UNIT LEVEL TEST REPORT UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)	
Project number	4791831145.2
File number	N/A
Date of issue	2026-07-08, Amendment No.1: 2026-08-26
Total number of pages	41
UL report office	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant name	[redacted]
Applicant address	[redacted]
Standard	UL 9540A:2025, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 5th Edition, March 12, 2025
Test procedure	Section 9
Non-standard test method	N/A

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General disclaimer:

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

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

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Picture of sample





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Cell information	
Model number	CB56
Rating, Vdc	3.2
Rating, Ah	100
Chemistry of test item	Lithium Iron Phosphate /Graphite
Format	Prismatic
Overall dimensions, mm	52.3±1 by 148.4±1 by 119.0±1
Cell weight, g	1930±150
Original equipment manufacturer (OEM)	REPT BATTERO Energy Co., Ltd.
Branding manufacturer (if not OEM)	N/A
Standard test item certified to	UL 1973
Organization that certified test item	UL solution (MH64238)
Summary of cell level test results	
Average cell surface temperature at gas venting, °C	166
Average surface temperature at thermal runaway, °C	210
Gas volume, L	58.9
Lower flammability limit (LFL), % volume in air at the ambient temperature	6.95
Lower flammability limit (LFL), % volume in air at the venting temperature	5.95
Burning velocity, (S_u) cm/s	125
Maximum pressure, (P_{max}) psig	98.7

Cell gas composition

Gas		Measured %
Carbon Monoxide	CO	9.302
Carbon Dioxide	CO_2	24.429
Hydrogen	H_2	57.227
Methane	CH_4	4.576
Acetylene	C_2H_2	0.164
Ethylene	C_2H_4	2.699
Ethane	C_2H_6	0.858
Propene	C_3H_6	0.264
Propane	C_3H_8	0.081
-	C4 (Total)	0.186
-	C5 (Total)	0.024
-	C6 (Total)	0.008
Toluene	C_7H_8	0.004
Dimethyl Carbonate	$C_3H_6O_3$	0.001
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.148
Total	-	100.0

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Module Information	
Module Manufacturer	[redacted]
Model number	RS51100
Rating, Vdc	51.2
Rating, Ah	100
Module cell configuration, xS/yP	16S1P
Module dimensions (W x D x H), mm	575±2*490±2*148.5±2
Module weight, kg	46.5±2
Original equipment manufacturer (OEM)	[redacted]
Branding manufacturer (if not OEM)	Rubix LLC 2310 Townhship Rd 444 Sugacreak Ohio 44681 USA
Standard test item certified to	N/A
Organization that certified test item	N/A
Summary of module level test results	
Number of initiating cells	1
Thermal runaway propagation	Yes
Maximum smoke release rate, m^2/s	3.49
Total smoke released, m^2	737.65
Total smoke released duration	0:41:56 to 02:30:00
Peak chemical heat release rate, kW	No flaming observed
External flaming	No
Location(s) of flame venting and length, m	N/A
Flying debris	No
Re-ignitions	No
Maximum temperature measured on module case	255.2

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Summary of module level test gas analysis data

Gas analysis method:

☒ Flame ionization detection

☐ Fourier-Transform infrared Spectrometer

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

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

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

Gas Compound	Gas Type	Pre-Flaming, L	Flaming, L	Minimum detectable flow rate, LPM
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	731.19	No flaming observed	0.11
Carbon Dioxide	Carbon Containing	87.28	No flaming observed	0.42
Carbon Monoxide	Carbon Containing	145.57	No flaming observed	0.54
Hydrogen	Hydrogen	169.30	No flaming observed	3.84

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Unit Information	
Model number	RS51800
Rating	51.2 Vdc, 800 Ah
BESS dimensions (W x D x H, mm)	575*490*1482.9
BESS configuration, xS/yP	1S/8P
Number of modules in BESS	8 Modules
Module cell configuration, xS/yP	16S/1P
Number of cells in module	16
BESS weight, kg	393.1
BESS enclosure material	SGCC
BESS Intended Installation: a) Indoor floor mounted non-residential b) Indoor floor mounted residential c) Outdoor ground mounted non-residential d) Outdoor ground mounted residential e) Indoor wall mounted non-residential f) Indoor wall mounted residential g) Outdoor wall mounted non-residential h) Outdoor wall mounted residential i) Rooftop residential j) Open parking garage non-residential	Indoor floor mounted non-residential, Indoor floor mounted residential
Residential Indoor Use: Smallest volume room installations specified.	28 m^3
Original Equipment Manufacturer (OEM)	[redacted]
Branding Manufacturer (if not OEM)	Rubix LLC 2310 Township Rd 444 Sugarcreek Ohio 44681 USA
Was the unit certified?	No
Standard the unit was certified to	N/A
Organization that certified the unit	N/A
Summary of unit level test results	
Number of initiating cell(s)	1
Number of initiating modules	1
Thermal Runaway Propagation:	Yes
External Flaming from BESS:	No
Location(s) of Flame Venting:	N/A
Maximum Temperature[1], °C - Target BESS	31.4

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Maximum Temperature[1], °C - Wall Surface	48.7
Peak Chemical Heat Release Rate, kW	No flaming observed
Peak Convective Heat Release Rate, kW	No flaming observed
Maximum Smoke Heat Release Rate, m^2/s	0.74
Maximum Heat Flux[1] - Instrumented Walls, kW/m^2	0.42
Maximum Heat Flux[1] - Target Modules, kW/m^2	0.02
Maximum Heat Flux[1] - Egress Path, kW/m^2	N/A
Flying Debris:	No
Re-ignitions:	No

Cell failure test method performed for the unit level
☒ External heating using thin film heater ☐ Nail Penetration ☐ Overcharge ☐ External short circuit ☐ Overdischarge ☐ Others:
Description of method used to fail cells if other than external thin film heater with thermal ramp: N/A
Description of components employed within the BESS that serve to supress propagation (fire protection features): N/A
Deviation from the module level test: N/A

[1] Averaged over 60 seconds.

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Summary of unit level test gas analysis data

Gas analysis method:

☒ Non-Dispersive Infrared Spectrometer (NDIR)

☒ Flame ionization detection

☐ Fourier-Transform infrared Spectrometer

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

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

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

Gas Compound	Gas Type	Pre-Flaming, L	Flaming, L	Minimum detectable flow rate, LPM
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	99.96	No flaming observed	0.47
Carbon Dioxide	Carbon Containing	8.63	No flaming observed	0.19
Carbon Monoxide	Carbon Containing	81.05	No flaming observed	3.10
Hydrogen	Hydrogen	215.03	No flaming observed	12.37

Summary of test results

Compliance with performance criteria in accordance with Table 9.1 for indoor floor mounted residential unit [was] ~~[was not]~~ achieved.

Installation level testing ~~[is]~~ [is not] required.

[X] Charring or ignition of the cheesecloth indicator is not observed;

[X] Surface temperatures of modules3) 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 7.3.1.10;

[X] Surface temperature measurements on wall surfaces do not exceed 97 °C (175 °F) of temperature rise above ambient;

[X] Explosion hazards are not observed, including deflagration or detonation; and

[X] The concentration of flammable gas does not exceed 25 % LFL air for the smallest specified room installation size.

Compliance with performance criteria in accordance with Table 9.1 for indoor floor mounted non-residential unit [was] ~~[was not]~~ achieved.

Installation level testing ~~[is]~~ [is not] required.

[X] Flaming outside the initiating BESS unit is not observed;

[X] Surface temperatures of modules[3)] 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 7.3.1.10;

[X] Surface temperature measurements on wall surfaces do not exceed 97°C (175 °F) of temperature rise above ambient;

[X] Explosion hazards are not observed, including deflagration or detonation.

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Testing Laboratory information		
Testing Laboratory and testing location(s)		
Testing Laboratory	South Testing and Certification Co., Ltd.	
Testing location/ address	Likou Road Section, Guangshan Road, Zengjiang Street, Zengcheng District, Guangzhou City, Guangdong Province, China	
Tested by (name)	Shiyi Chen	
Witnessed by (for 3rd Party Lab Test Location) (name, signature)	Huang Fei	Huang Fei
Project Handler (name, signature)	Sunny Guan	Sunny Guan
Reviewer (name, signature)	Arui Zhou	Arui Zhou
Amendment No.1 Project Handler (name, signature)	Alex Lin(T)/Sunny Guan	Alex. Lin Sunny Guan
Amendment No.1 Reviewer (name, signature)	Gavin Chen	Gavin chen

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List of Attachments (including a total number of pages in each attachment)		
Attachment	**Description**	**Pages**
A	BESS Charge Profiles	***28*** *through* ***28***
B	BESS Construction Photos	***29*** *through* ***29***
C	BESS Instrumentation Photos	***30*** *through* ***32***
D	Temperature Profiles and Heat Flux Measurements	***33*** *through* ***35***
E	BESS Testing Photos	***36*** *through* ***39***
F	BESS Gas Flow Rate, Smoke Release Rate Profiles	***40*** *through* ***41***

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Test Verdicts	
Clause Requirement Does Not Apply to the Test Item:	N/A (Not Applicable)
Clause Requirement Met**:**	M (Met)
Clause Requirement Not Met:	NM (Not Met)
Clause Requirement Completed:	C (Completed)
Clause Requirement Completed with Modification	Mod (Modified)
Test Dates	
Date of Receipt of Test Item	2026-05-18
Date(s) of Performance of Tests	2026-05-21~2026-05-22
General remarks	
"(See Attachment #)" refers to additional information appended to the report. Throughout this report a point is used as the decimal separator.	
The unit can be manufactured at more than one location. The manufacturer provided a written declaration stating that the manufacturing process at all manufacturing locations is identical and product from one manufacturing location is representative of all manufacturing locations listed below.	☐ **Yes** ☒ **Not applicable**
Name and address of factory(ies) supplying samples for test:	[redacted]

General product information and other remarks:

[redacted] Lithium-ion Battery Cabinet, Model RS51800, rated nominal 51.2Vdc, 800 Ah is configurated by 8 Lithium-ion batteries in series.

