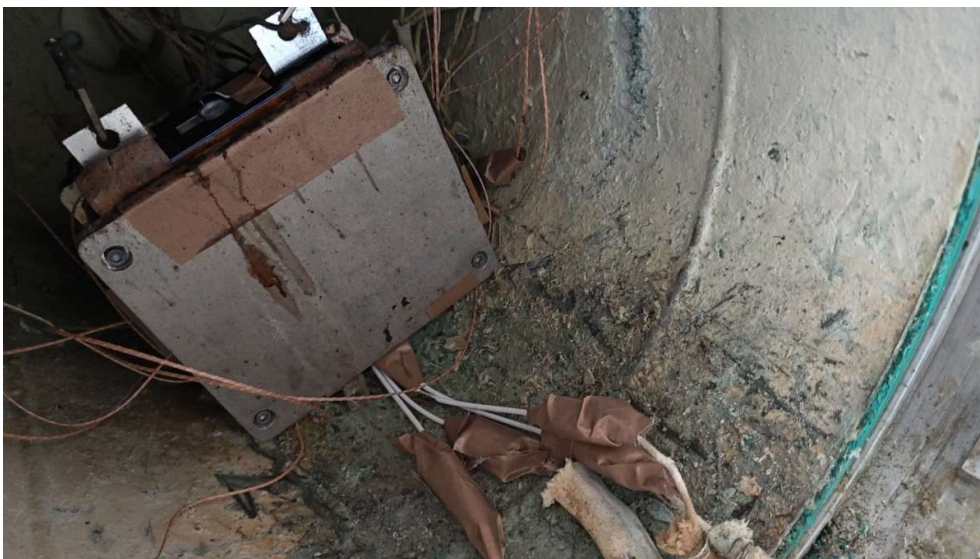
Cell photos



Thermal runaway test setup



Gas generation and capturing setup



Test sample #01 at ambient condition



Venting

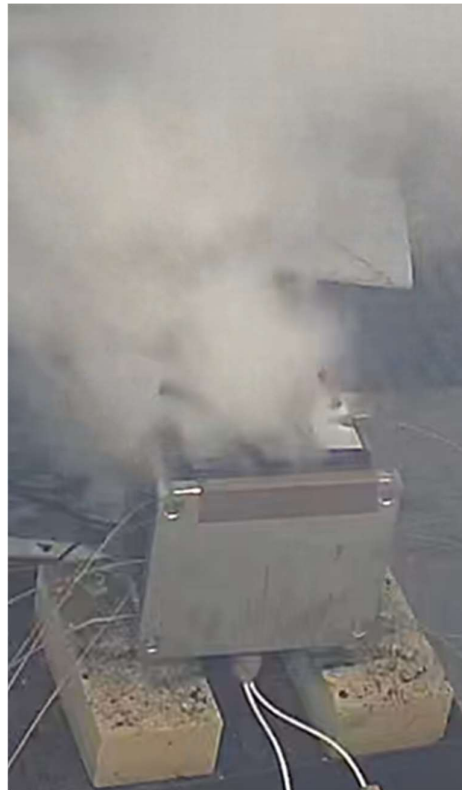


Thermal runaway

Test sample #02 at ambient condition



Venting



Thermal runaway

Test sample #03 at ambient condition



Venting



Thermal runaway

Test sample #04 at ambient condition



Venting



Thermal runaway

Cell sample after test

#01 cell



#02 cell



#03 cell



#04 cell



#05 cell



Attachment F: List of Test and Measurement Instruments

No.	Equipment	Model	Rating	Inventory no.	Cal. expire date
1.	Ambient monitor	WSB-2-H1	0-40°C, 10-90%RH	S-055	2025.01.03
2	Ambient monitor	WSB-2-H1	0-40°C, 10-90%RH	S-050	2025.01.03
3	Ambient monitor	WSB-2-H1	0-40°C, 10-90%RH	S-044	2025.01.03
4	Ambient monitor	WSB-2-H1	0-40°C, 10-90%RH	S-056	2025.01.03
5	Ambient monitor	WSB-2-H1	0-40°C, 10-90%RH	S-006	2025.01.03
6	Charge/discharge equipment	HRCDS-5V300A	5V/300A	S-057	2025.04.11
7	Ruler	300mm	300mm	S-051	2025.01.03
8	Electronic scale	HC311	0-6000g	S-047	2025.02.12
9	Digital multi-meter	FLUKE101	0-600V	S-038	2025.02.08
10	Heating control equipment	DTB4824	0-1000°C	S-060-3	2025.04.11
11	Data acquisition equipment	ADAM-4117	0-10V	S-060-1	2025.04.11
		ADAM-4118	0-1000°C	S-060-2	2025.04.11
12	Heating control equipment	DTB4824	0-1000°C	S-028-3	2025.02.08
13	Data acquisition equipment	ADAM-4117	0-10V	S-028-1	2025.02.08
		ADAM-4118	0-1000°C	S-028-2	2025.01.03
14	Heating control equipment	DTB4824	0-1000°C	S-030-3	2025.02.08
15	Data acquisition equipment	ADAM-4117	0-10V	S-030-1	2025.02.08
		ADAM-4118	0-1000°C	S-030-2	2025.02.08

