Prüfbericht-Nr.: *Test report no.:*	CN 5.1.2e ED 5.1.2e	**Auftrags-Nr.:** *Order no.:*	326064567	Seite 1 von 43 *Page 1 of 43*
Kunden-Referenz-Nr.: *Client reference no.:*	2633746	**Auftragsdatum:** *Order date:*	2024-11-21	
Auftraggeber: *Client:*	SHANGHAI ELECNOVA ENERGY STORAGE CO., LTD. T1-3F, Hong 5.1.2e 5.1.2e , 5.1.2e Shanghai P.R. China			
Prüfgegenstand: *Test item:*	Rechargeable Li-ion Battery Energy Storage System			
Bezeichnung / Typ-Nr.: *Identification / Type no.:*	ECO-E233LS			
Auftrags-Inhalt: *Order content:*	Test report			
Prüfgrundlage: *Test specification:*	UL 9540A: 2019 (Fourth Edition) Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems			
Wareneingangsdatum: *Date of sample receipt:*	2025-02-20			
Prüfmuster-Nr.: *Test sample no:*	#2025022001			
Prüfzeitraum: *Testing period:*	2025-02-21 ~ 2025-01-26			
Ort der Prüfung: *Place of testing:*	See page 5 of main report			
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüfergebnis*: *Test result*:*	See main report			

geprüft von:
tested by: 5.1.2e

Datum:
Date: 2025-03-17

Dandan Shen

genehmigt von:
authorized by: 5.1.2e

Ausstellungsdatum:
Issue date: 2025-03-17

Stellung / Position:	Project Engineer	**Stellung** / Position:	Authorizer

Sonstiges /
Other:

Zustand des Prüfgegenstandes bei Anlieferung:
Condition of the test item at delivery:
Prüfmuster vollständig und unbeschädigt
Test item complete and undamaged

* 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*

Anforderungen
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. *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.*
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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. *Test clauses with remark of * are subcontracted to qualified subcontractors and descripted under the respective test clause in the report.* *Deviations of testing specification(s) or customer requirements are listed in specific test clause in the report.*
4	Die Entscheidungsregel für Konformitätserklärungen basierend auf numerischen Messergebnisen 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 bezueglich des Risikos durch diese Entscheidungsregel siehe ILAC G8:2019. *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.*

TEST REPORT

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

Report Number. .....:	CN258QED 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, 5.1.2e District, Shanghai 5.1.2e, P. R. China
Applicant's name.....:	**SHANGHAI ELECNOVA ENERGY STORAGE CO., LTD.**
Address .....:	T1-3F, Hongqiao Hui, No 5.1.2e 5.1.2e, 5.1.2e Shanghai 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 unit 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: Diagrams of Setup for Unit Level Testing

Attachment B: Module Conditioning (Charge/discharge) Profiles

Attachment C: Observations and Records

Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing

Attachment E: Smoke Release Rate, Chemical Heat Release Rate, Convective Heat Release Rate and Heat Flux

Attachment F: Flammable Gas Generation and Composition Data

Attachment G: Sample Photos and Test Photos

Attachment H: List of Test and Measurement Instruments

Summary of testing:

Model No:	ECO-E233LS
Ratings (Vdc, kWh):	832 Vdc, 232.96 kWh
Cells in series/parallel:	1P260S
BESS dimensions :	1050 mm(W)×1350 mm(D)×2400 mm(H)
BESS weight (kg):	2570 kg
Maximum Target BESS Temperature (°C):	23.6
Maximum Wall Surface Temperature (°C):	21.1
BESS enclosure material:	Metal enclosure provided for BESS unit
BESS Intended Installation: **Non-Residential:** outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted, roof top, open garage **Residential:** Outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted	Non-Residential: indoor floor mounted
Total number of cell(s) went into thermal runaway:	5
Thermal Runaway and Propagation:	3 initiating cells went into thermal runaway and propagated to 2 adjacent cells
Maximum Smoke Release Rate (m^2/s):	0.2826
Total Smoke Released(m^2):	308.374
Total smoke released duration:	12:50 to 23:54
Peak Chemical Heat Release Rate (kW):	No flaming occurred
Peak Convective Heat Release Rate (kW):	No flaming occurred
Total Heat Release(kJ):	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

Summary of Unit 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)	☒

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

Gas Compound	Gas Type	Pre-Flaming(L)	Flaming(L)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	28.6	No flaming
Carbon Monoxide	Carbon Containing	32.7	No flaming
Carbon Dioxide	Carbon Containing	88.2	No flaming
Hydrogen	Hydrogen	413.8	No flaming

Note: 1) The collection time is from 12:50 to 23:54.

2) See Attachment F for detail gas analysis data.

Summary of BESS Unit Test Results

Performance Criteria in accordance with Table 9.1 for Indoor Floor Mounted non-residential unit

Flaming outside the initiating BESS unit was not observed;	☒
Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit did not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	☒
For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces did not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;	☒
Explosion hazards were not observed, including deflagration, detonation; and	☒
Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.	☒

Necessity for an Installation level test

The performance criteria of the unit level test as indicated in Table 9.1 of UL 9540A 4th edition has not been met, therefore an installation level testing in accordance with UL 9540A will need to be conducted on the representative the installation with this unit installed.	☐
The performance criteria of the unit level tests as indicated in Table 9.1 of UL 9540A 4th edition has been met, therefore an installation level testing in accordance with UL 9540A need not be conducted	☒

Tests performed (name of test and test clause): UL 9540A cl 9. Unit Level	**Testing location:** SRF Testing and Certification (Changzhou) Co. , Ltd No.56, 5.1.2e , Bieqiao, Liyang, jiangsu, China
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.....:	2025-02-20
Date (s) of performance of tests .....:	2025-02-21 to 2025-02-26
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**	

UL 9540A testing information:

Cell level information	
Manufacturer :	Xiamen Hithium Energy Storage Technology Co., Ltd.
Model number :	LFP71173207/280Ah
Chemistry :	$LiFePO_4$
Physical configuration :	Prismatic
Electrical rating :	Rated capacity: 280 Ah
	Nominal voltage: 3.2 V
Compliance with UL1973..... :	☒ Yes Report No.: CN23I8YY 001 Cert. No. : CU 72403672 0001 ☐ No
UL 9540A cell test report number ..... :	CN22Y93I 004
Average cell surface temperature at gas venting:	274.3 °C
Average cell surface temperature at thermal runaway:	330.4 °C
Gas Volume:	234.3 L
Lower flammability limit (LFL), % volume in air at the ambient temperature:	5.6%
Lower flammability limits (LFL), % volume in air at the venting temperature:	4.3%
Burning velocity (Su):	0.813 m/s
Maximum pressure (Pmax):	0.864

Cell level Gas Composition:

Gas component		Concentration % (v/v)
Methane	CH_4	9.51
Acetylene	C_2H_2	0.32
Ethylene	C_2H_4	6.38
Ethane	C_2H_6	1.92
Propylene	C_3H_6	3.57
Propane	C_3H_8	0.52
Isobutane	C_4H_{10}	0.07
Butane	C_4H_{10}	0.07
Pentane	C_5H_{12}	0.35
Hexane	C_6H_{14}	0.03
Hydrogen	H_2	42.47
Carbon Monoxide	CO	8.02

Carbon Dioxide	CO_2	26.78
-	Total	100

Module Level Information	
Model No:	ECO-P1P52LS
Ratings (Vdc, kWh) :	166.4 V, 46.592 kWh
Cells in series/parallel:	1P52S
Module dimensions (W x D x H (mm)) :	800 mm(W)×1135 mm(D)×248 mm(H)
Module weight (kg) :	343 kg
Module enclosure material:	Metal enclosure
UL 9540A module test report number:	CN25SS3P 001
Total number of cell(s) went into thermal runaway:	6
Thermal Runaway and Propagation:	3 initiating cells went into thermal runaway and propagated to 3 adjacent cells
Maximum Smoke Release Rate (m^2/s)	6.969
Total Smoke Released: (m^2)	1176.369
Total smoke released duration	13:47 to 00:05
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

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

Gas Compound	Gas Type	Pre-Flaming (L)	Post-Flaming (L)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	97.8	No flaming
Carbon Monoxide	Carbon Containing	95.7	No flaming
Carbon Dioxide	Carbon Containing	242.5	No flaming
Hydrogen	Hydrogen	365.1	No flaming

Note: 1) The collection time is from 13:47 to 00:05.
2) See attachment E for detail gas analysis data.

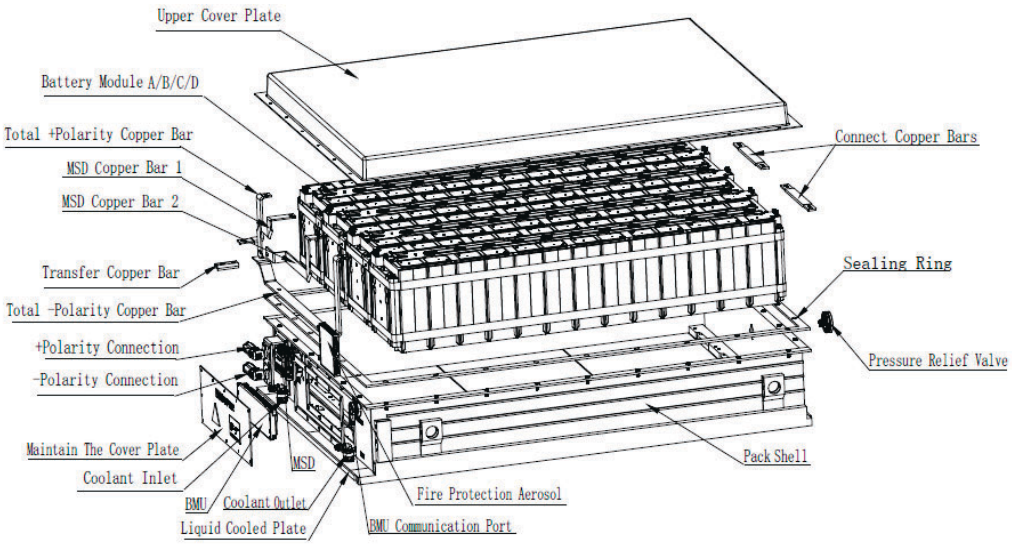
General product information

Photo of Battery system:

Battery system information		
Cell type	LFP 280Ah	Remarks
Configuration	1P260S	
Rated capacity	280 Ah	
Nominal voltage	832 V	
Standard Power	232.96kWh	100%DOD, (25±2)°C, 0.5P
Operating voltage range	728~936V DC	Cell lower limit voltage 2.8V Cell upper limit voltage 3.6V
Energy conversion efficiency	≥89%	Excluding auxiliary power consumption
Charging/discharging rate	≤0.5P	
Discharge depth	95%DOD	
Cycle life	≥8000 times (25±2°C)	Rated operating conditions: 25±2°C, 0.5P and 95%DOD
Protection level	IP55	
Cooling method	Active liquid cooling	
Operating temperature	-25 to 55°C	
Relative humidity	0-95%RH	
Working Altitude	≤2000m	Derated above 2,000m, maximum application altitude ≤ 4000m
Dimensions (W*D*H)	1050*1350*2400mm	
Total weight	Approximately 2,570kg	

