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

Project Number.....:	**4790931774**
Date of issue.....:	**2023-10-27**
Total number of pages.....:	**44**

UL Report Office .....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name.....:	**Contemporary Amperex Technology Co., Limited**
Address .....:	**No.2 Xin'gang Road, Zhangwan Town, Jiaocheng District, Ningde, Fujian, China**
Test specification:	4th Edition, Section 9, November 12, 2019
Standard.....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure .....:	9.1 – 9.8
Non-standard test method .....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

General disclaimer:

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

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

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Cell level information	
Cells in Module:	
●Manufacturer Name	**Contemporary Amperex Technology Co., Limited**
●Part Number	**CBDD0**
●Chemistry	**Lithium Iron Phosphate**
●Format	**Prismatic**
Ratings (Vdc, Ah) :	**3.2V, 306Ah**
Cell certified? :	**Yes**
Standard the cell was certified to:	**UL 1973**
Organization that certified the cell:	**MH62898**
Average cell surface temperature at gas venting, °C:	**154**
Average cell surface temperature at thermal runaway, °C:	**241**
Gas Volume:	**204L**
Lower flammability limit (LFL), % volume in air at the ambient temperature:	**8.595**
Lower flammability limits (LFL), % volume in air at the venting temperature:	**7.24**
Burning velocity (S_u) cm/s:	**54.20**
Maximum pressure (P_{max}) psig:	**102.74**

Cell level Gas Composition:

Gas		Measured %
Carbon Monoxide	CO	14.596
Carbon Dioxide	CO_2	26.925
Hydrogen	H_2	43.066
Methane	CH_4	7.051
Acetylene	C_2H_2	0.119
Ethylene	C_2H_4	3.289
Ethane	C_2H_6	1.060
Propylene	C_3H_6	0.686
Propane	C_3H_8	0.260
-	C4 (Total)	0.865
-	C5 (Total)	0.399
-	C6 (Total)	0.148
1-Heptene	C7H14	0.025
Styrene	C8H8	0.013
Benzene	C_6H_6	0.082
Toluene	C_7H_8	0.012
Dimethyl Carbonate	$C_3H_6O_3$	1.304
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.101
Total	**-**	**100**

Module level Information	
Model No..... :	M02306P05L01

Ratings (Vdc, Ah)..... :	166.4V, 612Ah
Module dimensions (X x **Y** x **Z** (mm)**)…….:**	830mm*2235mm * 250mm
Module cell configuration (xS/**y**P**) …...:**	52S2P
Module weight (kgs)…… :	653±5kg
Module enclosure material…….. :	Bottom enclosure -Material: Al6063.T6 -Thickness: ≥2mm -Size: L*W*H(mm) (2235±3.5)*(830±3)*(31±3) Top Plastic enclosure: -Material: PP -Thickness: ≥2.5mm -Size: L*W*H（mm）2203.1*830*218.5 -Fire rating: V-0 -Maximum ambient temperature: 90±2°C
Was the module certified? …….:	No
Standard the module was certified to ……..:	N/A
Organization that certified test item …….:	N/A
Number of initiating cells failed to achieve propagation.	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to three adjacent cells.
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
Test Maximum Smoke Release Rate (m^2/s)	0.52
Test Total Smoke Released: (m^2)	1.41
Test Peak Chemical Heat Release Rate: (kW):	No flaming occurred

Module level test 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	260.29	No flaming	0.50
Carbon Monoxide	Carbon Containing	77.57	No flaming	0.61
Carbon Dioxide	Carbon Containing	217.03	No flaming	1.82
Hydrogen	Hydrogen	263.37	No flaming	14.29

Unit level Information	
Model No. :	C02306P05L01-R
Ratings (Vdc, Ah) ..... :	1331.2V, 612Ah
BESS dimensions (W x **D** x **H** (mm)**)…….:**	2698mm(H)*936mm(W)*2252.5mm(D)
BESS module configuration	8S1P
Number of modules in BESS	8
Module cell configuration (xS/**y**P**) …...:**	52S2P
Number of cells in module.:	104
BESS weight (kgs)…… :	7200kg
BESS enclosure material…….. :	No enclosure provided for BESS unit, racks are directly mounted on the container frames
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 in a container. For a container system BESS including those intended for outdoor installation only, the unit level test shall be in accordance with the indoor floor mounted unit level test using the battery system racks as the test units and with the test installation set up in accordance with the installation layout within the container. According to 9.1.2.1 from the CRD, it should be treated as indoor floor mounted application
Residential Indoor Use: Smallest volume room installations specified.	N/A
Original Equipment Manufacturer (OEM):	Contemporary Amperex Technology Co., Limited
Branding Manufacturer (if not OEM):	N/A
Was the unit certified? …….:	No
Standard the unit was certified to ……..:	N/A
Organization that certified the unit …….:	N/A
Cell failure test method performed (summary of method and test clause): ☒ External heating using thin film with 4°C to 7°C thermal ramp. ☐ Nail Penetration ☐ Overcharge ☐ External short circuit (***X*** Ω *external resistance*) ☐ Others	
Description of method used to fail cells if other than external thin film heater with thermal ramp, :N/A	

Description of components employed within the BESS unit that serve to suppress propagation (fire protection features)

N/A

Deviation from the module level test

N/A

Number of initiating cell(s)	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to at least two adjacent cells.
External Flaming from BESS:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred
Maximum Target BESS Temperature, °C	30.5
Maximum Wall Surface Temperature[1], °C	28.3
Peak Chemical Heat Release Rate, kW	No flaming occurred
Peak Convective Heat Release Rate, kW	No flaming occurred
Maximum Smoke Heat Release Rate, m^2/s	0.12
Maximum Heat Flux on Target Modules, kW/m^2	0.01
Maximum Heat Flux of Egress Path, kW/m^2	0
Flying Debris:	No flaming occurred
Re-ignitions:	No further re-ignitions were observed during post test observation

Gas Analysis:

☒ Flame ionization detection (FID)

☒ Non-Dispersive Infrared Spectrometer (NDIR)

☐ Fourier-Transform infrared Spectrometer

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

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

Summary of Unit level test Gas Analysis Data:

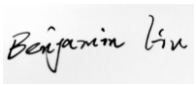
Unit level Gas Composition & Volume for Each Compound (Pre-flaming and After flame):

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate(LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	111.98	No flaming	4.13
Carbon Monoxide	Carbon Containing	59.54	No flaming	3.08
Carbon Dioxide	Carbon Containing	138.34	No flaming	3.97
Hydrogen	Hydrogen	3.54	No flaming	104.03