The battery Module, Model RS51100, which consists of 16S/1P Lithium-ion Battery Cells, Model CB56, is manufactured by [redacted] with a capacity of 100Ah and nominal voltage 51.2 Vdc.

The Battery Cell used is Model CB56, which is manufactured by REPT BATTERO Energy Co., Ltd., with a capacity of 100 Ah (Note) and nominal voltage 3.2Vdc.

This report was prepared for [redacted] as requested by [redacted]

Amendment No.1:
The original Test Report No. 4791831145.2, issue date 2026-07-08, was modified on 2026-08-26, to add the branding manufacturer, see page 6 for detail. No test was conducted in this amendment investigation of project 4792363725.

For correction, see page 6, the OEM was corrected from [redacted]

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UL 9540A, Edition 5			
Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
	PERFORMANCE		
9.1	**Sample and test configuration**		
9.1.1	The unit level test conducted with BESS units installed as described in the manufacturer's instructions.	See Attachment C for test installations Installation type: Indoor floor mounted non-residential use BESS and Indoor floor mounted residential use BESS	C
9.1.2	The unit level test required one initiating BESS unit in which a thermal runaway condition resulting in cell to cell thermal runaway propagation in accordance with the module level test is initiated and target adjacent BESS units representative of an installation.	See Attachment C for test installations	C
	Tests conducted for indoor floor mounted installations for residential BESS are representative of both indoor floor mounted and outdoor ground mounted installations.		N/A
	Tests conducted indoors with fire propagation hazards and separation distances between initiating and target units representative of the installation.		C
	Testing conducted outdoors for outdoor only installations with following in place: a) Wind screens with wind speed of ≤ 12 mph; b) Temperature range is 10°C to 40°C (50°F to 104°F); c) Humidity is < 90% RH; d) Sufficient light to observe the testing; e) There is no precipitation; f) There is control of vegetation and combustibles in the test area; and g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area.		N/A
9.1.3	For outdoor non-residential high temperature batteries installed in a container, the unit level test is waived.		N/A
9.1.4	For installations where the high temperature battery modules are not installed on racks but rather within separate compartments within the container, the modules is considered the test unit.		N/A
9.1.5	Testing to determine fire characterization was done at the battery system level rather than a complete BESS	Testing conducted on one initial unit and one target unit were used for test.	C

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Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
9.1.6	For outdoor and open parking garages where egress is less than 3 m (10 feet) from the BESS, testing will be conducted as described in this section (Section 9.2).		N/A
9.1.7	The initiating BESS contained components representative of a BESS unit in a complete installation.		C
	Combustible components that interconnect the initiating and target BESS units was included.		N/A
9.1.8	Target BESS units include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components. The target BESS may also include one live, populated module at the location of the highest anticipated temperature of the enclosure.	Target unit include module enclosure and related component; no live module was included in the target BESS	C
9.1.9	The initiating BESS was at the maximum operating state of charge (MOSOC),	See Table 2 and Attachment A	C
	After charging and prior to testing, the initiating BESS was at rest for a minimum period of 1 hour at room ambient.	See Table 2 The last charging time is 2026-05-21, 12:47:08. The test start time is 2026-05-22, 12:45:00	C
9.1.10	Voltage shall be measured prior to initiating the test. If less than 0.1% of the fully charged voltage, the initiating BESS shall be charged again.		C
9.1.11	The BESS unit included an integral fire suppression system.		N/A
9.1.12	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.	No BMS was operating during the testing	C
	Included a fire suppression control in accordance with UL 864 that is external to the BESS.		N/A
9.2	**Test method – Indoor floor mounted BESS units**		
9.2.1	Test room ambient temperature within 10°C (50°F) to 32°C (90°F).	See Table 2 See Attachment D	C
9.2.2	Access door(s) or panels on the initiating BESS unit and adjacent target BESS units were closed, latched and locked duration of the test.	No door or panel provided	N/A
9.2.3	The initiating BESS unit was positioned adjacent to two instrumented wall sections.	Attachment C	C

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Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
9.2.4	Instrumented wall sections extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of target BESS units.	The size of the unit was 575 mm in width, 490 mm in depth, and 1482.9 mm in height The front wall was 2.4 m in width and 3.66 m in height The side wall was 2.4 m in width and 3.66 m in height The distance between the initial unit and the target unit is 600 mm. The distance from the initial unit to the front wall is 50mm. The distance from the initial unit to the side wall is 50mm.	C
9.2.5	Instrumented wall sections were at least 0.61-m (2-ft) taller than the BESS unit height, and not less than 2.13 m (7 ft) in height above the floor.	The front and side wall height were 3.66 m.	C
9.2.6	The surface of the instrumented wall sections was covered with gypsum wall board and painted flat black. An incremental visual reference shall be provided on the instrumented wall sections for scale so that flame extension can be accurately measured if applicable. The gypsum wall board shall be 13-mm (1/2-inch) thick at minimum.	The gypsum wall board thick more than 13 mm. See Attachment C	C
9.2.7	The initiating BESS unit was centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.		C
9.2.8	The light transmission in the calorimeter's exhaust duct was measured using a white light source and photo detector. The smoke release rate was calculated.	See Table 11 See Attachment F	C
9.2.9	The chemical and convective heat release rates were measured for the duration of the test.	No flaming observed during the test. See Table 11 See Attachment F	C
9.2.10	The heat release rate measurement system was calibrated using an atomized heptane diffusion burner. The calibration was performed using flows of 3.8, 7.6, 11.4 and 15.2 L/min (1, 2, 3 and 4 gpm) of heptane.		C

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Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
9.2.11	The chemical heat release rate was measured using the following equipment: ● Paramagnetic oxygen analyser ● Non-dispersive infrared carbon dioxide and carbon monoxide analyser ● Velocity probe ● Type K thermocouple		C
9.2.12	The chemical heat release rate at each of the flows was calculated.	No flaming observed during the test.	C
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls was representative of the intended installation.	See Attachment C	C
9.2.14	Separation distances were specified by the manufacturer for distance between: a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units.	See Attachment C The distance between the initial unit and the target unit is 600 mm. The distance from the initial unit to the front wall is 50mm. The distance from the initial unit to the side wall is 50mm.	C
9.2.15	Wall surface temperatures were 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, Type-K exposed junction thermocouples.	The thermocouples on the front wall and side wall surfaces were aligned with the center of the Initiating Unit.	C
	The thermocouples for measuring the temperature on wall surfaces were horizontally positioned in the wall locations to receive greatest thermal exposure from the initiating BESS unit. Temperatures shall be measured continuously, averaging over every 60-second interval. The maximum of these averages shall be documented for each thermocouple location.		C
9.2.16	Thermocouples were secured to gypsum surfaces and the thermocouple tip was depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement.	Gypsum wall for this test	C

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Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
9.2.17	Heat flux was measured with at least two water-cooled Schmidt-Boelter or Gardon gauges at the surface of each instrumented wall. Heat flux shall be measured continuously, averaging over every 60-second interval. The maximum of these averages shall be documented for each gauge location. a) Both are collinear with the vertical thermocouple array; b) One is positioned to receive the greatest heat from the initiating module; and c) One is positioned to receive the greatest heat flux during potential propagation within the initiating BESS unit.	Each wall was instrumented with two heat flux gauges. One is located at the central height of the initial battery module, and the other at the central height of battery module #4.	C
	Exception: If (b) and (c) are deemed to be at the same location based on a construction review, only one gauge is required.		N/A
9.2.18	Heat flux was measured with 2 water-cooled Schmidt-Boelter or Gardon gauges at the surface of each adjacent target BESS units facing initiating BESS unit. Heat flux shall be measured continuously, averaging over every 60-second interval. The maximum of these averages shall be documented for each gauge location: a) One is positioned at the elevation estimated to receive the greatest heat flux from the initiating module; and b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to initiating BESS.	Target unit was instrumented with two heat flux gauges. One is located at the central height of battery module #3, and the other at the central height of battery module #4.	C
	Exception: If (a) and (b) are deemed to be at the same location based on a construction review, only one gauge may be installed on the target unit for the measurement.		N/A
9.2.19	For BESS intended for installation outdoors or in open parking garages, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter or Gardon gauge positioned at the mid height of the initiating unit at the minimum horizontal distance from the BESS specified by the manufacturer or the point where the majority of off-gas venting is expected from the initiating unit. Heat flux shall be measured continuously, averaging over every 60-second interval.		N/A
9.2.20	No. 24-gauge or smaller, Type-K exposed junction thermocouples were installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module.	See Attachment C	C