Module Construction

Figure 1. Layout of the battery system contents



Diagrams of setup for battery system testing

Figure 2. Thermocouples (no. xx) locations of initiating cell

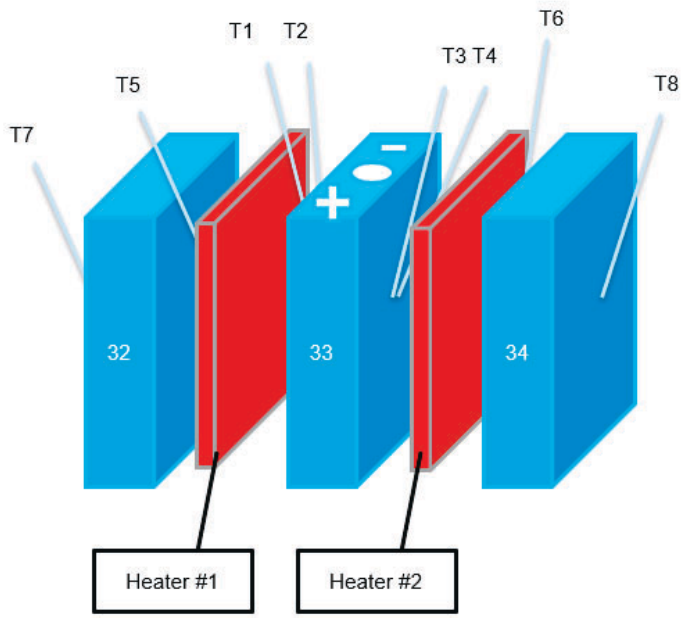


Figure 3. Cell numbering, heater location and thermocouples (no. xx) locations inside the sub-module

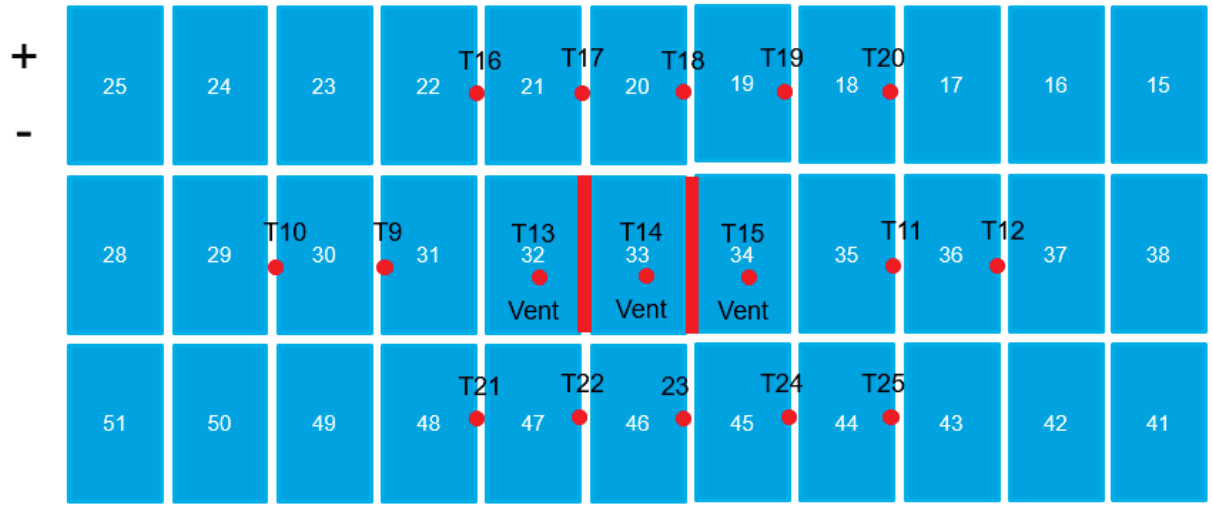
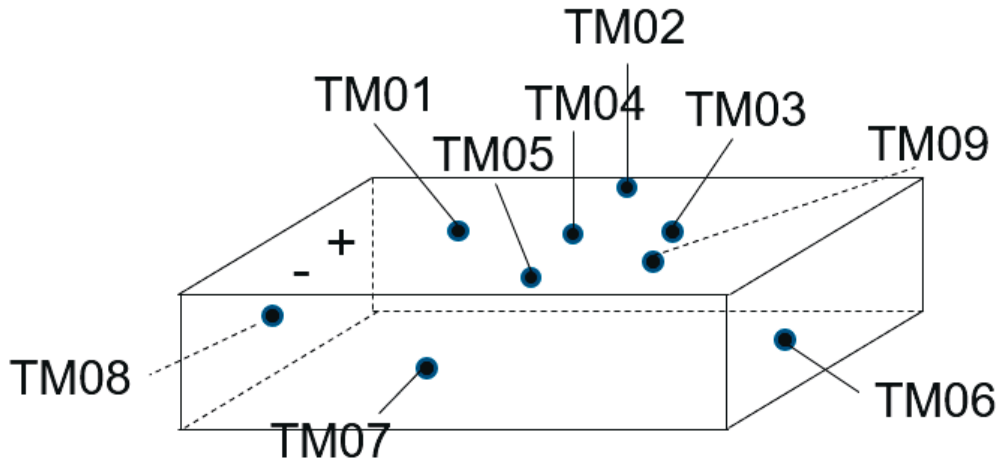


Figure 4. Thermocouples' locations outside module



ANSI/CAN/UL 9540A:2019			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
CONSTRUCTION			--
5	**General**		--
5.1	**Cell**		P
5.1.1	The cells associated with the BESS that were tested shall be documented in the test report	Accepted test report by TUV Rheinland, test report: CN22Y93I 004	P
5.1.2	The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973		P
5.1.3	Refer to 7.6.1 for further details		N/A
5.2	**Module**		P
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report	See Product Specification on Page 8	P
5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973		NA
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, the documentation included in the test report shall include the number of modules in the BESS, electrical configuration of the module, and physical layout of the modules in the BESS, battery management system (BMS) and other major components of the BESS. It shall be documented as to whether the battery system complies with UL 1973 in addition to the overall BESS compliance to UL 9540.		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 for further details		P
5.4	**Flow Batteries**	Not applicable for lithium product.	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
PERFORMANCE			--
6	**General**		--

ANSI/CAN/UL 9540A:2019			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires, explosions, smoke, off gassing of flammable and toxic materials, exposure to toxic and corrosive liquids, and potential exposure to hazardous voltages and electrical energy. See Annex B for recommended testing practices.		P
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications		P
9	**Unit Level**		--
9.1	**Sample and test configuration**		P
9.1.1	The unit level test shall be conducted with BESS units installed as described in the manufacturer's instructions and this section. Test configurations include the following:	Applied a). Indoor floor mounted unit level for the outdoor ground mounted non-residential use BESS.	P
	a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS; f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; and i) Rooftop and open garage non-residential use BESS installations.		P
9.1.2	The unit level test requires one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation	See figure 5-11 for test installations	P
	Exception: Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place:	Indoor floor mounted unit level testing method	N/A

ANSI/CAN/UL 9540A:2019			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
	a) Wind screens are utilized with a maximum wind speed maintained at ≤ 12 mph; b) The temperature range is within 10°C to 40°C (50°F to 104°F); c) The humidity is < 90% RH; d) There is sufficient light to observe the testing; e) There is no precipitation during the testing; f) There is control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; and g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing.		N/A
9.1.3	Depending upon the configuration and design of the BESS (e.g. the BESS is composed of multiple separate parts within separate enclosures), this testing to determine fire characterization can be done at the battery system level	Testing at battery rack level	P
9.1.4	The initiating BESS unit shall contain components representative of a BESS unit in a complete installation.		P
9.1.5	Target BESS units shall include the outer cabinet (if part of the design), racking, module enclosures, and components		P
9.1.6	The initiating BESS unit shall be at the maximum operating state of charge (MOSOC),	100% SOC	P
9.1.7	If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT	No integral fire suppression system	N/A
9.1.8	Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing.		P
9.2	**Test method – Indoor floor mounted BESS units**		P
9.2.1	Samples and test configurations are in accordance with 9.1.	Indoor floor mounted	P
9.2.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units shall be closed,		P
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections	See figure 5	P
9.2.4	Instrumented wall sections shall extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.		P
9.2.5	Instrumented wall sections shall be at least 0.61-m (2-ft) taller than the BESS unit height		P
9.2.6	The surface of the instrumented wall sections shall be covered with 16-mm (5/8-in) gypsum wall board and painted flat black		P
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter		P

ANSI/CAN/UL 9540A:2019			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
9.2.8	The light transmission in the calorimeter's exhaust duct shall be measured using a white light source and photo detector for the duration of the test		P
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, using the methodologies specified in 8.2.11 and 9.2.12, respectively	See attachment E	P
9.2.10	With reference to 9.2.9, the heat release rate measurement system shall be calibrated	See attachment E	P
9.2.11	With reference to 9.2.9, the convective heat release rate shall be measured using thermopile	See attachment E	P
9.2.12	With reference to 9.2.9, the convective heat release rate shall be calculated using the following equation: $HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$		P
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation	The test installation set up in accordance with indoor floor mounted non-residential use BESS.	P
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		P
	a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units.	See figure 5	P
9.2.15	Wall surface temperature measurements shall be collected for BESS intended for installation in locations with combustible construction.		P
9.2.16	Wall surface temperatures shall be measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller,		P
9.2.17	Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires		P
9.2.18	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall:		P
	a) Both are collinear with the vertical thermocouple array;		P
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		P
	c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.		P
9.2.19	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:		P

ANSI/CAN/UL 9540A:2019			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
	a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and		P
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		P
9.2.20	For non-residential use BESS, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge		P
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples shall be installed to measure the temperature of the surface		P
9.2.22	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth	Non-residential	N/A
9.2.23	An internal fire condition in accordance with the module level test shall be created within a single module in the initiating BESS unit:		P
	a) The position of the module shall be selected to present the greatest thermal exposure		P
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same as that used to initiate and propagate thermal runaway within the module level test	Same as module level test	P
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct		P
9.2.25	The hydrocarbon content of the vent gas shall be measured using flame ionization detection		P
9.2.26	The test shall be terminated if:		P
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;	Applicable	P
	b) The fire propagates to adjacent units or to adjacent walls; or		N/A
	c) A condition hazardous to test staff or the test facility requires mitigation		N/A
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation	Non-residential	N/A
9.3	**Test method – Outdoor ground mounted units**		N/A
9.4	**Test Method – Indoor wall mounted units**		N/A
9.5	**Test Method – Outdoor wall mounted units**		N/A
9.6	**Rooftop and open garage installations**		N/A
9.7	**Unit level test report**		P
9.7.1	The report on the unit level testing shall identify the type of installation being tested, as follows:		P

ANSI/CAN/UL 9540A:2019			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
	a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; i) Rooftop installed non-residential use BESS; or j) Open garage installed non-residential use BESS.	Indoor floor mounted non-residential use BESS.	P
9.7.2	With reference to 9.7.1, if testing is intended to represent more than one installation type, this shall be noted in the report	One installation type	N/A
9.7.3	The report shall include the following, as applicable:		P
	a) Unit manufacturer name and model number (and whether UL 9540 compliant);	See Product Description of Unit level information	P
	b) Number of modules in the initiating BESS unit;	See figure 6	P
	c) The construction of the initiating BESS unit per 5.3;	See Product Description of Unit level information	P
	d) Fire protection features/detection/suppression systems within unit;		N/A
	e) Module voltage(s) corresponding to the tested SOC;	See Attachment C	P
	f) The thermal runaway initiation method used;	External heater	P
	g) Location of the initiating module within the BESS unit;	See figure 6	P
	h) Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	See figure 5	P
	i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	See Attachment C	P
	j) Chemical and convective heat release rate versus time data;	See Attachment E	P
	k) Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1);	See figure 5	P
	l) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	See figure 5	P
	m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	See Attachment D	P