Summary of BESS Unit Test Results

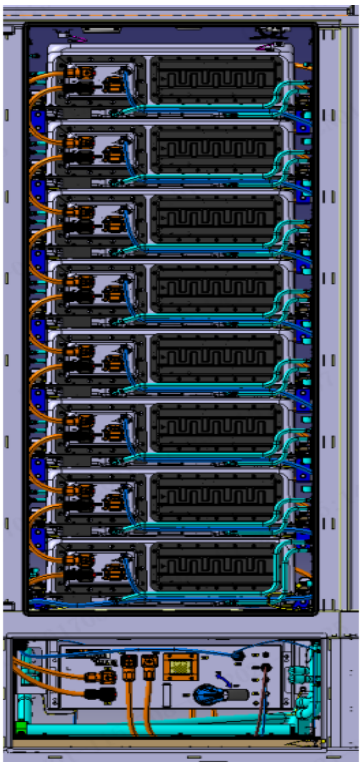
Performance Criteria in accordance with Table 9.1 for Indoor Floor Mounted non-residential unit

[1] Maximum wall surface temperature averaged on 60 seconds.

[X] Flaming outside the initiating BESS unit was not observed; **[X]** 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; **[X]** 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; **[X]** Explosion hazards were not observed, including deflagration, detonation; and **[X]** 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. **[X]** 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.		
Testing Laboratory Information		
Testing Laboratory and testing location(s):		
Testing Laboratory:	Beijing Building Materials Testing Academy	
Testing location/ address..... :	Block 1, B15 Yaxin Road, Doudian Town, Fangshan district, Beijing 102402, CN PSN: 3369533	
Tested by (name, signature) ..... :	Zhang Qi, Oliver Zhao	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) ..... :	N/A	N/A
Project Handler (name, signature)..... :	Arui Zhou	
Reviewer (name, signature) ……:	Benjamin Liu	

List of Attachments (including a total number of pages in each attachment):
Attachment A: Sample Charging, OCV and SOC Measurement Profiles - (*Pages **27** through **30***)
Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams - (*Pages **31** through **31***)
Attachment C: BESS and Equipment Instrumentation and Test Installation Layout Photos/Diagrams - (*Pages **32** through **35***)
Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. - (*Pages **36** through **39***)
Attachment E: BESS Unit Testing and Post Testing Photos - (*Pages **40** through **41***)
Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles - (*Pages **42** through **44***)

Photo(s) of BESS unit:



Test Item Charge/Discharge Specifications:	C02306P05L01-R
• Charge Power, kW:	50.91 kW, then 5.091 kW for module 407.34 kW, then 40.734 kW for rack
• Standard Full charge voltage, Vdc:	Any cell reaches of 3.65V or 189.8V for module Any cell reaches of 3.65V or 1500V for rack
• Charge temperature range, °C:	-25~55
• End of charge Power, kW:	Any cell reaches of 3.65V or 189.8V for module Any cell reaches of 3.65V or 1500V for rack
• Discharge Power, kW:	50.91 kW for module, 407.34 kW for rack
• End of discharge voltage, Vdc:	Any cell reaches of 2.5V or 130V for module Any cell reaches of 2.5V or 1040V for rack
• Discharge temperature range, °C:	-25~55
• Storage temperature range, °C:	-30~60

Test item particulars .....:	
Possible test case verdicts:	
- test case does not apply to the test object.....:	N/A
- test object does meet the requirement .....:	P (Pass)
- test object does not meet the requirement.....:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Testing.....:	
Date of receipt of test item .....:	2023.08.27
Date (s) of performance of tests.....:	2023.09.22

General remarks:

"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.

Throughout this report a point is used as the decimal separator.

Manufacturer's Declaration of samples submitted for test:

The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided.....:	☐ **Yes** ☒ **Not applicable**
Name and address of factory (ies) ..... :	Contemporary Amperex Technology Co., Limited Xin'gang Road, Zhangwan Town, Jiaocheng District, Ningde, Fujian, China

General product information and other remarks:

Battery Unit Model C02306P05L01-R is lithium-ion racks manufacturer by Contemporary Amperex Technology Co., Limited. The rack consists of 8 battery modules Model M02306P05L01 connected in series with a control box. The rack frame is part of the container frame and test was conducted with initiating rack and target racks installed in the container enclosure.

In the test, 3 racks were placed inside the container. Container size: 2698mm(H)*936mm(W)*2252.5mm(D).

Battery Module Model M02306P05L01 employs cell Models CBDD0 manufactured by Contemporary Amperex Technology Co., Limited, rated 166.4V, 612Ah.

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

5.0	**CONSTRUCTION**		**Verdict**
5.3	**Battery energy storage system unit Construction**		—
5.3.1, 5.3.2	Construction information	See Test Item Description at the beginning of this report	—
5.3.2	General layout of BESS unit contents	See Attachment B	—
5.3.3	Details of integral fire suppression system		
5.3.1	BESS certified to UL 9540		
	Organization that certified BESS:		—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		C
9.1	**Sample and test configuration**		C
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, container type	C
9.1.2	The unit level test required 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 Attachment C for test installations	C
	Tests conducted for indoor floor mounted installations 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