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Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
	Each non-initiating module enclosure within the initiating BESS unit was instrumented with at least one No. 24-gauge or smaller Type-K thermocouple(s) within non-initiating modules.	See Attachment C	C
	Additional thermocouples were placed to account for convoluted geometries. Temperatures shall be measured continuously, averaging over every 60-second interval. The maximum of these averages shall be documented for each thermocouple location.		C
9.2.21	For residential use, the DUT was covered with a single layer of cheese cloth ignition indicator. The cheesecloth was untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in^2) area.	The initial unit is wrapped entirely with cheesecloth.	C
9.2.22	Cell to cell thermal runaway propagation in accordance with the module level test was created within a single module in the initiating BESS unit: a) The position selected to present the greatest thermal exposure to adjacent modules; and b) The setup was the same as that used to initiate and propagate thermal runaway within the module level test.	See Attachment C	C
9.2.23	Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.		C
	The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state analyzer. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.		C
9.2.24	At the request of the manufacturer, the hydrocarbon content of the vent gas may also be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer.		N/A

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Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
9.2.25	The test shall be terminated if: a) There are three consecutive temperature readings measured inside each module within the initiating BESS unit that are determined to be falling over 15-minute intervals; b) The modules return to a temperature less than 60°C (140°F) c) The fire propagates to adjacent units or to adjacent walls d) A condition hazardous to test staff or the test facility requires mitigation, or e) Flaming outside the test room is observed		C
9.2.26	For residential use systems, the gas collection data gathered shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25 % LFL in air.	Calculated value based on the LFL from the cell level test and the volume of the gas from the unit level test	C
9.7	**Unit level test report**		C
9.7.1	Installation type tested:	Indoor floor mounted non-residential use BESS Indoor floor mounted residential use BESS	C
9.7.2	Testing is intended to represent more than one installation type.	Indoor floor mounted residential as representative installation type	C
9.7.3	a. Unit manufacturer name and model number (and whether UL 9540 compliant);		N/A
	b. Number of modules in the initiating BESS unit	8 battery modules in series.	C
	c. BESS construction features;	See Attachment C See Critical Components Table	C
	d. Fire protection features/ detection/ suppression systems within unit		N/A
	e. Module voltages corresponding to the tested SOC;	See Table 12	C
	f. Thermal runaway initiation method used;	See Attachment C	C
	g. Location of the initiating module within the BESS unit;	See Attachment C	C
	h. Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, soffits as applicable, and thermocouples;	See Attachment C No ceiling was installed No soffit was installed	C
	i. Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	See Table 14	C
	j. Chemical and convective heat release rate versus time data;	See Table 11 See Attachment F	C

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Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
	k. Separation distances from the initiating BESS unit to target walls and target heat flux gauges	See Attachment C	C
	l. Separation distances from the initiating BESS unit to target BESS units	See Attachment C	C
	m. The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	Tables 5, 6 and 6A	C
	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;	Table 7	C
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;		N/A
	q. Flammable gas generation and composition data if conducted indoors;	See Tables 8, 9 and 10 See Attachment F	C
	r. Peak smoke release rate and total smoke release data if conducted indoors.	See Table 11 See Attachment F	C
	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(s) of flying debris or explosive discharge of gases unless mitigated by an engineered deflagration protection system;	See Table 13	C
	u. Observation of re-ignition(s) from thermal runaway events	See Table 14	C
	v. Observation(s) of sparks, electrical arcs, or other electrical events;	See Table 13	C
	w. Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits;	See Table 14	C
	x. Video of the test.		C
	y. Circumstances of test termination, when terminated in accordance with 9.2.25		C
	z. Module level test report summary and cell level test report summary		C
9.8	**Performance at Unit level testing**		M
9.8.1	Installation level testing in Section 10 was not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.		M
Non-Residential Installations – Indoor floor mounted:			M
	a) Flaming outside the initiating BESS unit is not observed;	No flaming was observed outside of the initiating unit	M

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UL 9540A, Edition 5			
Clause	**Requirement + Test**	**Result – Remark**	**Verdict**
	b) Surface temperatures of modules within target BESS units do not exceed the temperature at which thermally initiated cell venting occurs;	The maximum temperature measured on the surface of modules within target BESS units averaged on 60 seconds was 31.4°C, which is lower than cell's average venting temperature, 166°C, measured in Cell Level Test.	M
	c) Surface temperature measurements on wall surfaces do not exceed 97°C (175°F) rise above ambient;	The maximum temperature measured on wall surfaces averaged on 60 seconds was 48.7°C.	M
	d) Explosion hazards are not observed, including deflagration or detonation;	No explosion observed during the test	M
Non-Residential Installations – Indoor floor mounted:			M
	a) Charring or ignition of the cheesecloth indicator is not observed;	No charring or ignition observed.	M
	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;	Max surface temperature 31.4°C didn't exceed the cell venting temperature 166.0°C.	M
	c) Surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient;	Max wall surface temperature 48.7°C didn't exceed 97°C rise above ambient.	M
	d) Explosion hazards are not observed, including deflagration or detonation;	No explosion observed.	M
	e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size.	Calculated value based on the LFL from the cell level test and the volume of the gas from the unit level test[2].	M

[2] Note: This volume is based upon the lower flammability limit (5.95 Vol%) determined from the gas composition obtained during the cell level test and the total gas volume (404.67L) generated throughout the unit level testing. It is important to note that this is an estimation and that the recommended minimum room size is 27.2 m^3 dependent upon many factors including ventilation in the room, shape of the room, location and number of systems installed and locations of any sources of potential ignition in the area. However, the fire code official is responsible for determining the design parameters of any explosion control system to be provided based on Unit Level test data and conditions at the installation site. Based on the gas volume generated from the unit level test, the smallest room where the flammable gas concentration does not exceed the 25% of LFL measured at the venting temperature.

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Table 1 – Specified conditioning parameters			
Charging		Discharging	
Current (CC), A	400	Current (CC), A	400
Full charge voltage, Vdc	57.6 or any cell reachs 3.6	End-of-discharge voltage, Vdc	44
End-of-charge current, A	/	Discharging test ambient, °C	-20~55
Charging test ambient, °C	-5~55	--	--
See Attachment A for charge/discharge profiles for each cell.			

Table 2 – Test Initiation Details	
Charge completion date, YYYY-MM-DD	2026-05-21
Charge completion time, hh:mm	12:47:07
Test Date, YYYY-MM-DD	2026-05-22
Test Start Time, hh:mm	11:45:00
Initial Lab Temperature, °C	27.2
Initial Relative Humidity, %RH	51.0
Module OCV at Start of Test, Vdc	53.82(for initiating module)

Table 3 – Approximate time of thermal runaway propagation through module			
Locations (Cell #)	**Event**	**Time, hh:mm:ss**	**Temperature of the cell**
Cell #9	Venting	00:49:53	164.17
Cell #9	Thermal Runaway	00:51:39	181.45
Cell #12	Thermal Runaway	00:57:30	167.53
Cell #8	Thermal Runaway	01:10:07	130.99
Cell #11	Thermal Runaway	01:18:49	150.96
Other Cells*	Thermal Runaway*	*	*
*Note: During the observation period of the test, thermal runaway in additional cells was suspected. However, due to the absence of thermocouples in those locations, the specific cell(s) involved could not be confirmed.			