ANSI/CAN/UL 9540A:2019			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
	n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;		N/A
	o) The maximum incident heat flux on target wall surfaces and target BESS units;	See Attachment E	P
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;		N/A
	q) Gas generation and composition data;	See Attachment F	P
	r) Peak smoke release rate and total smoke release data;	See Attachment E	P
	s) Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;		N/A
	t) Observation of flying debris or explosive discharge of gases;	See Attachment C	P
	u) Observation of re-ignition(s) from thermal runaway events;	See Attachment C	P
	v) Observation(s) of sparks, electrical arcs, or other electrical events;	See Attachment C	P
	w) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits; and	See Attachment C	P
	x) Photos and video of the test.	Recorded	P
9.8	**Performance at unit level testing**		P
9.8.1	Installation level testing in Section 10 is not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.	Installation level testing is not required according to the performance conditions.	P
	a) Flaming outside the initiating BESS unit is not observed;	No flaming observed	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	Max. Temperature during the test: 23.6°C Criteria Temperature: 274.3°C	P
	c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;	Max. Temperature during the test: 20.1°C Criteria Temperature: 117.1°C	P

ANSI/CAN/UL 9540A:2019			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	No explosion observed	P
	e) Heat flux in the center of the accessible means of egress2) shall not exceed 1.3 kW/m2.		P

--End of report--

Attachment A: Diagrams of Setup for Unit Level Testing

Diagrams of setup for unit level testing

Figure 5. Test site setup diagram with separation distance. (Top view)

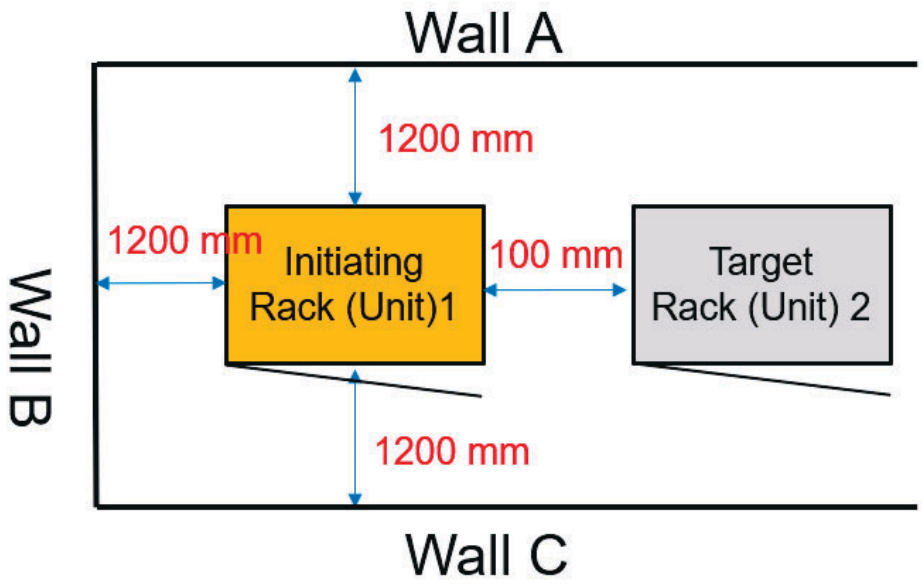


Figure 6. Module numbering in units

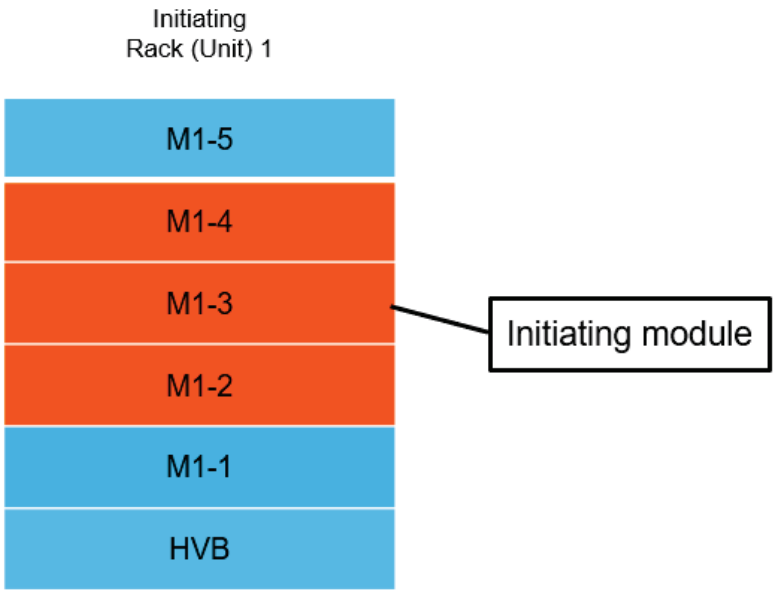
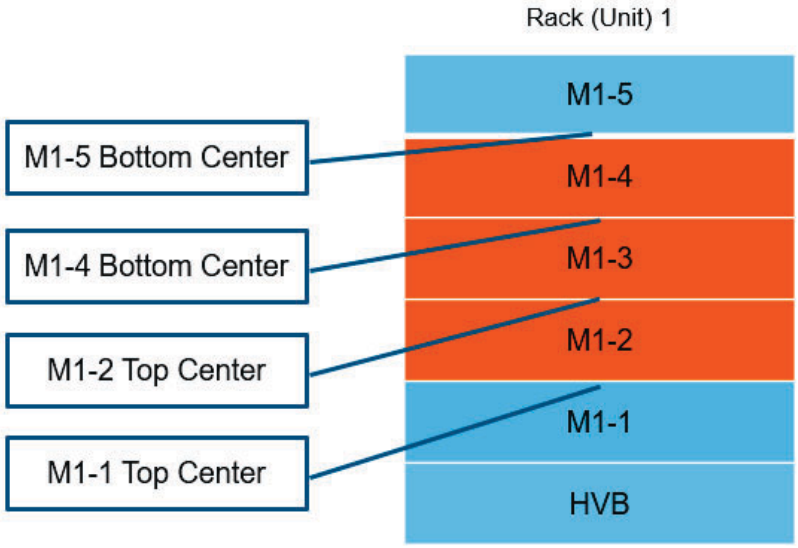
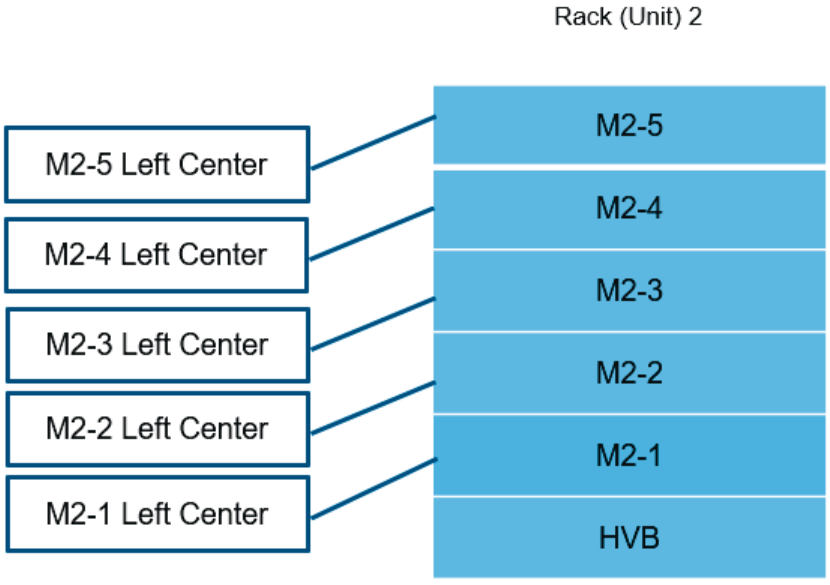


Figure 7. Thermocouple location on modules in initial unit 1



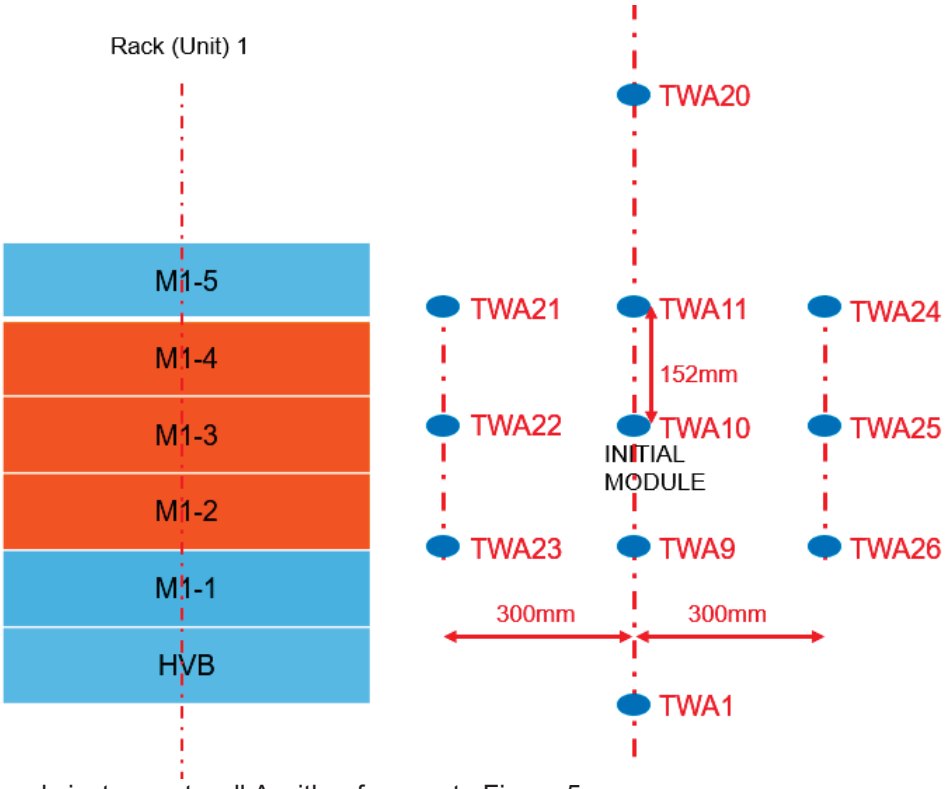
View direction: towards instrument wall A with reference to Figure 5

Figure 8. Thermocouple location on modules in target unit 2



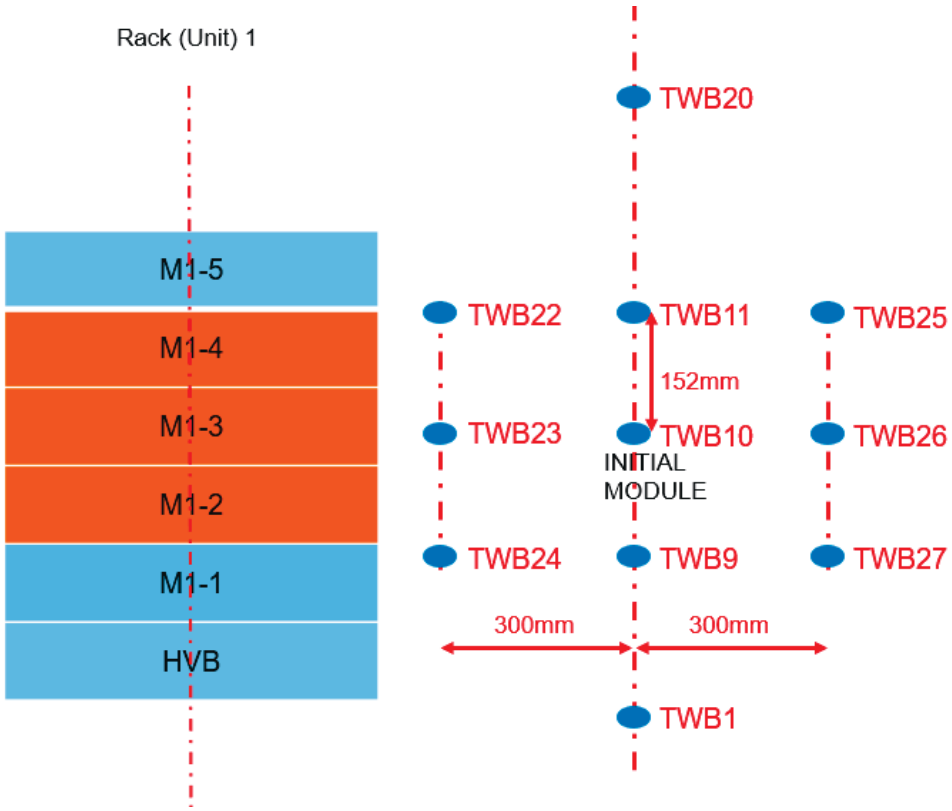
View direction: backward instrument wall A with reference to Figure 5