16	Heating control equipment		DTB4824	0-800°C	S-058-3	2025.04.11
17	Data acquisition equipment		ADAM-4117 ADAM-4118	0-10V 0-1000°C	S-058-1 S-058-2	2025.04.11 2025.04.11
18	Gas Chromatography		PE Clarus680	—	T-177	2024.11.16
19	Gas Chromatography		GC-2014C	—	T-251	2025.02.10
20	Gas acquisition system 82L	Thermopile	WRNK-191 K	0-1000°C	S-020-1~10	2025.01.03
		Pressure sensor	BD-801KZ	0~90kPa	S-020-11	2025.02.08
		Data acquisition equipment	DTM DTB4824 DTM	0-1000°C 0-1000°C 0-10V	S-020-12 S-020-13 S-020-14	2025.01.03
21	Gas acquisition system 10L	Thermopile	GG-K-30-1000	0-800°C	S-046-1~10	2025.06.15
		Pressure sensor	BD-801KZ	0~90kPa	S-020-11	2025.02.08
		Data acquisition equipment	DTM DTB4824 DTM	0-1000°C 0-1000°C 0-10V	S-020-12 S-020-13 S-020-14	2025.01.03
22	Gas acquisition system 86L	Thermopile	GG-K-30-1000	0-800°C	S-052-2~11	2025.04.08
		Pressure sensor	BD-801KZ	0~0.5MPa	S-052-1	2025.04.08
		Data acquisition equipment	ADAM-4117 ADAM-4118 DTB4824	0-10V 0-1000°C 0-1000°C	S-071-1 S-071-2 S-071-3	2025.04.08
23		Thermopile	GG-K-30-1000	0-800°C	S-071-6~15	2025.04.08

	Gas acquisition system 340L	Pressure sensor	PTX-50G2-TC-A3-CA-HO-PB PTX-50G2-TC-A3-CA-HO-PB	0~2MPa -0.1~1MPa	S-071-4 S-071-5	2025.04.08
		Data acquisition equipment	DTM	0-1000℃	S-020-12	2025.01.03
	DTB4824		0-1000℃	S-020-13		
			DTM	0-10V	S-020-14	
24	Oxygen analyzer		HM-BX-02	0-20.9%	S-014	2024.12.20
25	Gas explosion test system (5L)	Temperature measurement	TJ120-CAXL-116U-10-SMPW-M	0-200℃	S-021-1	2025.02.08
		High frequency dynamic pressure sensor	Kistler 603CAA	0~100MPa	S-021-2	2025.05.26
		Pressure gauge	PTX 50G2-TC-A3-CA-H0-PB	-0.1~+0.5MPa	S-021-3	2025.05.26
		Pressure gauge	PTX 50G2-TC-A3-CA-H0-PB	-0.1~+0.3MPa	S-021-4	2025.05.26
26	Gas flammability testing equipment (5L)	Pressure gauge	PTX 50G2-TC-A3-CA-H0-PB	- 0.1~+0.15MPa	S-053-1	2025.03.24
		Temperature measurement	TJ120-CAXL-116U-10-SMPW-M	0-300℃	S-053-2	2025.03.24
27	Combustible gas combustion rate device	Temperature measurement	TJ120-CAXL-116U-10-SMPW-M	0~200℃	S-022-1	2025.02.08
		Temperature measurement	TJ120-CAXL-116U-10-SMPW-M	0~200℃	S-022-2	2025.02.08

		Pressure gauge	PTX 50G2-TC-A3-CA-H0-PB	-0.1~+0.5MPa	S-022-4	2025.03.24
		straight steel ruler	Shuguang 1m	1000mm	S-040	2024.12.19
		High speed camera	Photron fastcam miniAX50	216000fps	S-022-3	/