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Table 4 – Test overview timeline		
Time (hh:mm:ss)	**Event**	**Description**
00:00:00	Test Start	The test was started, and the heater was turned on to heat the initiating cell 9 at a ratio of 4 ~ 7 °C/min. See Figure (a).
00:49:53	Venting (Cell #9)	The venting time was determined based on the temperature dip on the initiating cell, Cell #9. The smoke was not observed externally. See Figure (b).
00:51:39	Thermal Runaway (Cell #9)	Initiating cell #9 was at around181.45°C. Smoke and electrolyte leakage continuously from the front panel with no flame observed and the temperature of cell 9 began to increase in an uncontrollable manner. See Figure (c).
00:57:30	Thermal Runaway (Cell #12)	The adjacent cell #12 occurred thermal runaway, around 167.53°C. Smoke and electrolyte leakage continuously from the front and back panel with no flame observed and the temperature of cell 12 began to increase in an uncontrollable manner. See Figure (d).
01:10:07	Thermal Runaway (Cell #8)	The adjacent cell #8 occurred thermal runaway, around 130.99°C. Smoke and electrolyte leakage continuously from the front and back panel with no flame observed and the temperature of cell 8 began to increase in an uncontrollable manner. See Figure (e).
01:18:49	Thermal Runaway (Cell #11)	The thermal runaway was determined based on the temperature rise on the target Cell #11, and vent smoke plume was observed from the initial module. See Figure (f).
Around 02:30:35~02:32:30	More gas released	During this period, an increase in visible gas was observed. See Figure (g).
03:19:58	Test Finished	Datalogging was finished at 03:19:58, however, the samples were in the testing room overnight and all the temperatures were confirmed to be ambient temperature. During the overnight watch period, no flaming nor additional thermal runaway was observed. See Figure (h).

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Table 5 - Maximum Temperatures in Target Units	
Cell vent temperature from cell test data, °C	166
Target module 1, °C	30.9
Target module 2, °C	31.1
Target module 3, °C	31.3
Target module 4, °C	31.3
Target module 5, °C	31.4
Target module 6, °C	31.4
Target module 7, °C	31.2
Target module 8, °C	31.2
Note: Temperatures are measured constantly and then averaged every 60-seconds	

Table 6 – Maximum Temperatures on Instrumented Wall (Front Wall)					
Ambient Temperature: 28.4°C					
UL 9540A performance criteria, Ambient + 97°C: 125.4°C					
Height, mm	Maximum Temperature, °C	Height, mm	Maximum Temperature, °C	Height, mm	Maximum Temperature, °C
30	34.0	1385	32.6	2601	31.4
170	30.5	1537	31.5	2753	31.4
321	32.3	1689	31.6	2905	31.4
473	34.7	1841	31.3	3057	31.4
625	36.7	1993	31.3	3209	31.5
777	36.2	2145	31.3	3361	31.5
929	35.0	2297	31.2	3513	31.6
1081	34.7	2449	31.4	3660	31.6
1233	33.7	--			
Note: Temperatures are measured constantly and then averaged every 60-seconds					

Table 6A – Maximum Temperatures on Instrumented Wall (Side Wall)					
Ambient Temperature: 28.4°C					
UL 9540A performance criteria, Ambient + 97°C: 125.4°C					
Height, mm	Maximum Temperature, °C	Height, mm	Maximum Temperature, °C	Height, mm	Maximum Temperature, °C
20	32.1	1388	30.8	2604	31.1
172	29.0	1540	31.0	2756	31.2
324	31.0	1692	31.1	2908	31.2
476	34.7	1844	31.3	3060	31.3
628	48.7	1996	31.2	3212	31.1
780	44.1	2148	31.1	3364	31.1
932	35.4	2300	31.1	3516	31.1
1084	31.8	2452	31.2	3660	31.1
1236	31.1	--			
Note: Temperatures are measured constantly and then averaged every 60-seconds					

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Table 7 – Heat Flux Measurements			
Summary of maximum heat flux in target units		Summary of maximum heat flux measured on instrumented wall	
Heat Flux Gauge No.	kW/m^2	Heat Flux Gauge No.	kW/m^2
Target 1, at the elevation of initiating module: HF6	0.02	Front wall, at the elevation of initiating module: HF4	0.14
Target 1, at the mid height of the module #4: HF5	0.02	Front wall, at the elevation of the module #4: HF3	0.12
--	--	Side wall, at the elevation of initiating module: HF2	0.42
--	--	Side wall, at the elevation of the module #4: HF1	0.22
Note: Heat fluxes are measured constantly and then averaged every 60-seconds			

Table 8 – Gases measured and measurement methods used in unit level testing			
Measurement Method	**Gases Measured**	**Chemical Formula**	**Gas Type**
Flame Ionization Detection (FID)	Total Hydrocarbons	-	Hydrocarbons
Solid-state Hydrogen Sensor	Hydrogen	H_2	-
Non-dispersive infrared spectroscopy (NDIR)	Carbon Dioxide	CO_2	Carbon Containing
	Carbon Monoxide	CO	Carbon Containing
~~[ ] Fourier-Transform Infrared Spectrometer (FTIR)~~	~~Acetylene~~	~~C_2H_2~~	~~Hydrocarbons~~
	~~Ethylene~~	~~C_2H_4~~	~~Hydrocarbons~~
	~~Methane~~	~~CH_4~~	~~Hydrocarbons~~
	~~Methanol~~	~~CH_3OH~~	~~Hydrocarbons~~
	~~Propane~~	~~C_3H_8~~	~~Hydrocarbons~~
	~~Formaldehyde~~	~~CH_2O~~	~~Hydrocarbons (Aldehydes)~~
	~~Hydrogen Bromide~~	~~HBr~~	~~Hydrogen Halides~~
	~~Hydrogen Chloride~~	~~HCl~~	~~Hydrogen Halides~~
	~~Hydrogen Fluoride~~	~~HF~~	~~Hydrogen Halides~~
	~~Ammonia~~	~~NH_3~~	~~Nitrogen Containing~~
	~~Hydrogen Cyanide~~	~~HCN~~	~~Nitrogen Containing~~
# - This table was modified to reflect the gases measured during testing.			

Table 9 – Gas generation periods	
Time	**Condition**
00:49:53 ~ 03:19:58[3]	Pre-Flaming
N/A	Flaming
External Flaming of Gas	
Condition	**Duration (mm:ss)**
External Flaming of Vent Gases: N/A	N/A

3 From the venting to the end of gas released.

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Table 10 – Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	Gas Type	During Pre-flaming, L	During Flaming, L	Minimum detectable flow rate, LPM
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	314.51	No flaming observed	1.49
Carbon Monoxide	Carbon Containing	27.15	No flaming observed	0.60
Carbon Dioxide	Carbon Containing	188.27	No flaming observed	9.82
Hydrogen	Hydrogen	676.53	No flaming observed	38.93

Table 11 – Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR, kW	No flaming observed	Maximum SRR, m^2/s	0.74
Peak Convective HRR, kW	No flaming observed	Total Smoke Released, m^2	295.62

Table 12 - Module OCV voltage measurement comparison before and after testing			
Module Location In Rack	OCV Prior to Test, V	OCV Post Test, V	Difference, V
3	53.82	*	--
*Note: The voltage after the test was interrupted due to the connection between the trigger module and other modules.			

Table 13 – Other Observations during Unit test			
	Observed, Yes/No	Comments/Location	
Flaming outside of Unit	No	Length of flame:	N/A
Flying debris	No	No	
Explosive discharge of gas	No	No	
Sparks or electrical arcs	No	No	

Table 14 – Post Test Observations	
Thermal runaway behaviour	No
Re-ignitions	No
Explosions	No
Other Observations	No

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Table 15 – Critical Components Information					
Component / part number	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cell	REPT BATTERO Energy Co., Ltd.	CB56	3.2V, 100 Ah	UL1973	ULS MH64238
Bottom Support for EESS	-	-	Made of SPCC， min. thickness 2.0mm.	-	-
Top cover for EESS	-	-	Made of SPCC, Surface coated with XM-027 spray paint, min. thickness 2.0mm.	-	-
P+ Copper tabs，P- Copper tabs	-	-	Make of copper, min. thickness 2.5 mm and min. width 30.0 mm	-	-
Insulating sleeve	-	-	min. 300VDC, 125°C, VW-1 or V-0.	-	YDPU2 or QMFZ2
Wire grommet	-	-	rated min. V-0, 80 °C	-	QMFZ2
Battery Module					
Enclosure	-	-	Material: SGCC Thickness: Top: 1.5mm Bottom: 1.2mm Front Panel: 1.5mm	-	-
Handle	-	-	rated min. 5VA, 80 °C	UL94, UL746B	QMFZ2
Display Screen	-	-	rated min. 5VA, 80 °C	UL94, UL746B	QMFZ2
End plate	-	-	Made of SPCC	-	-
Cell module Assemblies fixed bar	-	-	Made of SPCC, located on the top of the cell module assemblies, used to for fixing cell module, and fixed to end plate by screws	-	-
CCS	-	-	Min. rated V-0, 135°C.	UL746C	QMTS2
Foam	-	-	Rated min. V-1, 80 °C	UL94, UL746B	QMFZ2
Internal Wiring of Signal	-	-	rated min. 24AWG, 300V, 80°C, VW-1,	UL758	AVLV2
Power wire Connectors	Zhejiang Huaxi Technology Co Ltd	HRNB8-5S	rate 8 AWG, Str.	UL 486A-486B	ULS E495871
External power terminal fixed bracket	LG CHEM LTD	LUMID FB2306AF	PA6, V-0, 120°C	UL94，UL746B	ULS E67171
Glue	-	-	Rated min. V-2, 80°C.	UL94, UL746B	QMFZ2
Printed Wiring Board	-	-	rated min V-0, 130°C.	UL796	ZPMV2
Balance board enclosure	-	-	Made of carbon steel	-	-