Figure 9. Vertical position of the thermocouples on the wall A



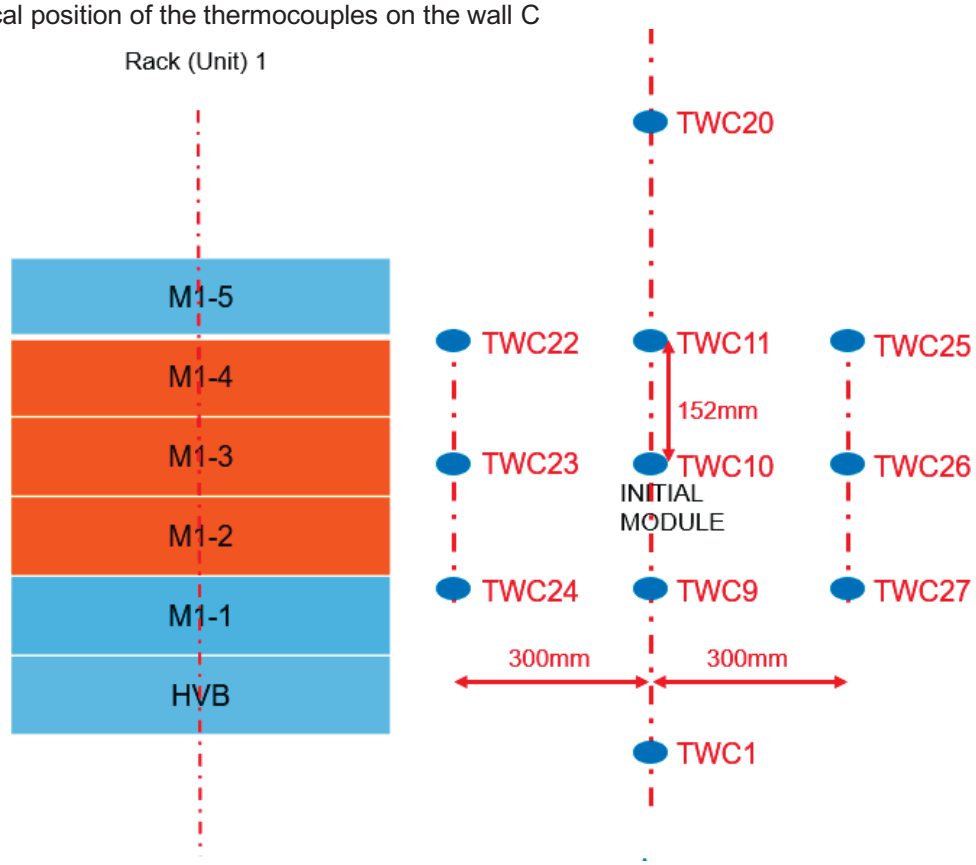
View direction: towards instrument wall A with reference to Figure 5

Figure 10. Vertical position of the thermocouples on the wall B



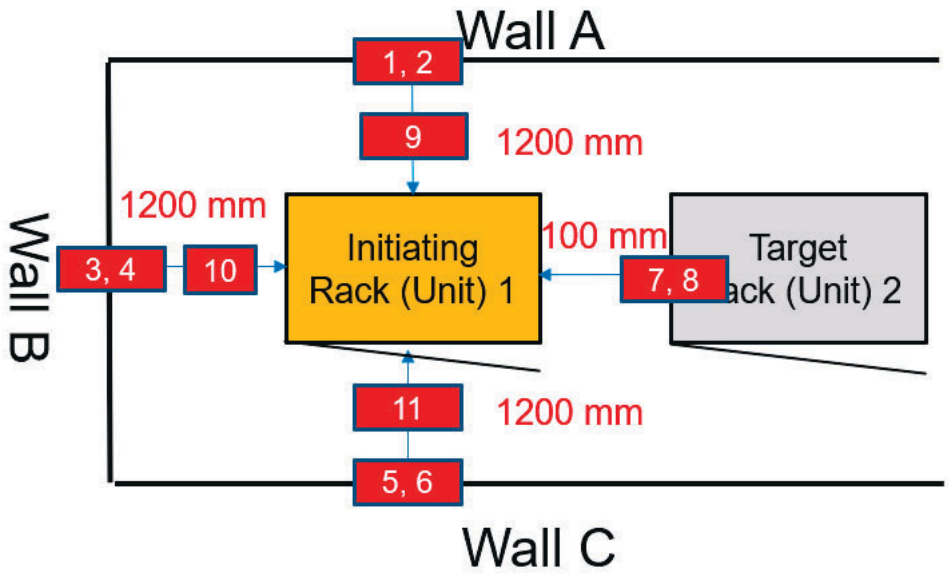
View direction: towards instrument wall B with reference to Figure 5

Figure 11. Vertical position of the thermocouples on the wall C



View direction: towards instrument wall C with reference to Figure 5

Figure 12. Heat flux sensor locations on instrument wall



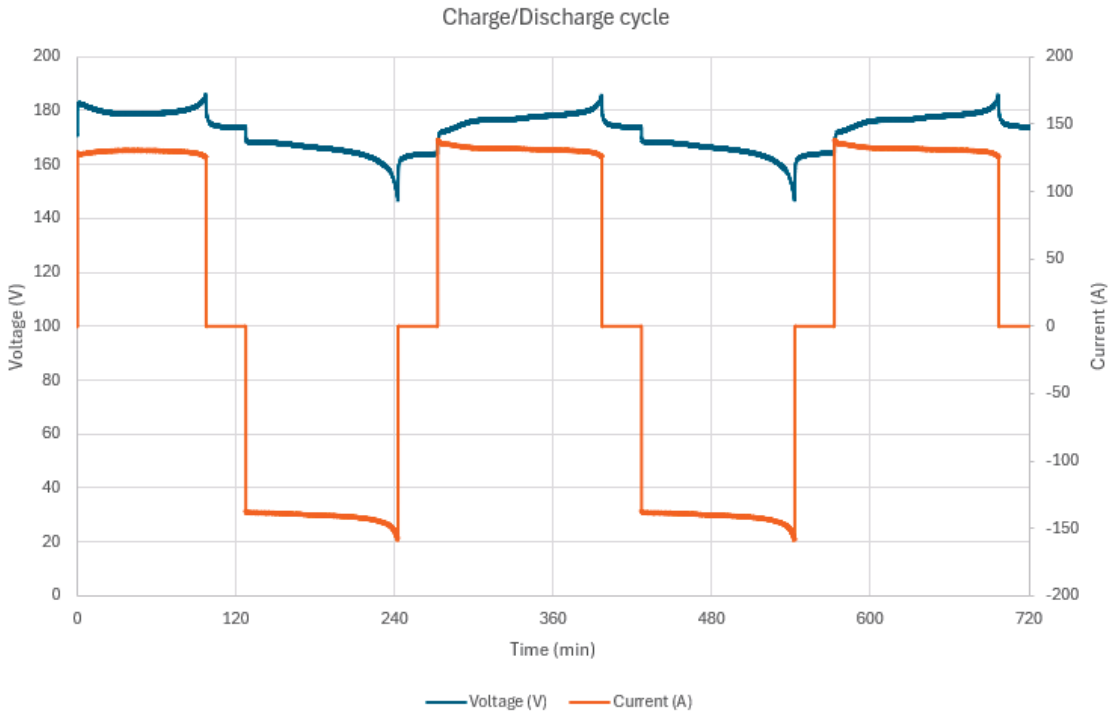
Attachment B: Module Conditioning (Charge/discharge) Profiles

Module sample was conditioned, prior to testing, through charge and discharge cycles of 3 cycles to verify that the module was functional.

Each cycle was defined as a charge to 100% SOC and allowed to rest several minutes and then discharged to an end of discharge voltage (EODV) determined by the manufacturer. Refer to module information mentioned above for charge and discharge profile.

The module sample was put in a climate chamber during charge and discharge. The ambient is kept at 25°C±2°C and 50%± 5% R.H.

Figure 13. Module charge and discharge voltage/current profiles



Attachment C: Observations and Records

Ambient conditions at the initiation of the test. :	20.1°C, 63.1% R.H.
Sample number ..... :	#2025022001
Open circuit voltage before test (V)..... :	173.5
Weight before test (kg) ..... :	342 (with thermocouples)
Weight after test (kg) ..... :	339 (with thermocouples)
Open circuit voltage after test (V)..... :	153.5
Weight loss (kg)..... :	3

Observations during test:

Location (Cell#)	Event	Time
/	Test start	12:50
33	Vent	13:25
34	Vent	13:43
32	Vent	13:43
33	Thermal runaway	13:43
34	Thermal runaway	13:54
32	Thermal runaway	13:54
-	Vent	13:59
-	Vent	14:10
31	Thermal runaway	14:11
35	Thermal runaway	14:16
-	Vent	14:24

Note:
1) No flying debris or explosive discharge of gases during test.
2) No sparks, electrical arcs, or other electrical events during test.
3) No flaming observed.

Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing

Figure 14. Temperatures of cell #32~#34

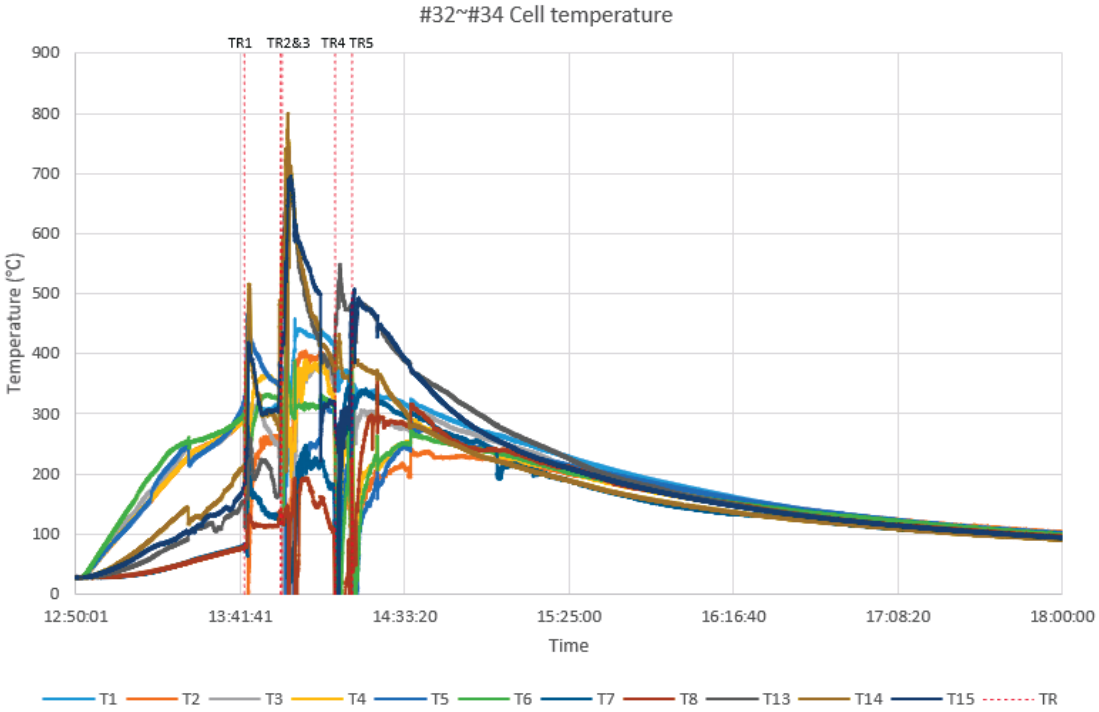
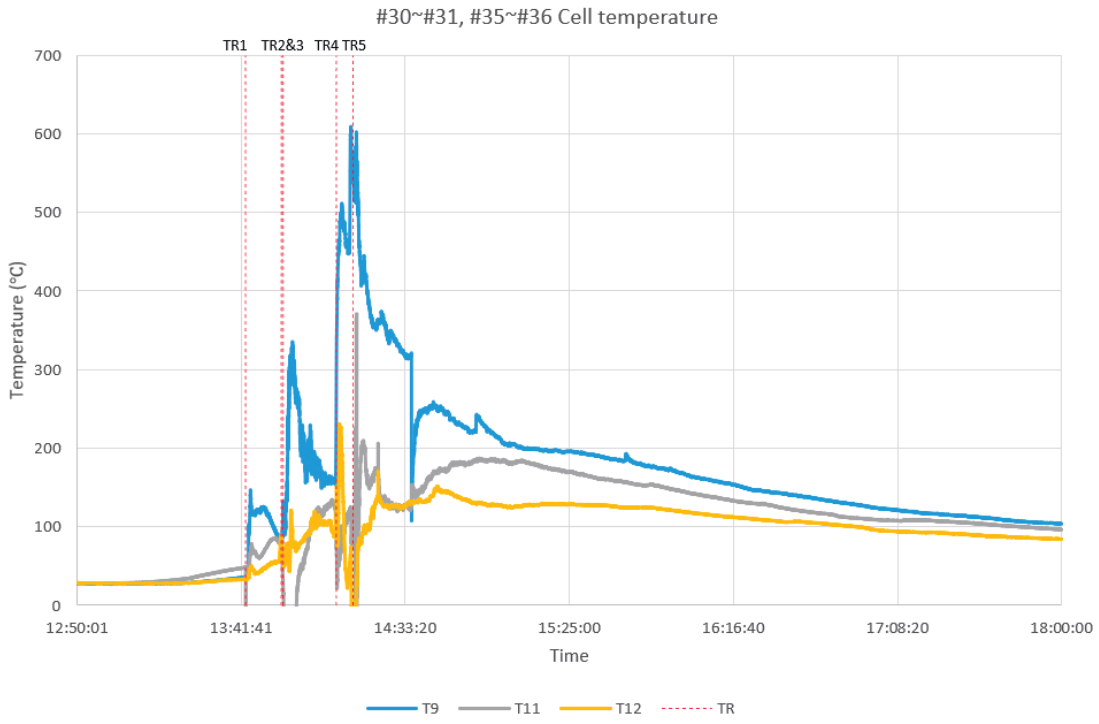


Figure 15. Temperatures of cell #30, #31, #35, #36



Note: Thermocouple T10 was damaged during the test.

Figure 16. Temperatures of cell #18~#22

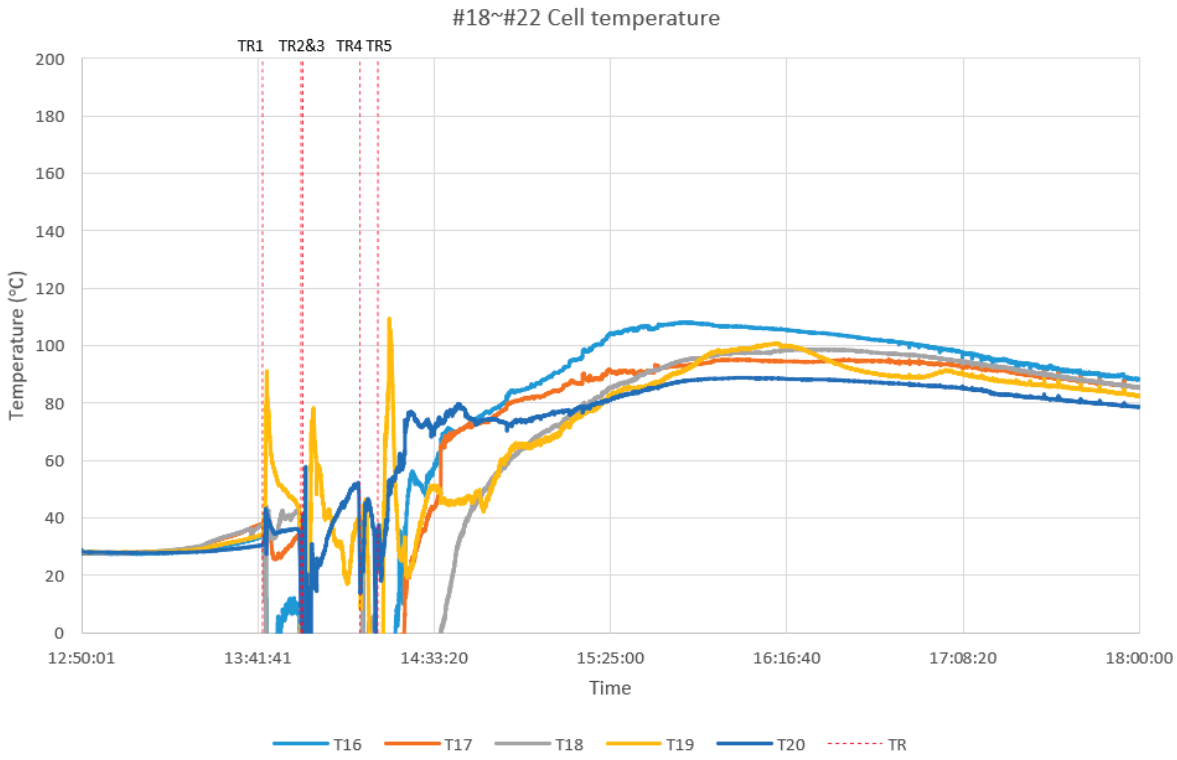


Figure 17. Temperatures of cell #44~#48

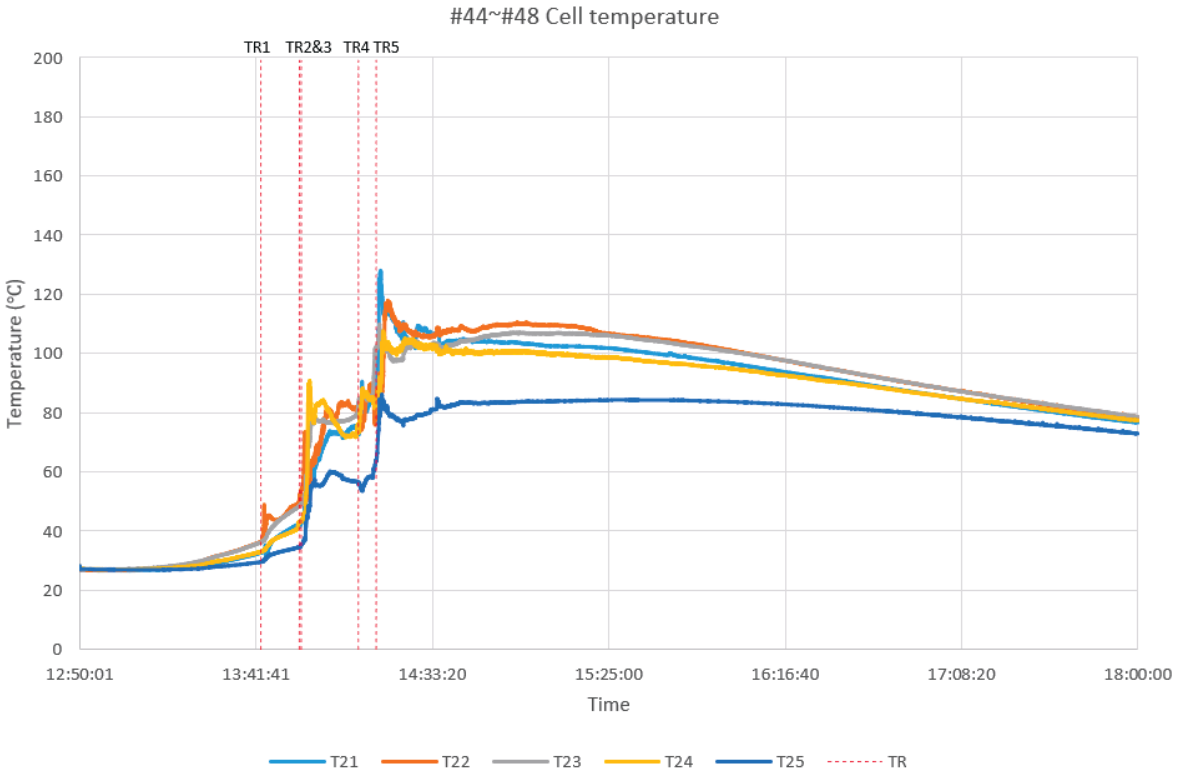


Figure 18. Temperatures of module surface

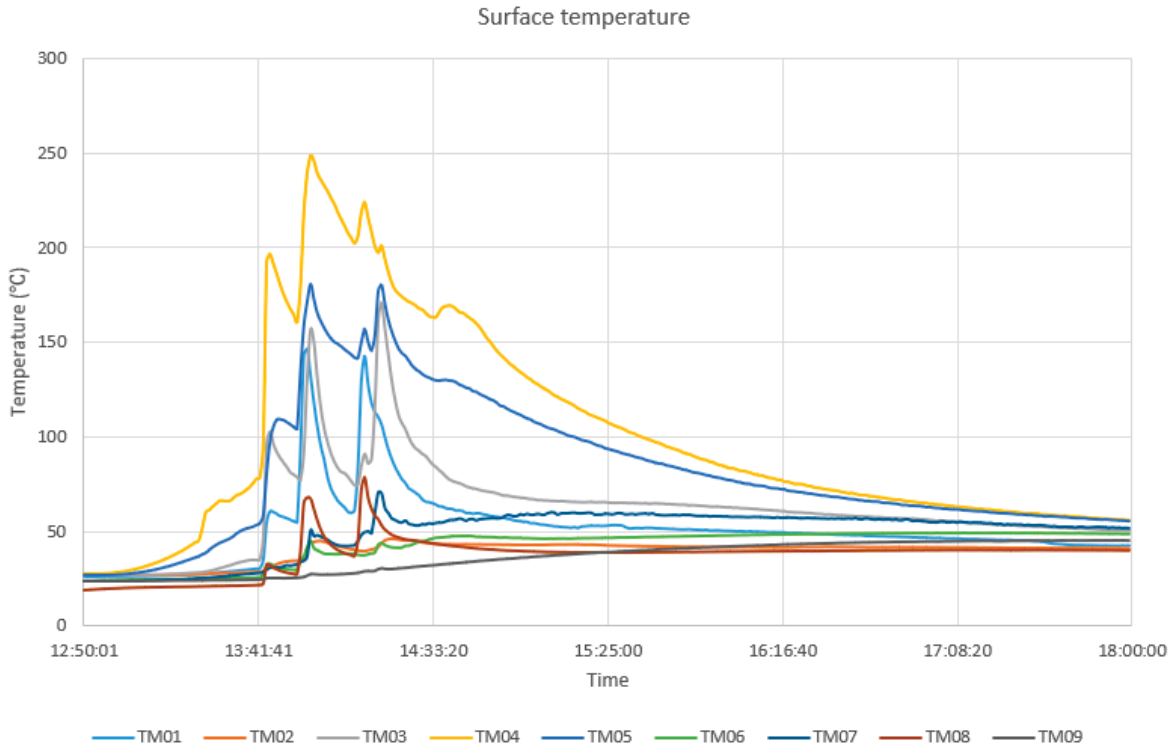


Figure 19. Surface temperatures of modules in initial unit 1 (refer to Figure 7)