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
9.1.3	Testing to determine fire characterization was done at the battery system level rather than a complete BESS	One initiating unit sample and two target unit samples were used for test. Power Conversion System was not involved in the test.	C
9.1.4	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.		C
9.1.5	Target BESS units include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components.		C
9.1.6	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 maximum period of 8 hours at room ambient.	See Table 2 All modules were fully charged before test for test setup. All module voltages were checked just before the test, and the voltages did not drop further compared to 1h to 8h after cycles.	M
9.1.7	The BESS unit included an integral fire suppression system.	No include integral fire suppression system.	N/A
9.1.8	Electronics and software controls such as the battery management system (BMS) are not relied upon for this 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**		C
9.2.1	Test room ambient temperature within 10°C (50°F) to 32°C (90°F).	See Table 2 See Attachment F	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.	There are no doors or panels for racks, racks are mounted on the container frame.	C
9.2.3	The initiating BESS unit was positioned adjacent to two instrumented wall sections.	Attachment C	C
9.2.4	Instrumented wall sections extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of target BESS units.	Front wall was 3.6m length, side wall was 7.2m length, rear wall was 6.2m length.	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
9.2.5	Instrumented wall sections were at least 0.61-m (2-ft) taller than the BESS unit height, but not less than 3.66 m (12 ft) in height above the bottom surface of the unit.	Front wall, side wall and rear wall were 3.7m high.	C
9.2.6	The surface of the instrumented wall sections were covered with 16-mm (5/8-in) gypsum wall board and painted flat black.	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.	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
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.		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 Racks were installed inside container frame. The spacing between the initiating rack and adjacent target racks (left and right of initiating unit) was 0mm. The spacing from the front wall to the container frame was 3000mm, side wall to the container frame was 1100mm and rear wall to the container frame was 200mm	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
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	C
9.2.15	Wall surface temperature measurements were collected	See Table 6 See Attachment D	C
	The intended installation is composed completely of non-combustible construction		N/A
9.2.16	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.		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.		C
9.2.17	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 .		C
9.2.18	Heat flux was measured with at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall: 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.	See Table 7	C
9.2.19	Heat flux was measured with 2 water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS units facing initiating BESS unit: 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.	See table 7	C
9.2.20	Heat flux was measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge positioned in the center of the accessible means of egress.	See table 7	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
9.2.21	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
	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.		N/A
9.2.22	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.	Non-residential use.	N/A
9.2.23	An internal fire condition 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
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases was measured within the calorimeter's exhaust duct. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.		C
	Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.		
	The hydrocarbon content of the vent gas may also be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer.	FTIR analysis was not used in accordance with the Certification Requirement Decision: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test.	N/A
9.2.25	The hydrocarbon content of the vent gas was measured using flame ionization detection.	See Tables 8, 9, 10 and 11	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
9.2.26	The test shall be terminated if: a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature; b) The fire propagates to adjacent units or to adjacent walls; or c) A condition hazardous to test staff or the test facility requires mitigation.	Test temperature recording was terminated until no noticeable phenomenon observed and all measured temperatures of the initiating unit return to ambient temperature.	C
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.	Non-residential unit.	C
9.7	**Unit level test report**		
9.7.1	Installation type tested:	Indoor floor mounted, non-Residential, container type For a container system BESS including those intended for outdoor installation only, the unit level test shall be in accordance with the indoor floor mounted unit level test using the battery system racks as the test units and with the test installation set up in accordance with the installation layout within the container. According to 9.1.2.1 from the CRD, it should be treated as indoor floor mounted application.	C
9.7.2	Testing is intended to represent more than one installation type.	See Test Item Description in beginning of this report.	C
9.7.3	a. Unit manufacturer name and model number (and whether UL 9540 compliant);		C
	b. Number of modules in the initiating BESS unit		C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	c. BESS construction features;	See Attachment C See Critical Components Table See Also “Description of components employed within the module that impact propagation (fire protection features)” at the beginning of this report.	C
	d. Fire protection features/ detection/ suppression systems within unit		N/A
	e. Module voltages corresponding to the tested SOC;	See Table 13 See Attachment F	C
	f. Thermal runaway initiation method used;	See Attachment C and F	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, and soffits;	See Attachment C	C
	i. Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	See Table 14 No flame observed outside of the initiating rack.	C
	j. Chemical and convective heat release rate versus time data;	See Table 11 See Attachment F	C
	k. Separation distances from the initiating BESS unit to target walls	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 and 6	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;	See Attachment F See Tables 7, 8, 9, and 10	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
	r. Peak smoke release rate and total smoke release data.	See Table 12 See Attachments F	C
	s. Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	See Table 13 No fire protection systems	N/A
	t. Observation(s) of flying debris or explosive discharge of gases;	See Table 15	C
	u. Observation of re-ignition(s) from thermal runaway events	See Table 15	C
	v. Observation(s) of sparks, electrical arcs, or other electrical events;	See Table 15	C
	w. Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits;	See Table 15	C
	x. Video of the test.		C
9.8	**Performance at Unit level testing**		P
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.	See Attachment F	P
Non-Residential Installations – Indoor floor mounted:			
	a) Flaming outside the initiating BESS unit is not observed;	No flaming observed	P
	b) Surface temperatures of modules within target BESS units do not exceed the cell venting temperature;	Max surface temperature 30.5°C didn't exceed the cell venting temperature 154°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) rise above ambient;	Max wall surface temperature 28.3°C didn't exceed 97°C rise above ambient	P
	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;	No explosion observed	P
	e) Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.	Measured heat flux 0kW/m2 didn't exceed 1.3 kW/m2	P

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

Table 1 – Specified Unit charging and discharging parameters			
Charging:		**Discharging:**	
Power (CP), kW	50.91 kW, then 5.091 kW for module 407.34 kW, then 40.734 kW for rack	Power (CP), kW	50.91 kW for module, 407.34 kW for rack
Standard Full Charge Voltage ,Vdc	Any cell reaches of 3.65V or 189.8V for module Any cell reaches of 3.65V or 1500V for rack	End of discharge voltage, Vdc	Any cell reaches of 2.5V or 130V for module Any cell reaches of 2.5V or 1040V for rack
End of Charge Voltage，Vdc	Any cell reaches of 3.65V or 189.8V for module Any cell reaches of 3.65V or 1500V for rack	Discharging Test Ambient, °C	-25~55
Charge temperature range, °C:	-25~55	-	-
Refer to Attachment A for charge/discharge profiles.			

Table 2 - Test Initiation Details	
Test Date	2023-09-22
Test Start Time (HH:MM:SS)	09:49:14
Initial Lab Temperature, °C	24.0°C
Initial Relative Humidity % RH	49% RH
Module OCV at Start of Test, Vdc	173.2V

Table 3 – Approximate time of thermal runaway propagation through module		
Locations (Cell #)	**Event**	**Time**
Cell 20-2	Vent	0:41:08
Cell 20-2	Thermal runaway	0:41:48
Cell 20-1	Thermal runaway	0:44:40
Cell 21-1	Thermal runaway	0:46:03
*	Thermal runaway	1:05:26
*Note: Suspect there is another one cell went into thermal runaway, as there is no more TC in the module, cannot determine the cell location, refer to the temperature curve of Cell 21-1, voltage drop of module, gases generation and video, another cell was suspected to be propagated around 65.5 mintues.		