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List of test equipment used:

No.	Equipment Name	Equipement ID	Caliration due date
1	Battery Charging/Discharging test system	NFC-YQ-W046	2026-12-01
2	Thermo-hygrometer	NFC-YQ-W048	2026-08-24
3	Data logger(temperature)	NFC-YQ-W042	2026-10-13
4	Digital Multimeter	NFC-YQ-W078	2026-11-13
5	Thermocouple	NFC-YQ-W042-57	2026-12-09
6	Gas analysis instrument	NFC-YQ-W042-10	2027-01-20
		NFC-YQ-W042-43	2027-03-10
		NFC-YQ-W042-44	2027-01-20
7	Pressure sensor	NFC-YQ-W042-4	2027-01-20
8	Optical fiber	NFC-YQ-W042-1	2027-01-25
9	Heat flux gauges	NFC-YQ-W042-58	2027-01-22
		NFC-YQ-W042-59	2027-01-22
10	Tape ruler	NFC-YQ-G067	2027-07-21

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Attachment A: BESS Charge Profiles - (*Pages **28** through **28***)

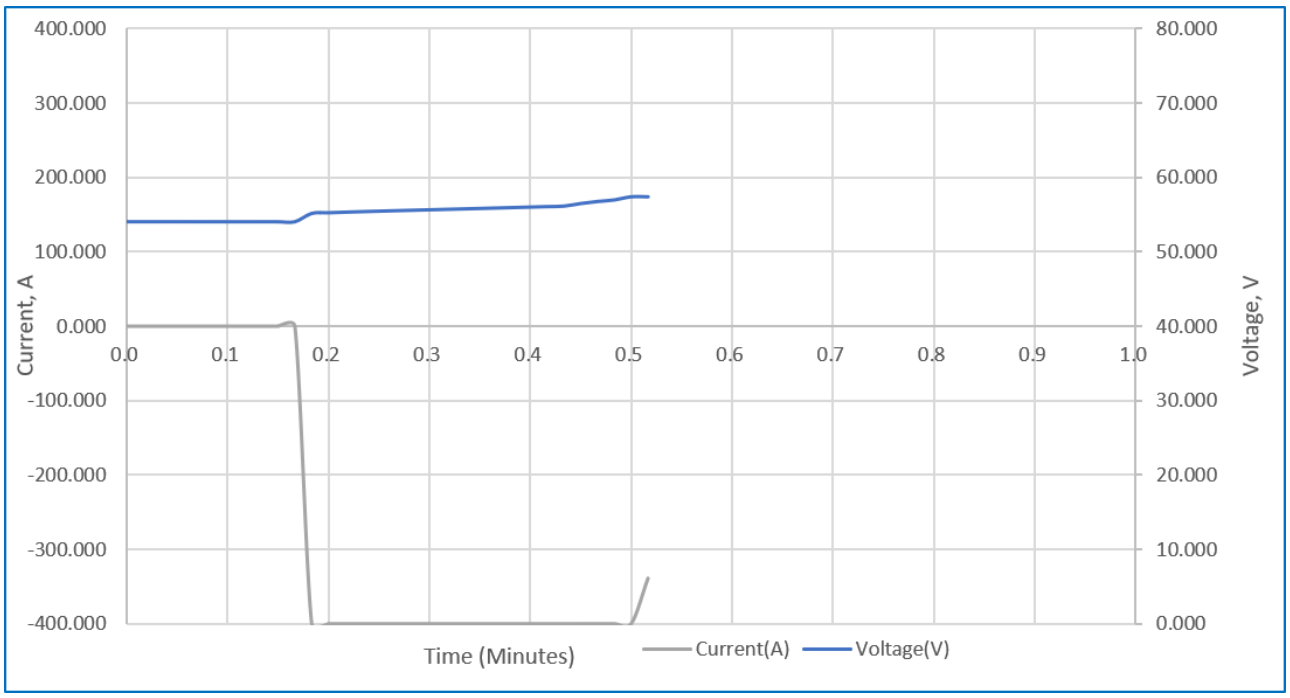


Figure 1: Initiating unit, charge to 100% SOC

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Attachment B: BESS Construction Photos - (*Pages **29** through **29***)



Figure 2: BESS unit Construction Photos

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Attachment C: BESS Instrumentation Photos - (*Pages* 30 *through* 32)

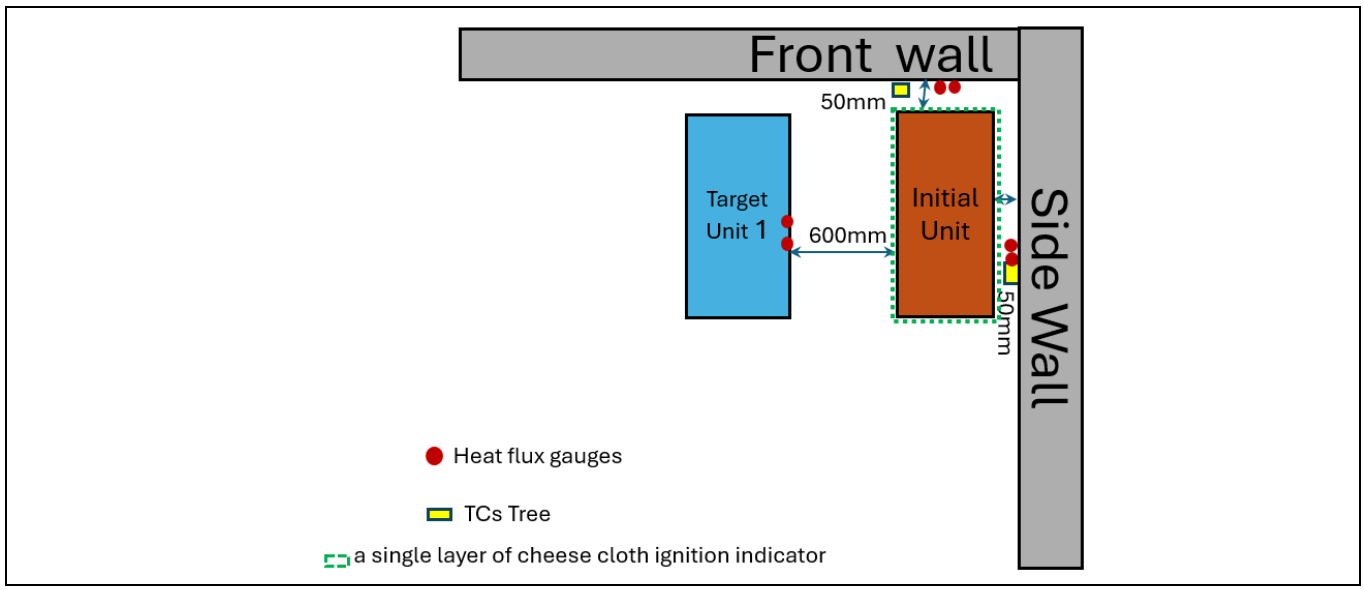
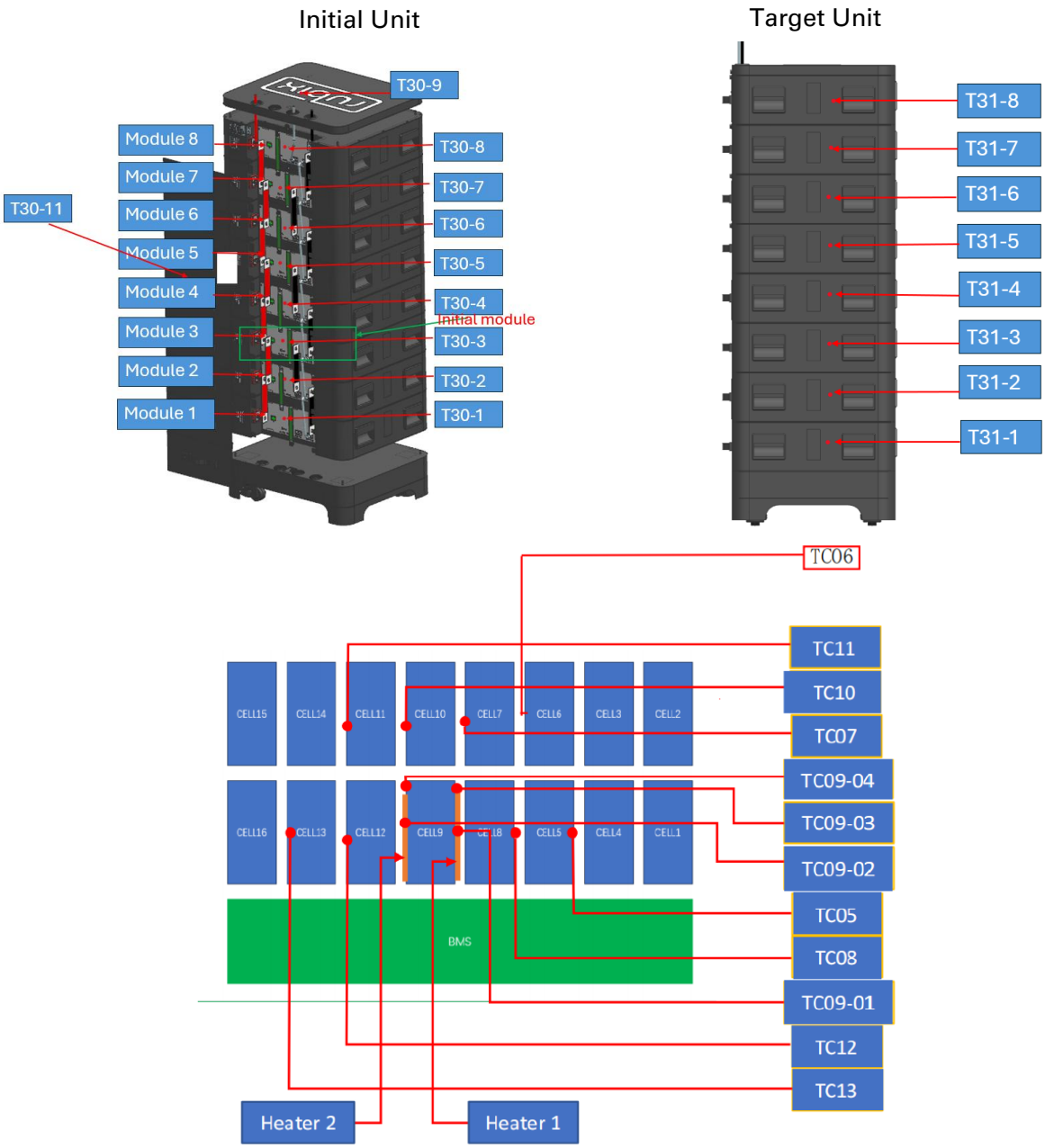