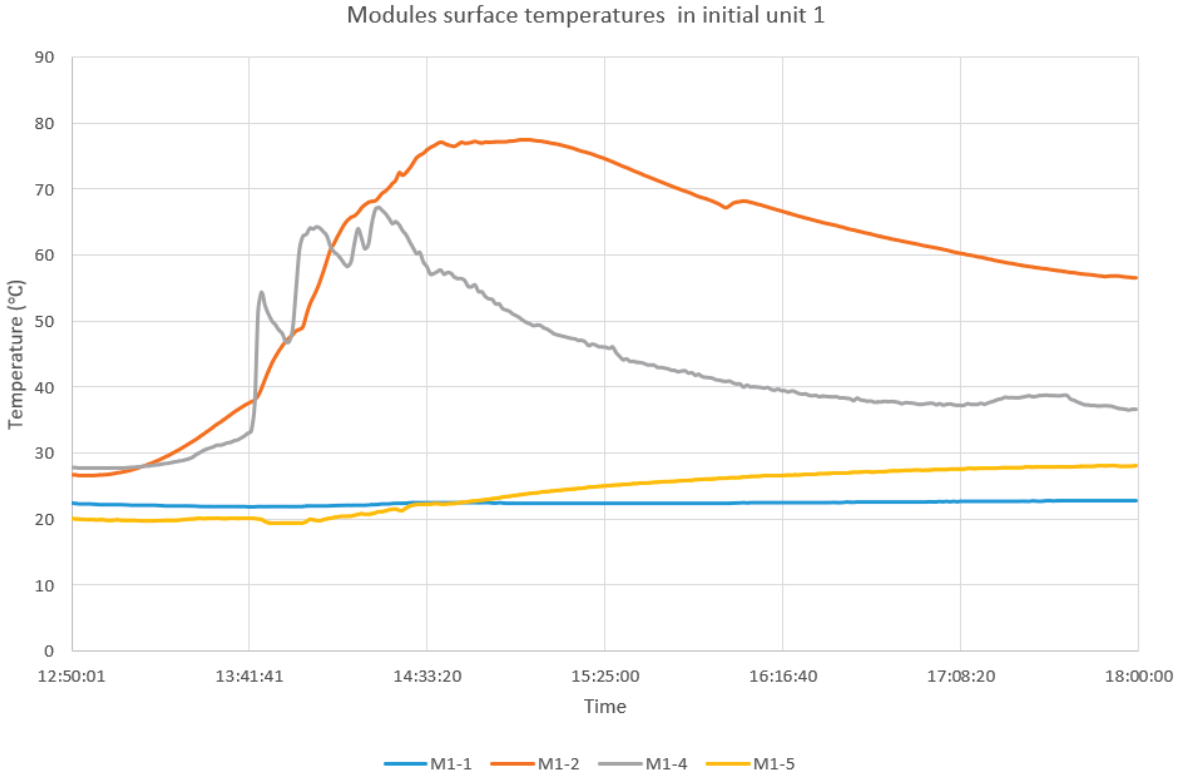
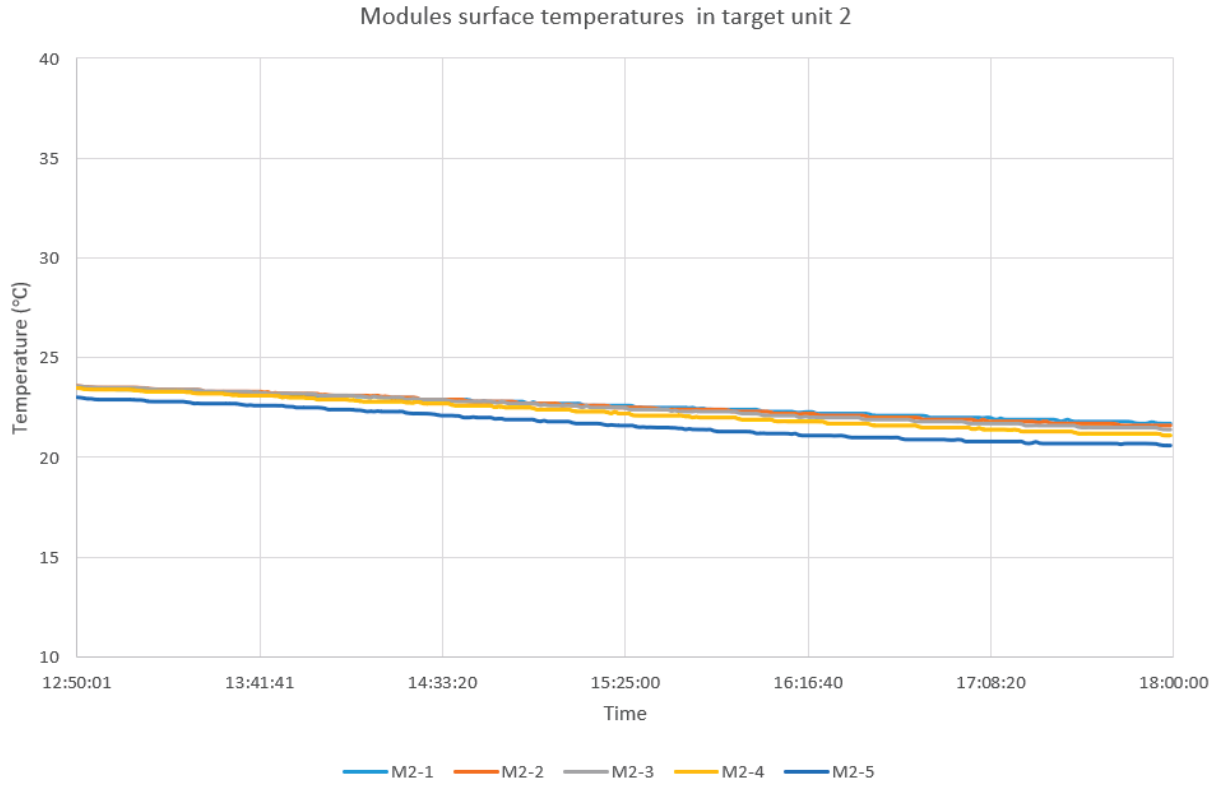


Figure 20. Surface temperatures of modules in target unit 2 (refer to Figure 8)



Maximum Temperatures in Target Units		
UL 9540A performance criteria, Cell Surface Temperature at Gas venting: 274.3 °C		
Location		Maximum Module Temperature (°C)
Surface temperatures of modules in target unit 2	M2-2	23.6