Table 4 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	The test started and the heater was turned on to heat the initiating cell (Cell 20-2) at a ratio of 4 ~ 7 °C/min.
00:41:08	Venting of initiating Cell	Initiating cell (Cell 20-2) vented at around 168.4 °C measured through TC 2-1 by an indication of sudden dip in cell's temperature curve. See Figure (b)
00:41:48	Thermal runaway of initiating cell	Initiating cell (Cell 20-2) was at around 145.1 °C measured through T2-1. The temperature of cell 20-2

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Clause	Requirement + Test	Result - Remark	Verdict

		began to increase inan uncontrollable manner, With the release of smoke. See Figure (c)
00:44:40	Thermal runaway of adjacent cell	Thermal runaway propagated to nearby cell (cell 20-1). More gas released. See Figure (d)
00:46:03	Thermal runaway of adjacent cell	Thermal runaway propagated to nearby cell (cell 21-1). More gas released. See Figure (e)
01:05:26	Thermal runaway of adjacent cell	Gas released.(Refer to the temperature curve of Cell 21-1, voltage drop of module, gases generation and video, another cell was suspected to be propagated around 65.5 mintues.) See Figure(f)
01:25:00	Test Termination	Data acquisition was stopped. The module was left in the test overnight and with video monitored.

Table 5 - Maximum Temperatures in Target Units			
Cell vent temperature from cell test data, °C			154°C
Target Unit 1		**Target Unit 2**	
Module Location No.	Temperature (°C)	Module Location No.	Temperature (°C)
Module -1	27.2	Module -1	26.9
Module -2	28.8	Module -2	28.1
Module -3	30.5	Module -3	28.7
Module -4	28.5	Module -4	28.0
Module -5	27.5	Module -5	27.7
Module -6	27.3	Module -6	27.2
Module -7	27.3	Module -7	27.0
Module -8	27.8	Module -8	27.5
Note: Temperatures are measured constantly and then averaged every 60-seconds			

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Clause	Requirement + Test	Result - Remark	Verdict

Table 6.1 - Maximum Temperatures on Instrumented Wall- Front Wall					
Ambient Temperature: 24.0°C					
UL 9540A performance criteria, Ambient + 97°C: 121.0°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	26.8	1368	27.2	2584	24.7
304	27.0	1520	27.0	2736	27.2
456	27.1	1672	27.0	2888	27.1
608	25.3	1824	27.2	3040	27.2
760	27.3	1976	27.2	3192	27.4
912	27.3	2128	27.4	3344	27.4
1064	27.0	2280	27.4	3496	27.4
1216	27.0	2432	27.2	3648	27.7
Note: Temperatures are measured constantly and then averaged every 60-seconds					

Table 6.2 - Maximum Temperatures on Instrumented Wall- Side Wall					
Ambient Temperature: 24.0°C					
UL 9540A performance criteria, Ambient + 97°C: 121.0°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	24.9	1368	26.8	2584	26.9
304	25.8	1520	26.9	2736	27.0
456	25.5	1672	26.9	2888	27.3
608	26.1	1824	26.8	3040	27.3
760	26.3	1976	26.7	3192	27.0
912	26.6	2128	26.8	3344	27.1
1064	26.7	2280	26.8	3496	27.0
1216	26.5	2432	27.0	3648	27.0
Note: Temperatures are measured constantly and then averaged every 60-seconds					

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

Table 6.3 - Maximum Temperatures on Instrumented Wall- Rear Wall					
Ambient Temperature: 24.0°C					
UL 9540A performance criteria, Ambient + 97°C: 121.0°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	26.7	1368	27.6	2584	27.2
304	27.2	1520	27.4	2736	27.5
456	26.8	1672	27.3	2888	27.5
608	26.9	1824	27.6	3040	27.6
760	27.0	1976	27.2	3192	27.6
912	27.1	2128	27.2	3344	27.5
1064	27.2	2280	28.1	3496	28.3
1216	27.1	2432	26.9	3648	27.7
Note: Temperatures are measured constantly and then averaged every 60-seconds					

Table 7 – Heat Flux Measurements			
Summary of maximum heat flux in target units		Summary of maximum heat flux measured on instrumented wall	
Maximum Heat Flux, kW/m^2			
Target Unit 1 Module No.3: 1#	0	Heat Flux Gauge No.	kW/m^2
Target Unit 1 Module No.4: 5#	0	Front wall 1350 mm high, 11#	0
Target Unit 2 Module No.3: 8#	0	Front wall 1600 mm high, 7#	0
Target Unit 2 Module No.4: 9#	0.01	Side wall 1350 mm high, 6#	0
-		Rear wall 1350 mm high, 10 #	0
-		Rear wall 1600 mm high, 4#	0
Egress path measurement- 1: 3 #			0
Egress path measurement- 2: 2#			0

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
# - This table was modified to reflect the gases measured during testing.			

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

Table 9 - Gas generation periods	
Time	**Condition**
From the venting point 0:41:08 to the end of test 2:00:00	Pre-Flaming
Flaming was not observed during the test.	Flaming
External Flaming of Gas	
Condition	**Duration (hh:mm:ss)**
External Flaming of Vent Gases:	Flaming was not observed during the test.

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	111.98	No flaming	4.13
Carbon Dioxide	Carbon Containing	59.54	No flaming	3.08
Carbon Monoxide	Carbon Containing	138.34	No flaming	3.97
Hydrogen	Hydrogen	3.54	No flaming	104.03

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)	0.12
Peak Convective HRR, (kW)	No flaming observed	Total Smoke Released (m^2)	0.23

Table 12 – Integral Fire suppression system Details of Operation
N/A

Table 13 - Module OCV voltage measurement comparison before and after testing			
Module Location In Rack	OCV Prior to Test (V)	OCV Post Test (V)	Difference (V)
1	173.2	173.2	0
2	173.2	173.2	0
3 (Initiating Module)	173.2	166.4	6.8
4	173.6	173.5	0.1
5	173.2	173.2	0
6	172.3	173.2	0.1
7	173.3	173.3	0
8	173.8	173.7	0.1

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Clause	Requirement + Test	Result - Remark	Verdict

Table 14 – Other Observations during Unit test			
	Observed, Yes/No	Comments/Location	
Flaming outside of Unit	No	Length of flame:	N/A
Flying debris	No	-	
Explosive discharge of gas	No	-	
Sparks or electrical arcs	No	-	

Table 15 - Post Test Observations	
Thermal runaway behaviour	No further thermal runaway after the test was completed
Re-ignitions	No re-ignition occurred
Explosions	No explosion occurred
Other Observations	N/A

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Clause	Requirement + Test	Result - Remark	Verdict