Figure 3: Test area layout

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Thermocouple No.	Thermocouple location	Thermocouple No.	Thermocouple location
TC05	body of cell 05, near cell 04	TC09-03	body of cell 09, not covered by heater, near cell 08
TC06	body of cell 06, near cell 07	TC09-04	body of cell 09, not covered by heater, near cell 12
TC07	body of cell 07, near cell 10	TC10	body of cell 10, near cell 11
TC08	body of cell 08, near cell 05	TC11	body of cell 11, near cell 14

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TC09-01	body of cell 09, under heater, near cell 08	TC12	body of cell 12, near cell 13
TC09-02	body of cell 09, under heater, near cell 12	TC13	body of cell 13, near cell 16
		TC14	Outer surface of enclosure of cell 9.
Initial Unit			
T30-1	The center point of the front panel of module 1 of initial unit	T30-6	The center point of the front panel of module 6 of initial unit
T30-2	The center point of the front panel of module 2 of initial unit	T30-7	The center point of the front panel of module 7 of initial unit
T30-3	The center point of the front panel of initial module of initial unit	T30-8	The center point of the front panel of module 8 of initial unit
T30-4	The center point of the front panel of module 4 of initial unit	T30-9	The top middle point of the initial unit
T30-5	The center point of the front panel of module 5 of initial unit	T30-11	The LCD of initial module of initial unit
Target Unit			
T31-1	The center point of the side panel of module 1 of target unit	T31-5	The center point of the side panel of module 5 of target unit
T31-2	The center point of the side panel of module 2 of target unit	T31-6	The center point of the side panel of module 6 of target unit
T31-3	The center point of the side panel of module 3 of target unit	T31-7	The center point of the side panel of module 7 of target unit
T31-4	The center point of the side panel of module 4 of target unit	T31-8	The center point of the side panel of module 8 of target unit

Figure 4: TC Location in the initiating unit

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Attachment D: Temperature Profiles - (*Pages* 33 *through* 35)