Figure 21. Temperatures on instrument wall A

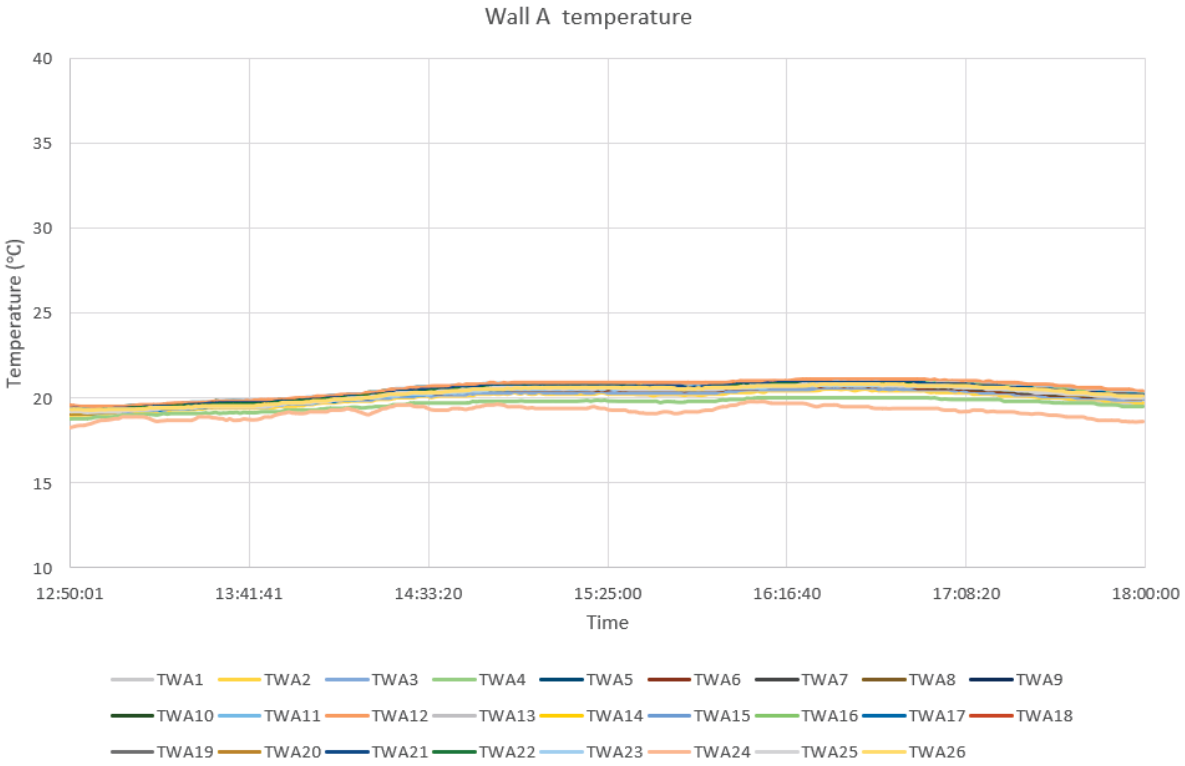


Figure 22. Temperatures on instrument wall B

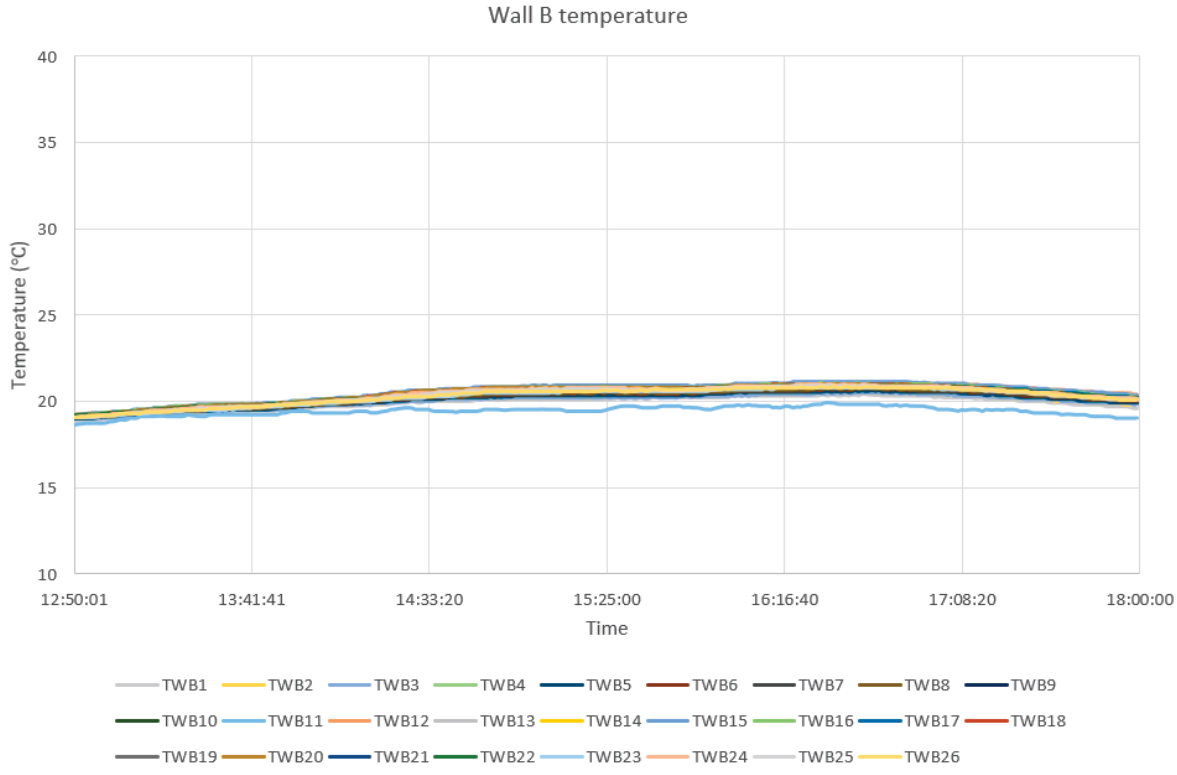
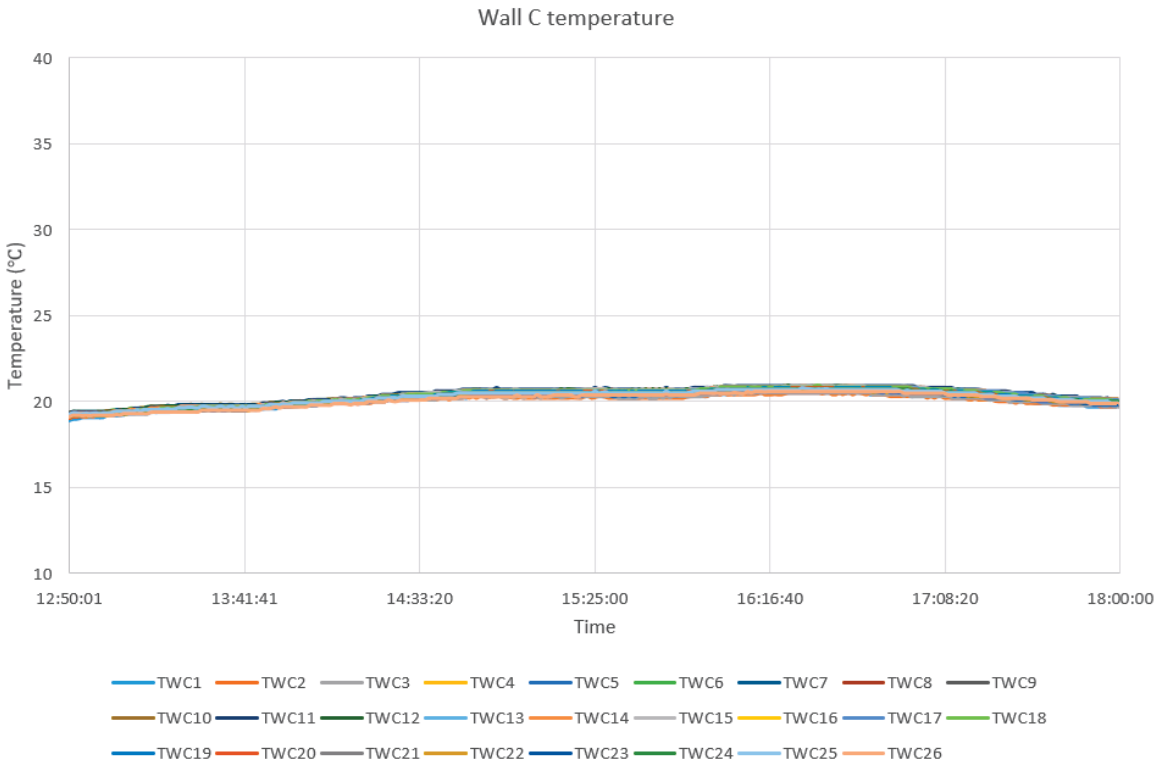
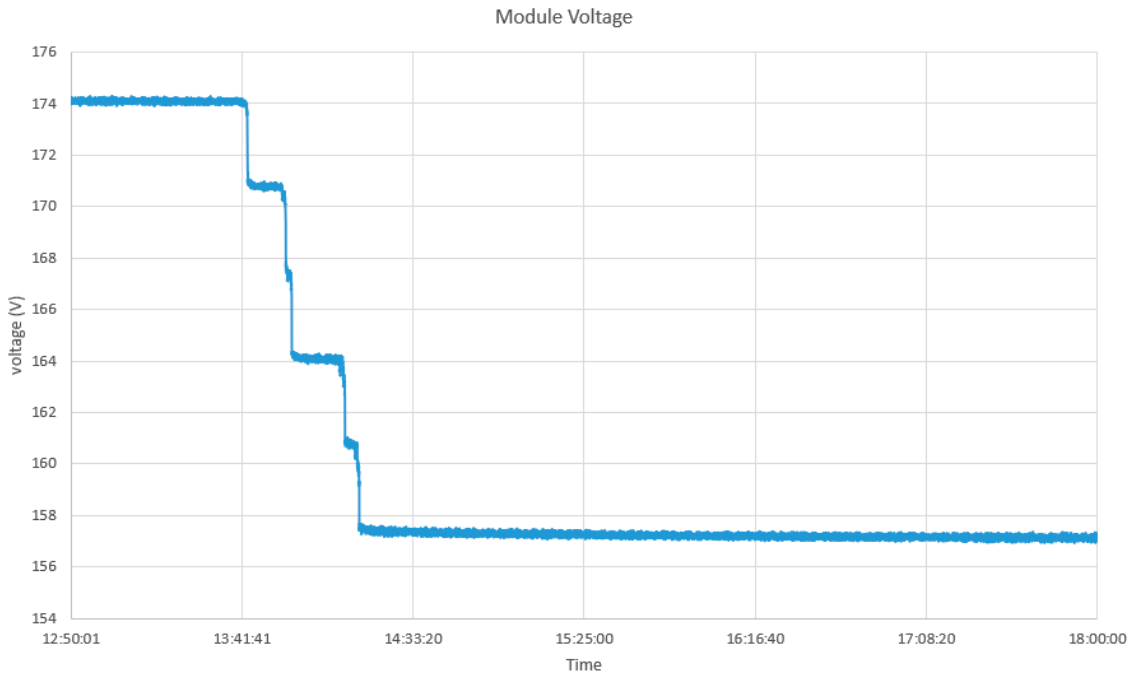


Figure 23. Temperatures on instrument wall C



Maximum Temperatures on Wall		
Ambient Temperature: 20.1°C		
UL 9540A performance criteria, Ambient + 97°C: 117.1°C		
Location		Maximum Wall Temperature (°C)
Wall A	TWA12	21.1
Wall B	TWB13	21.1
Wall C	TWC11	20.9

Figure 24. Module Voltage



Attachment E: Smoke Release Rate, Chemical Heat Release Rate, Convective Heat Release Rate and Heat Flux

Smoke and heat release rate		
Smoke Release Rate(SRR)	Maximum SRR(m^2/s)	0.2826
	Total Smoke Released(m^2)	308.374
Heat Release Rate(HRR)	Peak Chemical HRR(kW)	No flaming observed
	Peak Convective HRR(kW)	No flaming observed
	Total Heat Release(MJ)	No flaming observed

Figure 25. Smoke Release Rate

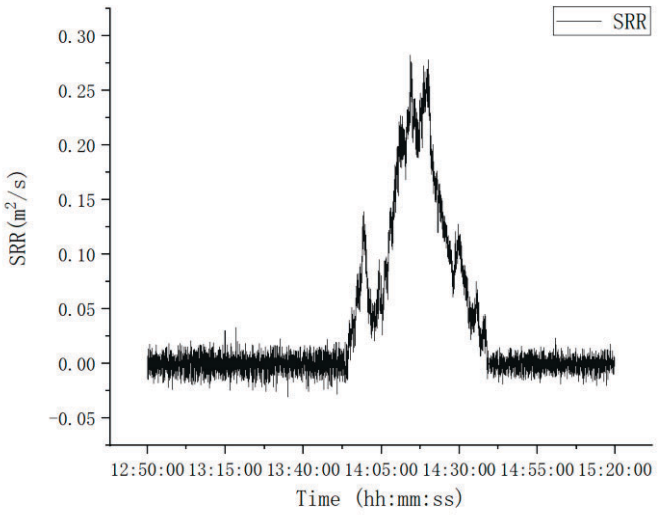


Figure 26. Total Smoke Released

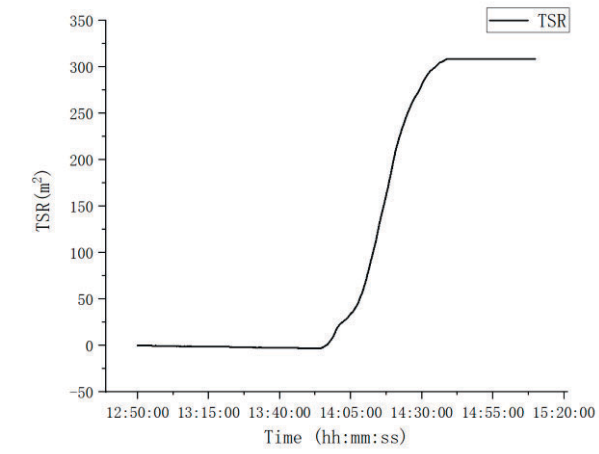
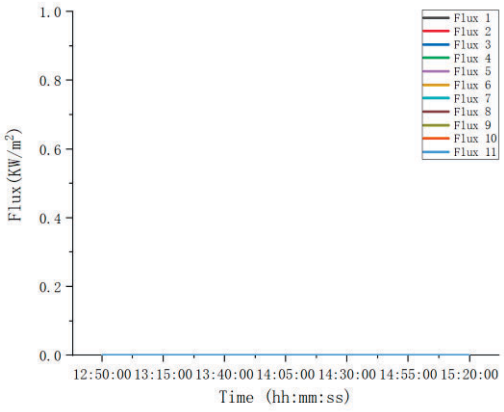


Figure 27. Heat Flux

Location of heat flux see figure 12.



Attachment F: Flammable Gas Generation and Composition Data

Measurement Method	Gas Compound	Gas Type	Pre-Flaming(L)	Flaming(L)
Flame ionization detection	Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	28.6	No flaming
Fourier-Transform infrared Spectrometer	Carbon Monoxide	Carbon Containing	32.7	No flaming
	Carbon Dioxide	Carbon Containing	88.2	No flaming
Solid-state Hydrogen Sensor	Hydrogen	Hydrogen	413.8	No flaming
Note: 1) The collection time is from 12:50-23:54.				