	TABLE: Critical components information				
Object / Part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Module construction					
Cells	CATL	CBDB0	Nominal voltage：3.2V d.c Rated capacity：306Ah	UL 1973 IEC 62619：2022	UL MH 62898 JPTUV-146897
Module	CATL	-	Nominal voltage：166.4V Rated capacity：612Ah	-	-
Metal enclosure	CATL	-	Material: Al6063.T6 Thickness: ≥2mm Size: L*W*H(mm) (2235±3.5)*(830±3)*(31±3)	–	–
Plastic enclosure	0000013277	NHPP-FR NHPP-FR-2	Fire rating：V-0 Material: PP RTI: 65°C	UL746	UL E171666
Connector	0000007975	REA4	Voltage：1500VDC Current：350A for TUV, 300A for UL Fire rating：V-0	UL4818 EN 61984	UL E526230 J 50586193
Connecting wire for HV	0000009966	3932	Voltage: 2000V Current-carrying capability: 75°C 350A Maximum ambient temperature:-40°C~+125°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 M.2021.206.C63716
Wire for LV	0000009966	3666	Voltage: 600V Wire diameter: (0.5~4mm2) Maximum ambient temperature: -40°C~+105°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 0B160705.DNTDS30
Plastic material (Harness isolation plate)	0000015262	PP C6540R-G20HF	Fire rating: V-0 Maximum ambient temperature: 90±2°C	UL94	SHMR220800424401
Plastic material (Output pole base)	0000007541	46GF30	Fire rating: V-0 Maximum ambient temperature: 180°C	UL94	UL E225348

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Clause	Requirement + Test	Result - Remark	Verdict

Plastic material (Buffer pad)	0000007929	MPP	Fire rating: V-0 Maximum ambient temperature: 100°C	UL94	UL E509966
Container					
Enclosure	0000014067	-	Material: steel High weather resistance rolled steel Thickness: 1.6mm/12mm Size: 6058*2438*2896(mm)	-	-
Plastic enclosure	0000014067	FR-4 Board	Material: epoxy plate Thickness: (4mm) Size: 516*70*4(mm) Fire rating: V0	ROHS UL 94	STT/22T1032-ROHS 2015-L738
Connector	0000007975	REA4	Voltage: 1500VDC Current: 350A for TUV, 300A for UL Fire rating: V-0	UL4818 EN 61984	UL E526230 J 50586193
Connecting wire for HV	0000009966	3932	Voltage: 2000V Current-carrying capability: 75°C 350A Maximum ambient temperature:-40°C~+125°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 M.2021.206.C63716
Main control box					
Enclosure	0000003592	-	Material: steel DC51D+Z&DC01 Thickness: ≥1.5mm Size: 751.5±5*741.4±5*239.3±5 mm	-	-
Wire for LV	0000009966	3666	Voltage: 600V Wire diameter: (0.5~4mm2) Maximum ambient temperature: -40°C~+105°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 0B160705.DNTDS30
Connector	0000007975	REA4	Voltage: 1500VDC Current: 350A for TUV, 300A for UL Fire rating: V-0	UL4818 EN 61984	UL E526230 J 50586193

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

Connecting wire for HV	0000009966	3932	Voltage: 2000V Current-carrying capability: 75°C 350A Maximum ambient temperature: -40°C~+125°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	E214184 M.2021.206.C63716
Sealing element	0000011532	LZ302Z(Sec A)	Fire rating: ≥V-0 Maximum ambient temperature: -50~+200°C	UL94	UL E529227

Attachment A: Sample Charging, OCV and SOC Measurement Profiles - (*Pages **27** through**30***)

Note: There were 8 modules in the initiating unit. Due to the voltage limitation of the charging device, the modules in the unit were divided into 8 groups and were then fully charged separately. The charging current of each module is 50.91 kW, then 5.091 kW, and the charging ends when any cell reaches of 3.65V or 1500V for rack.