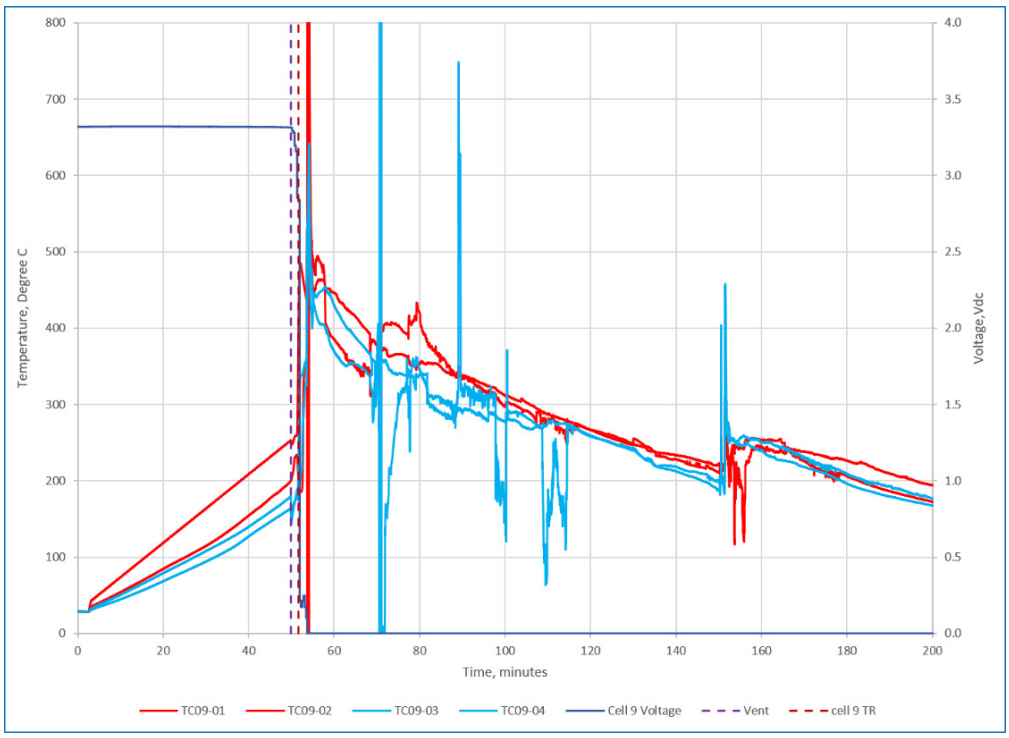


Figure 5: Initiating cell vent and thermal runaway

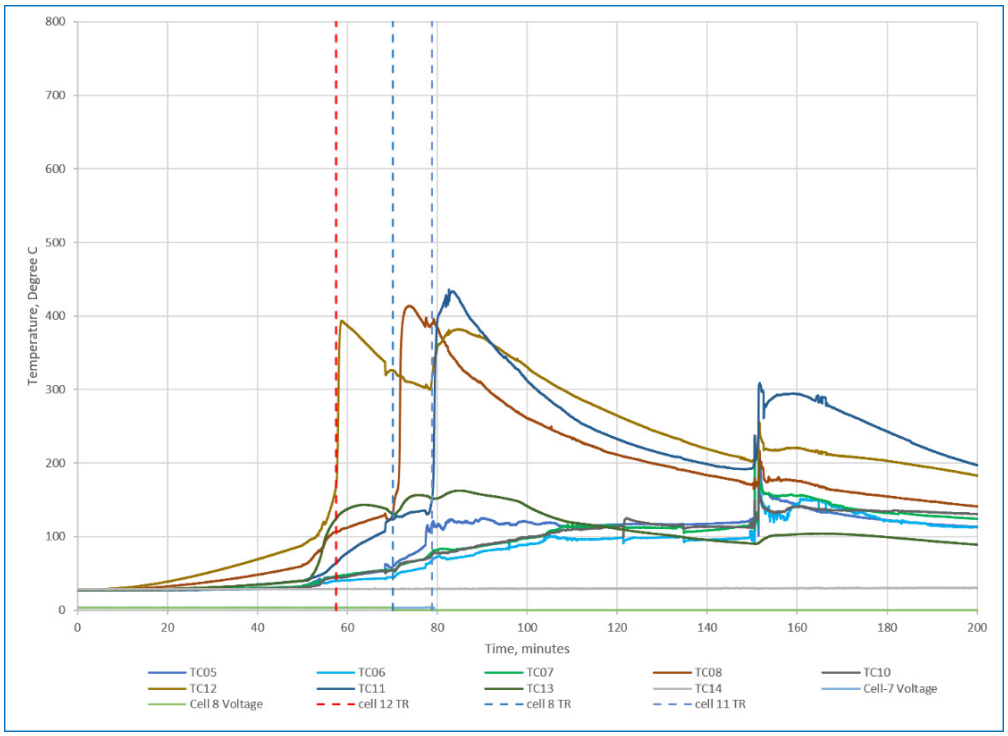


Figure 6: Temperatures in initiating module

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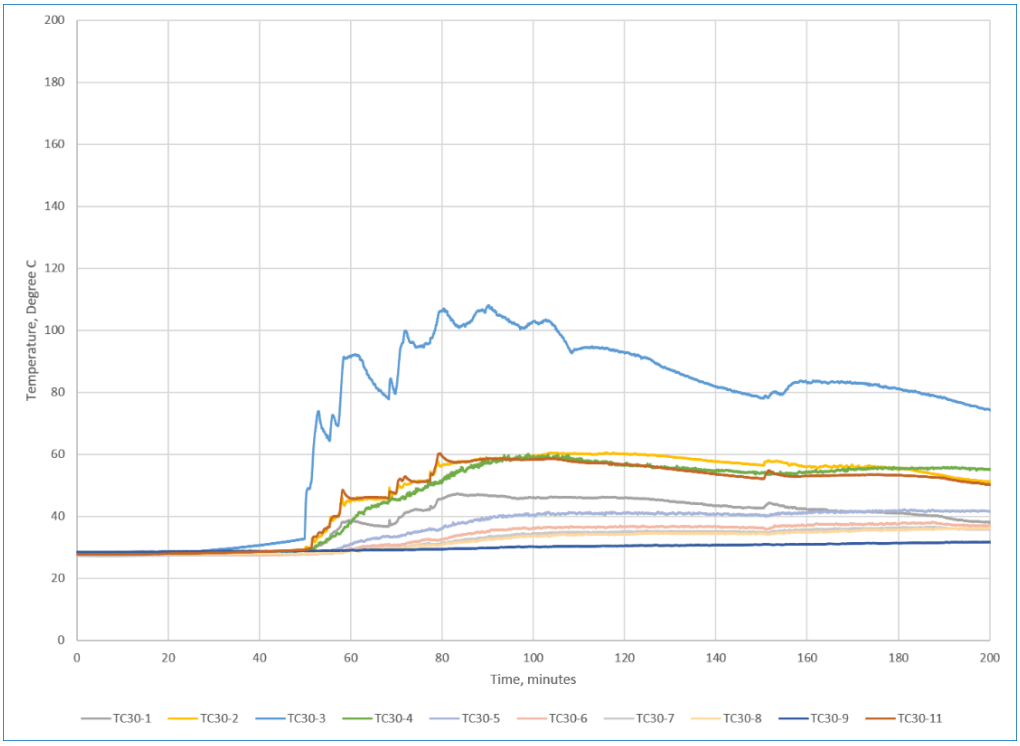


Figure 7: Temperatures in initiating unit

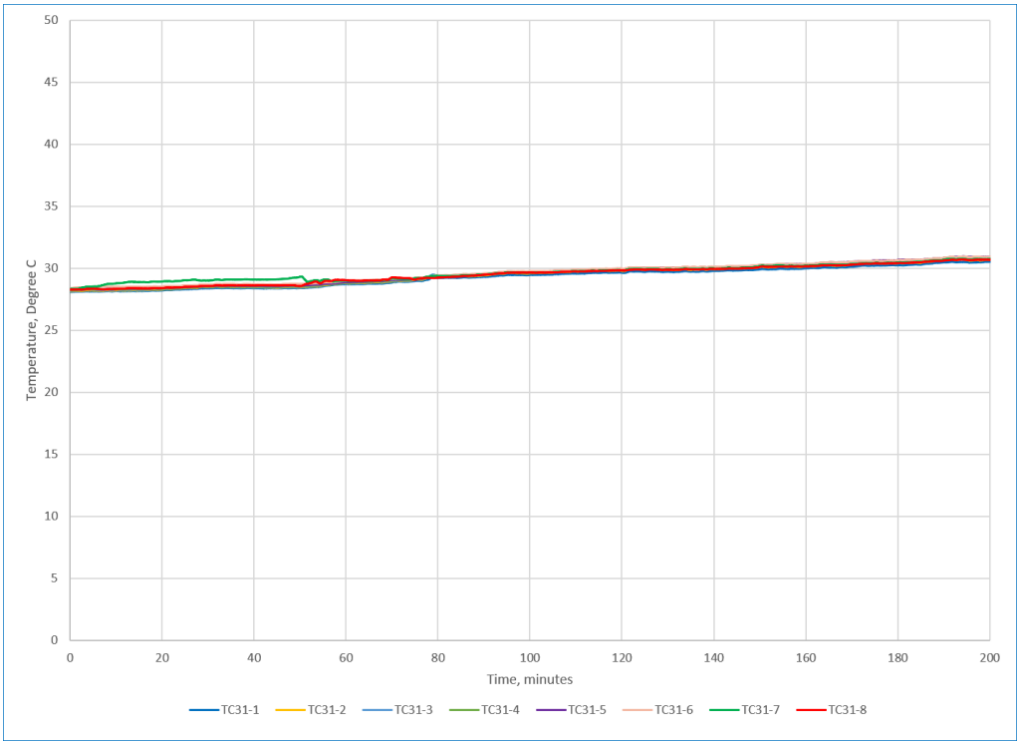


Figure 8: Target unit temperature

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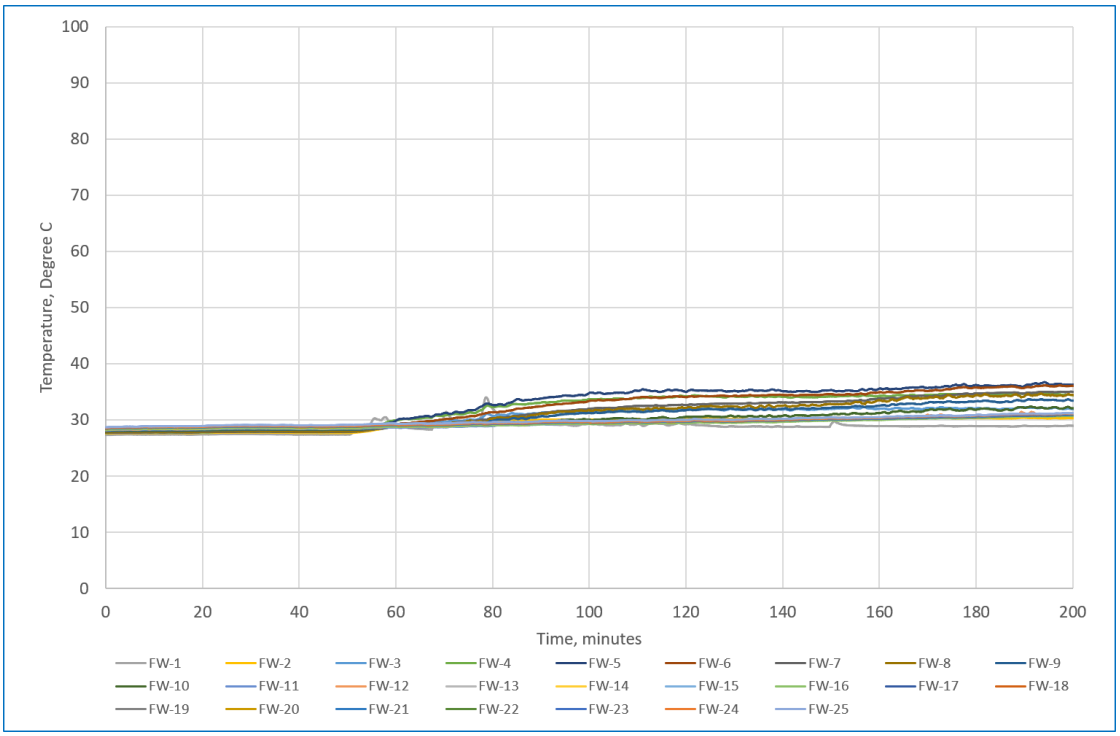