Figure 28. Total Hydrocarbons

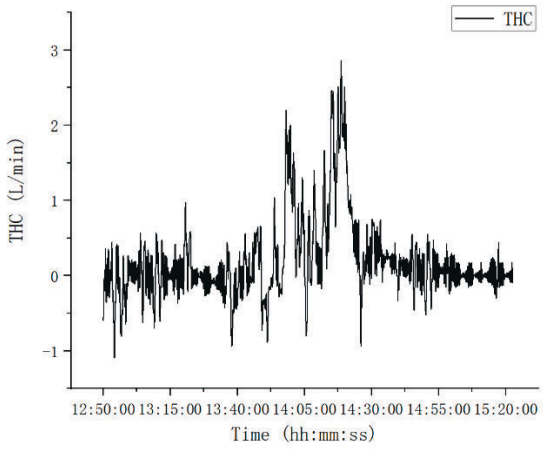
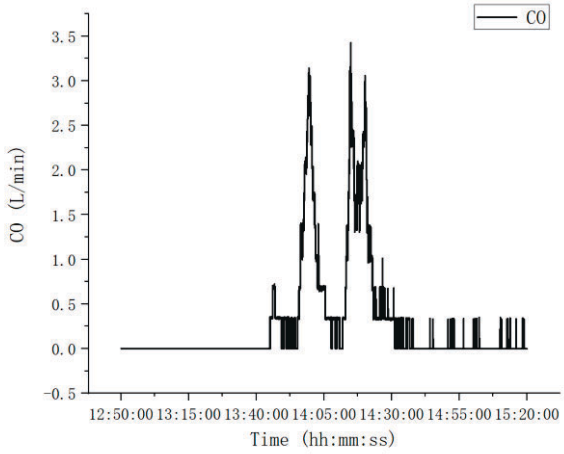


Figure 29. CO, CO_2



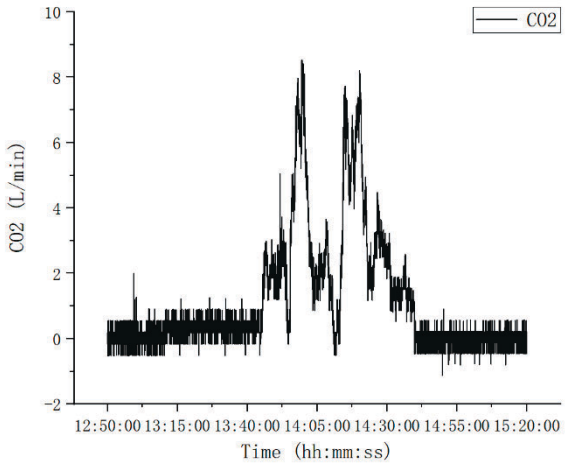
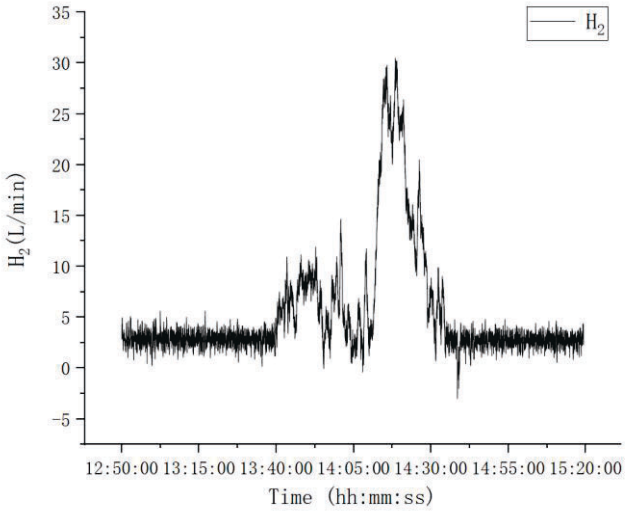


Figure 30. Hydrogen



Attachment G: Sample Photos and Test Photos

Figure 32. Photos before test

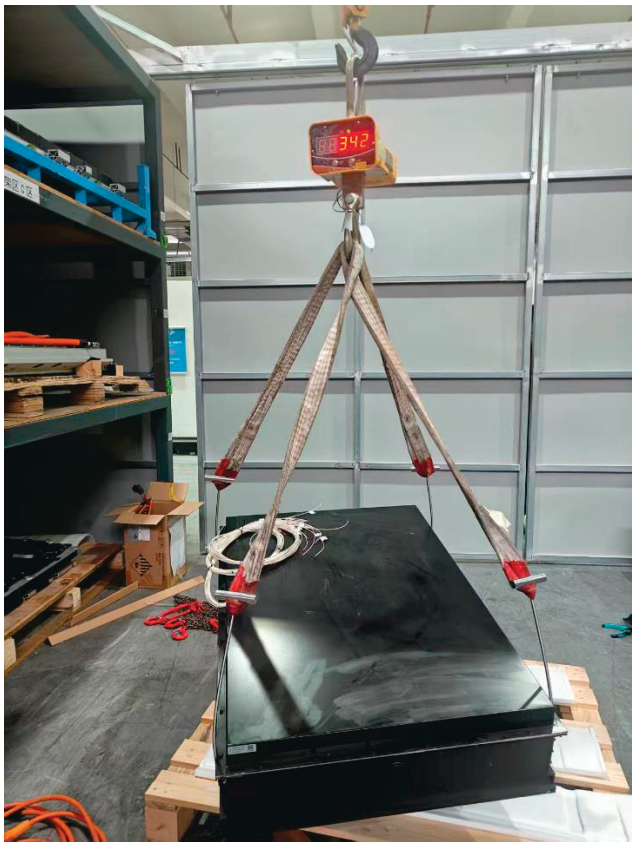


Figure 33. Test setup

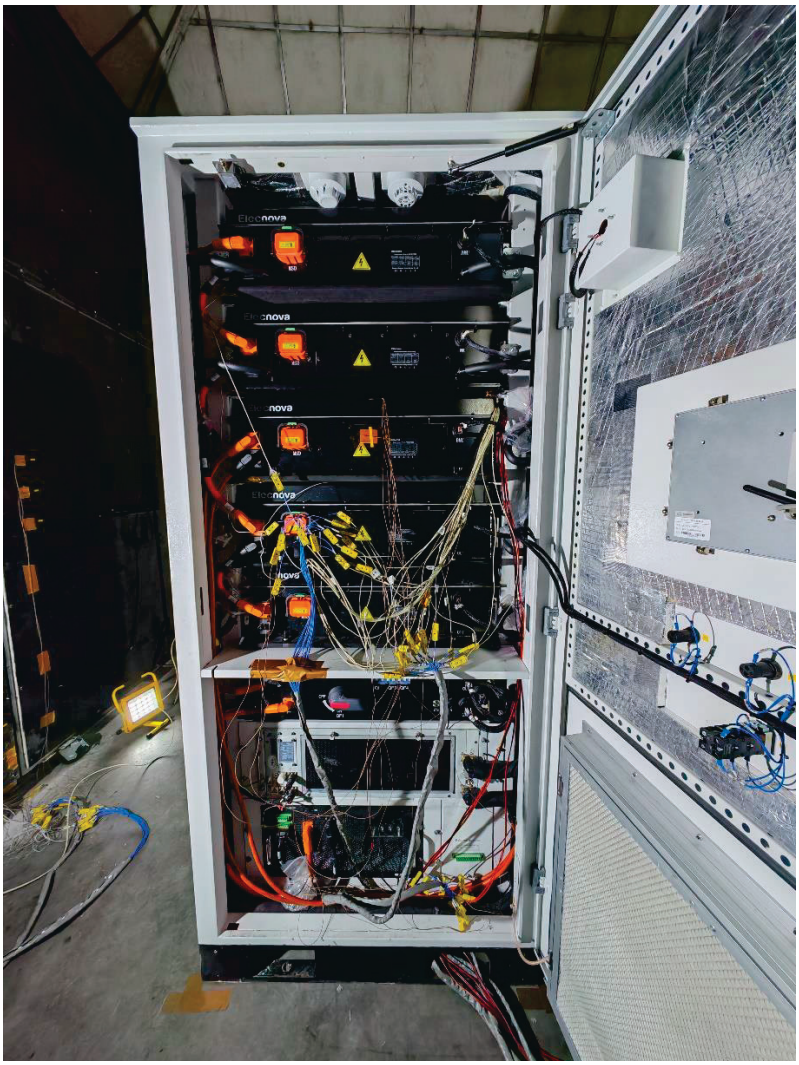


Figure 34. Smoke release during test

Figure 35. Sample after test


A
C
D

Attachment H: List of Test and Measurement Instruments

No.	Equipment	Model	Rating	Inventory no.	Cal. expire date
1	Heat-flow meter	SBG01-020	10.11~19.99kW/m^2	15030	2025-06-03
2	Heat-flow meter	SBG01-020	10.31~20.29 kW/m^2	15031	2025-06-03
3	Heat-flow meter	SBG01-020	10.34~20.09 kW/m^2	15025	2025-06-03
4	Heat-flow meter	SBG01-050	10.10~50.04 kW/m^2	15290	2025-06-03
5	Heat-flow meter	SBG01-050	10.20~50.29 kW/m^2	15288	2025-06-03
6	Heat-flow meter	SBG01-050	10.37~49.72 kW/m^2	15291	2025-06-03
7	Thermocouple	Type K	0~800°C	P2023251-WD-11	2025-05-14
8	Advantech module	ADAM-4118	0~15mV（CH1~CH8）	P2023251-YH-01~08	2025-05-29
9	ABB analysis meter (O2 concentration)	EL3020	0~21.6%	P2023251-O2	2025-05-14
10	ABB analysis meter (CO2 concentration)	EL3020	0~7.88%	P2023251-CO2	2025-05-14
11	ABB analysis meter (CO concentration)	EL3020	10~801u mol/mol	P2023251-CO	2025-05-14
12	ABB analysis meter (CH THC concentration)	EL3020	195~2000 u mol/mol	P2023251-CH4	2025-05-14
13	Imported palladium nickel-metal hydride analyzer	/	0.398~2.40%	P2023251-H2	2025-05-14
14	Micro differential pressure sensor	/	4~20mA	P2023251-YC-01	2025-05-14
15	Micro differential pressure sensor	/	4~20mA	P2023251-YC-02	2025-05-14
16	CO analysis meter	/	99.9~801 u mol/mol	P2023251-CO-1	2025-05-29
17	CH4 analysis meter	/	100~501 u mol/mol	P2023251-CH4-1	2025-05-29
18	C3H8 analysis meter	/	197~431 u mol/mol	P2023251-C3H8-1	2025-05-29

No.	Equipment	Model	Rating	Inventory no.	Cal. expire date
19	Optical filter	THORLABS	Wavelength: 600nm; Transmittance: 49.64%	/	2025-05-19
20	Optical filter	THORLABS	Wavelength: 600nm; Transmittance: 23.75%	/	2025-05-19
21	Optical filter	THORLABS	Wavelength: 600nm; Transmittance: 79.05%	/	2025-05-19
22	Walk-in high and low temperature humidity and heat test box	TOFH-B21000EXL	-40~120℃	AKJB240408	2025-05-30
23	Power battery module test system	MT-200-600-4ISO	1~200V	AKJB210504	2025-05-08
24	Hygrothermograph	BRW100-2001D	20~80%RH；-10~60°C	AKJI240430	2025-05-09
25	Digital multimeter	17B	0~1000V DC	AKJB230504	2025-05-10
26	Electronic crane scale	YTK-ZS-3ton	20~3000Kg	AKJB240318	2025-04-15
27	Data acquisition system	TK-TS112H-8HV16V-CAN	0~1000V DC	AKJB241008	2025-11-11

Legenda toegepaste uitzonderingsgrondslagen

In dit document zijn gegevens definitief geanonimiseerd op grond van:

Wet	Artikel	Omschrijving	Pagina's
Wet open overheid	Art. 5.1 lid 2 sub e	De eerbiediging van de persoonlijke levenssfeer	1, 3, 6
Burgerlijk wetboek 6	Art. 6:230b BW	Dit gegeven hoeft volgens art. 6:230b BW alleen verstrekt te worden aan de afnemer van de verleende diensten.	15