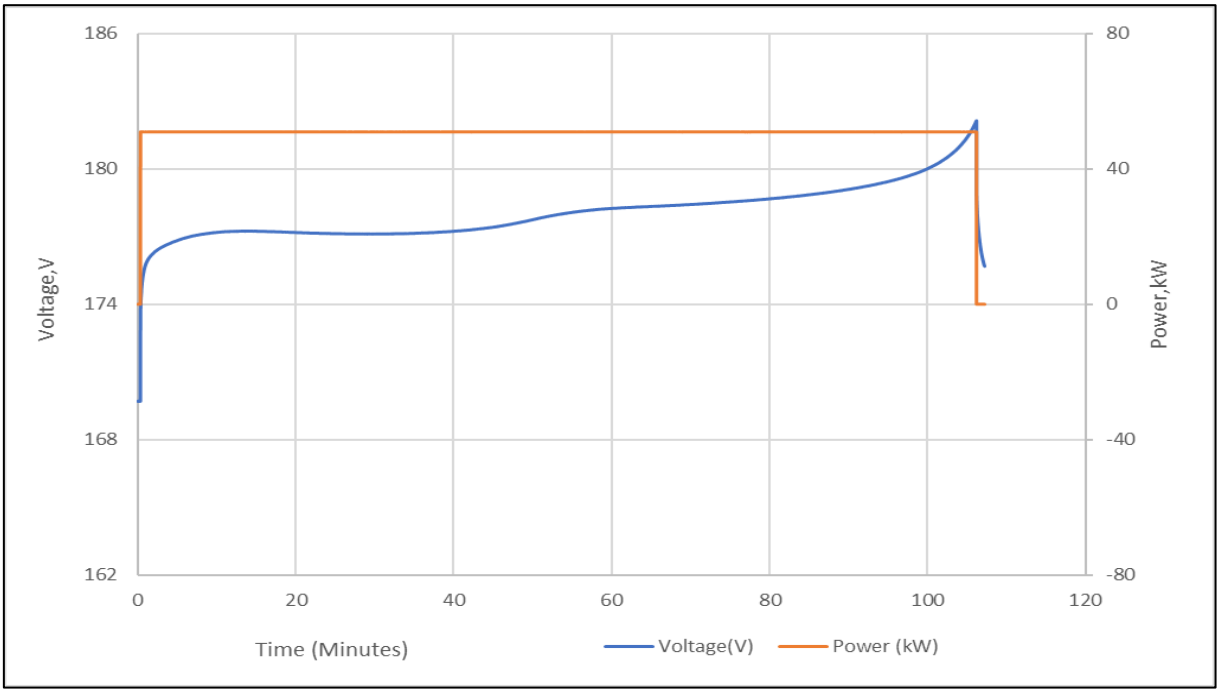


Figure 1: Initiating unit, module 1 charge to 100% SOC

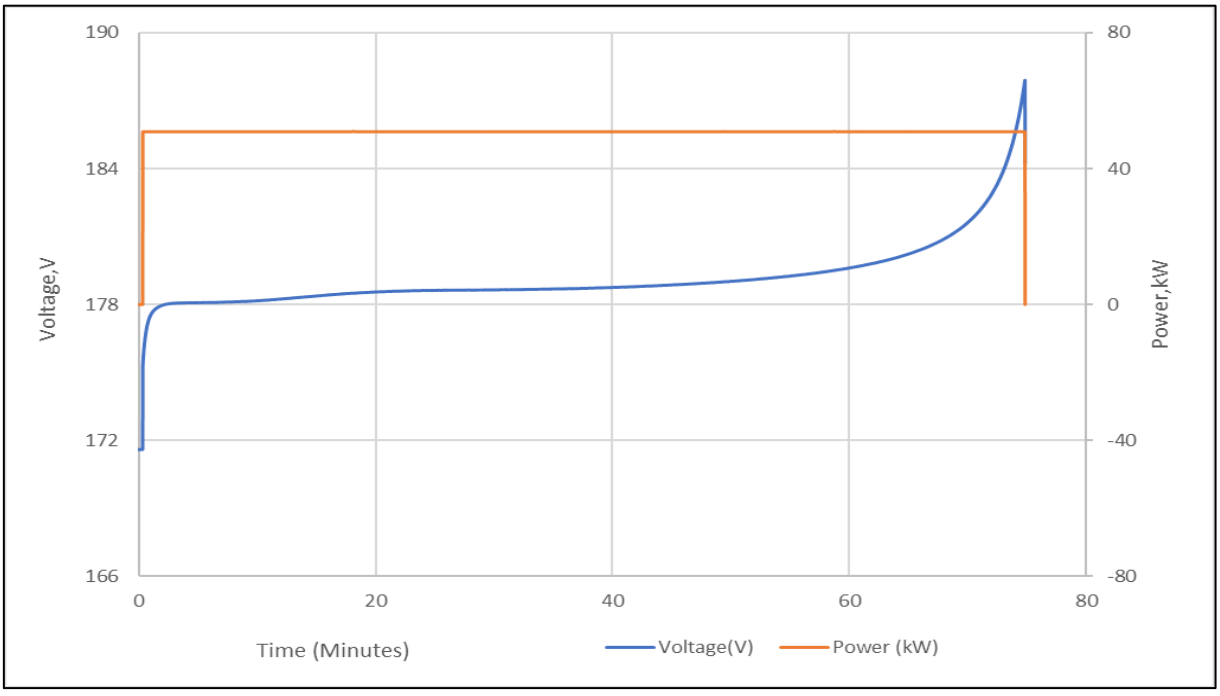


Figure 2: Initiating unit, module 2 charge to 100% SOC

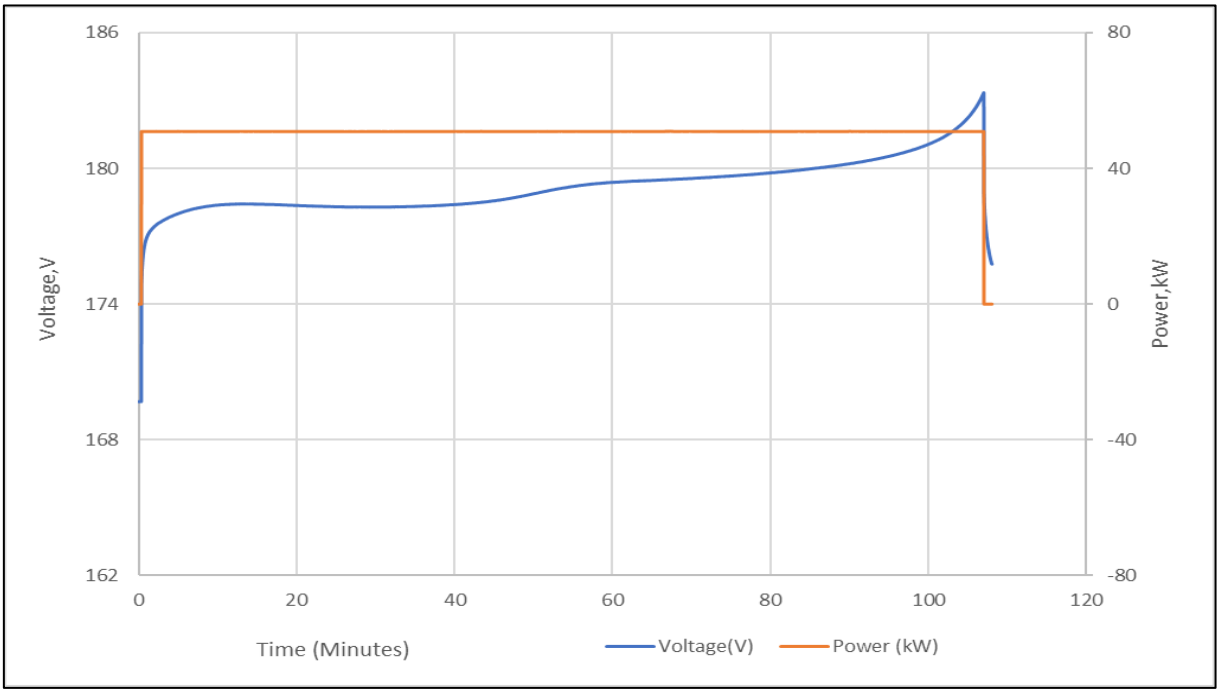


Figure 3: Initiating unit, module 3 charge to 100% SOC

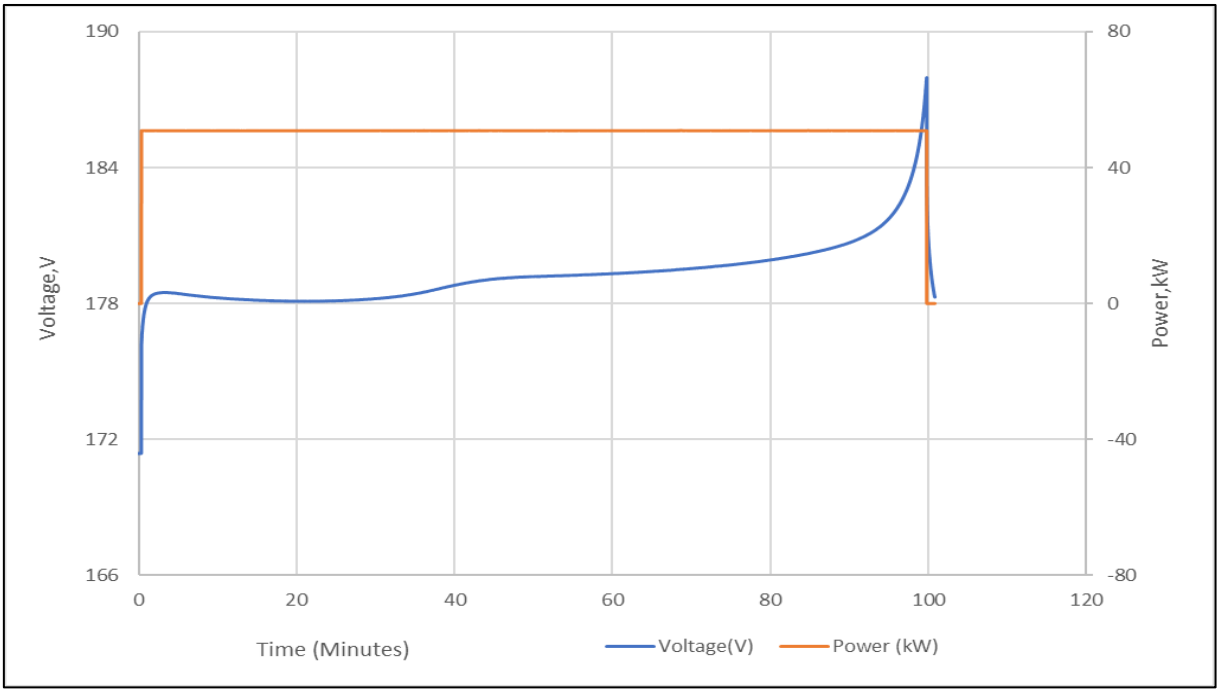


Figure 4: Initiating unit, module 4 charge to 100% SOC