Figure 9: Front wall temperature

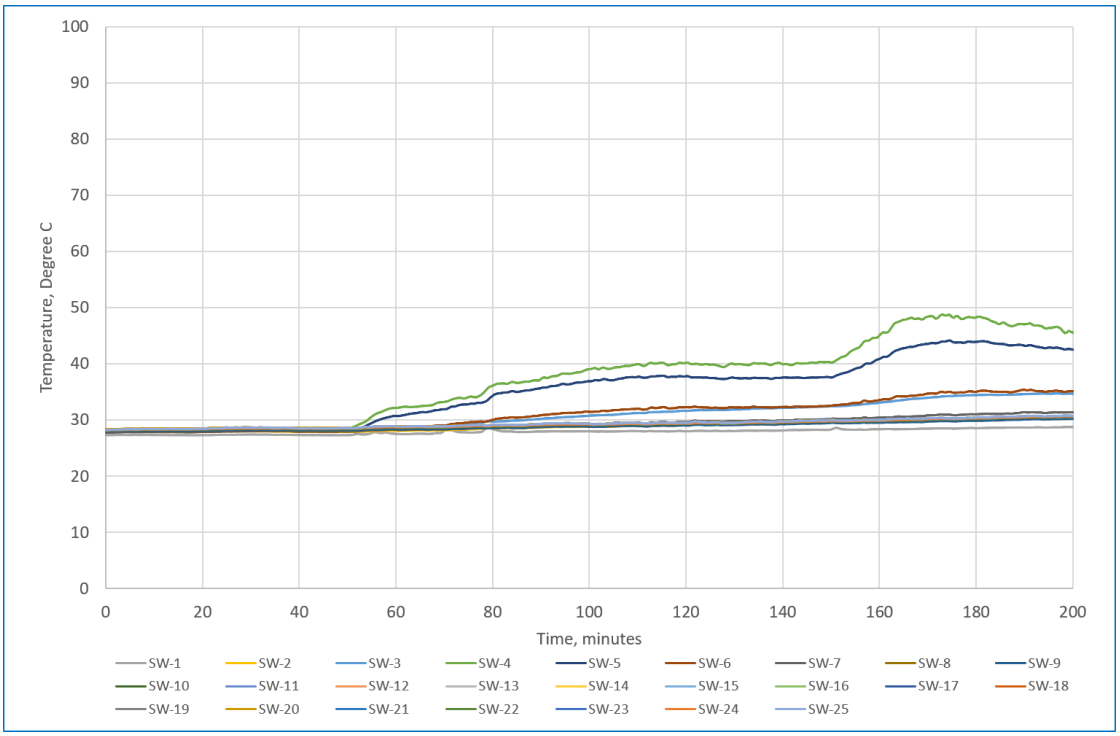


Figure 10: Side wall temperature

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Attachment E: BESS Testing Photos - (*Pages* 36 *through* 39)



(a) Test start
[00:00:00]



(b) Vent of initiating cell
[00:49:53]



(c) Initiating cell thermal runaway
[00:51:39]



(d) Cell 12 thermal runaway
[00:57:30]



(e) Cell 08 thermal runaway
[01:10:07]



(f) Cell 11 thermal runaway
[01:18:49]

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(g) More gas released
[02:30:35~02:32:30]



(h) Test end
[03:19:58]

Figure 10: BESS Unit Testing Photos





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Figure11: BESS Unit Photos after test

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Attachment F: BESS Gas Flow Rate, Smoke Release Rate Profiles - (*Pages* 40 *through 41*)

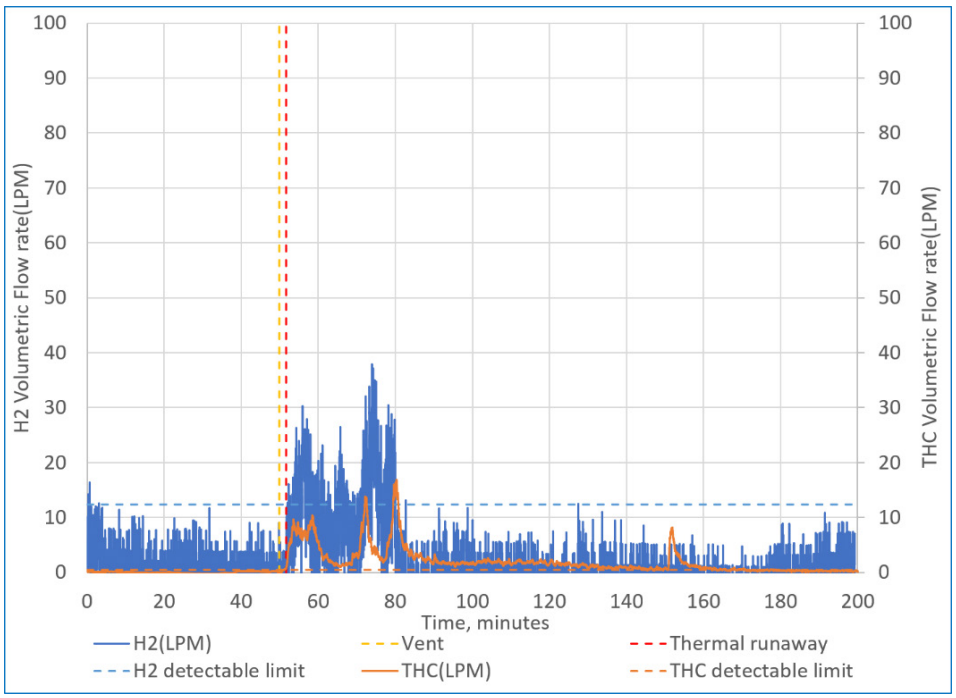


Figure 12: THC, H2 flow rates

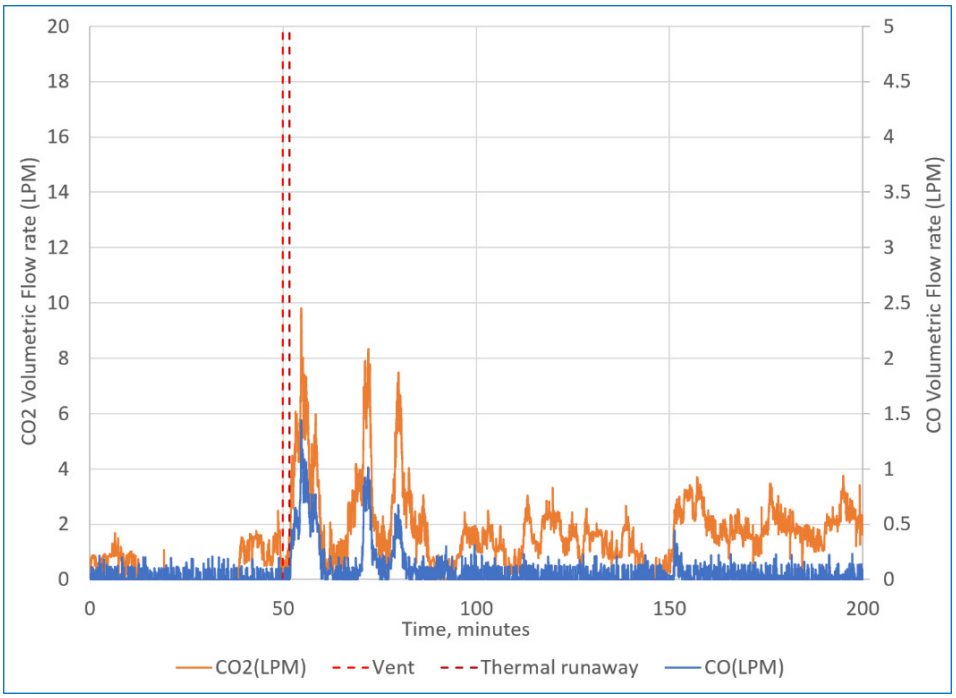


Figure 13: CO, CO2 flow rates

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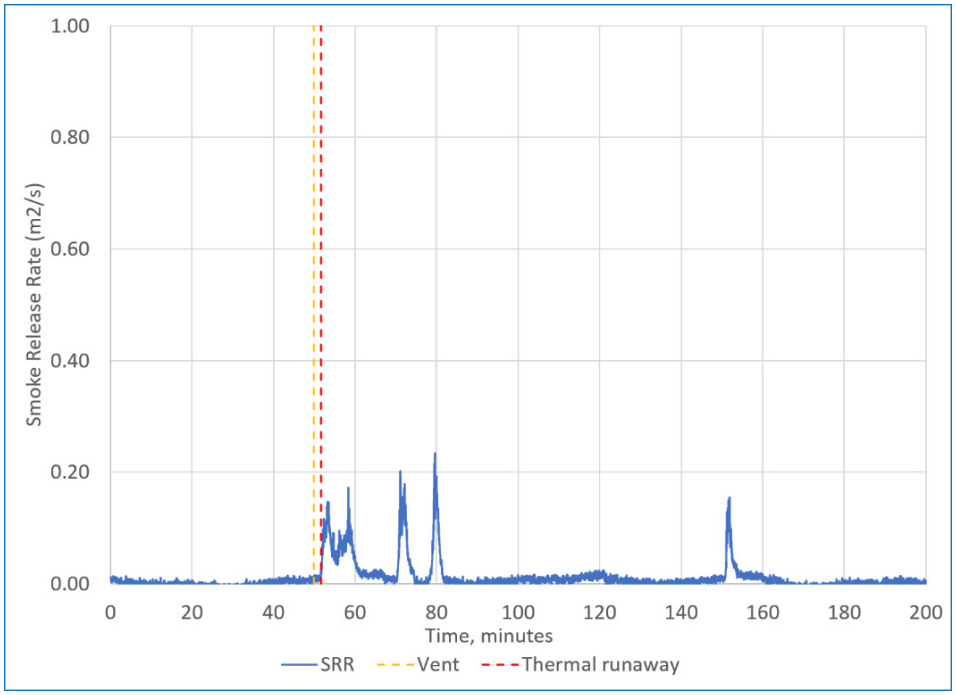


Figure14: Smoke release rate

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