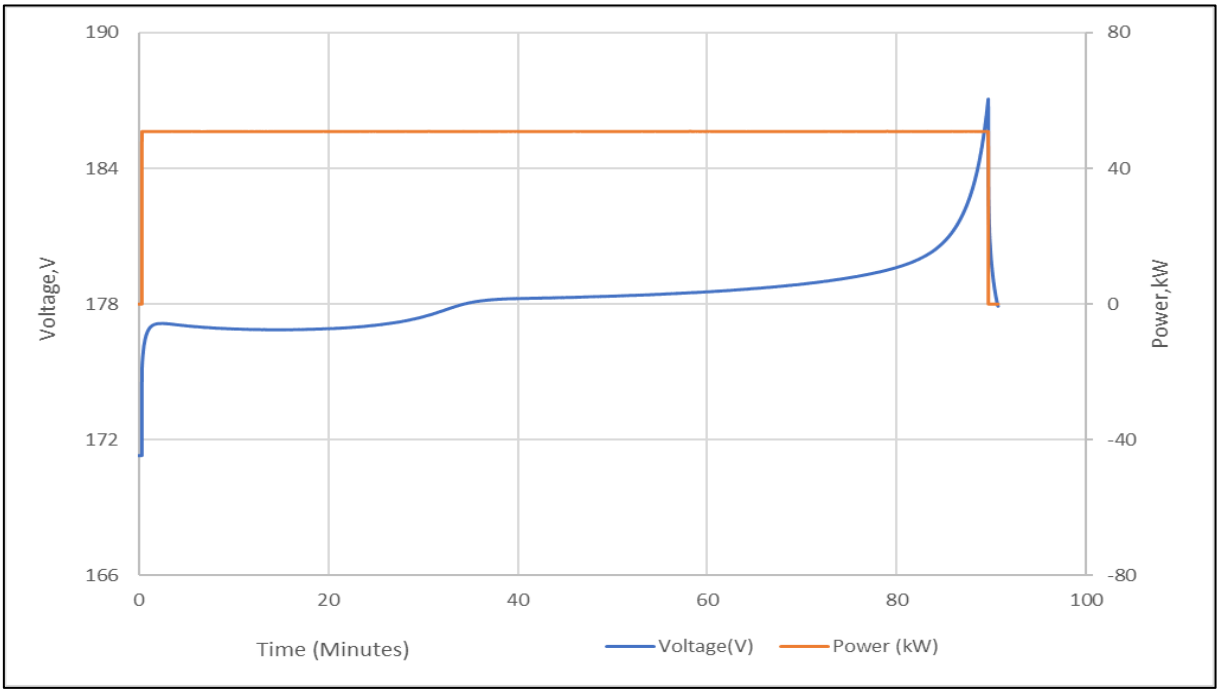


Figure 5: Initiating unit, module 5 charge to 100% SOC

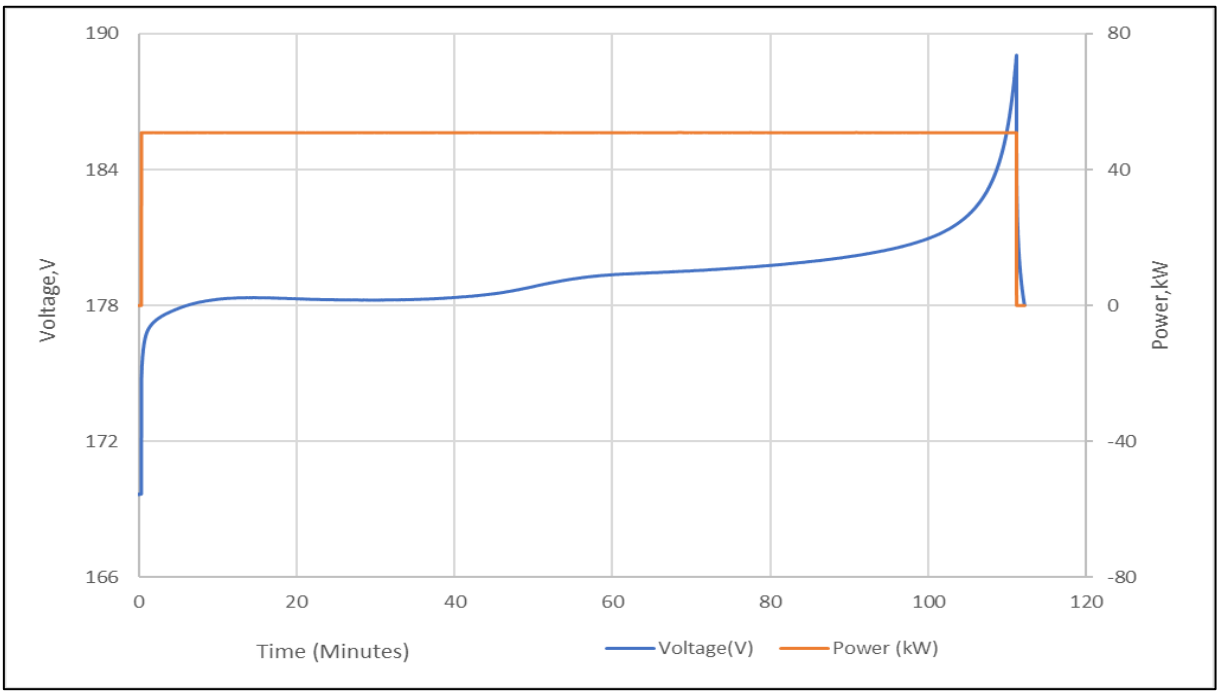


Figure 6: Initiating unit, module 6 charge to 100% SOC

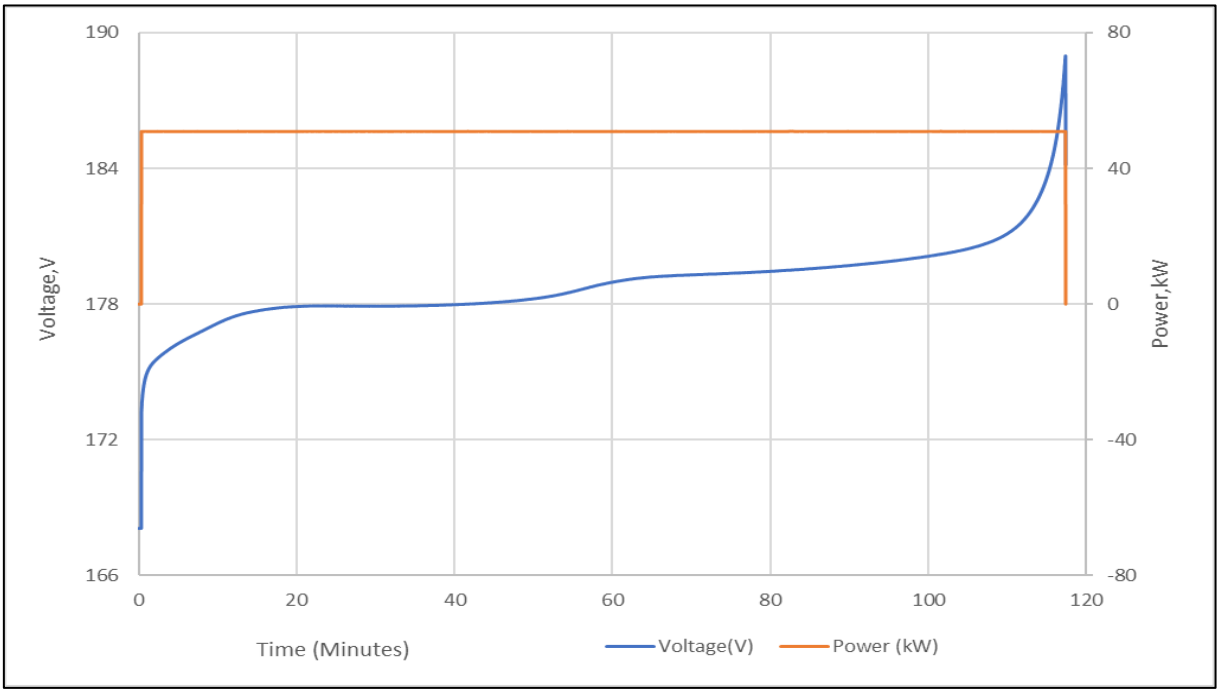


Figure 7: Initiating unit, module 7 charge to 100% SOC

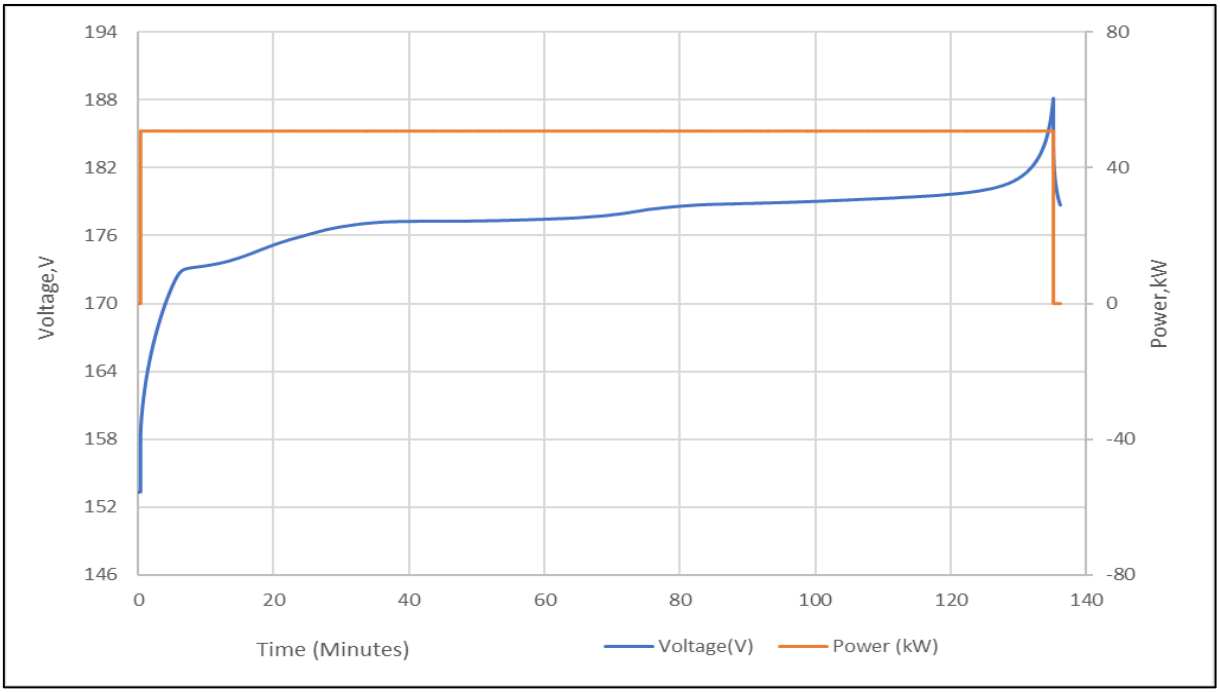


Figure 8: Initiating unit, module 8 charge to 100% SOC

Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams - (*Pages **31** through **31***)






BESS unit and module Construction Photos

Note: there is no fire detection and suppression systems in the Unit BESS.

Attachment C: BESS and Equipment Instrumentation and Test Installation Layout Photos/Diagrams - (*Pages **32** through **35***)

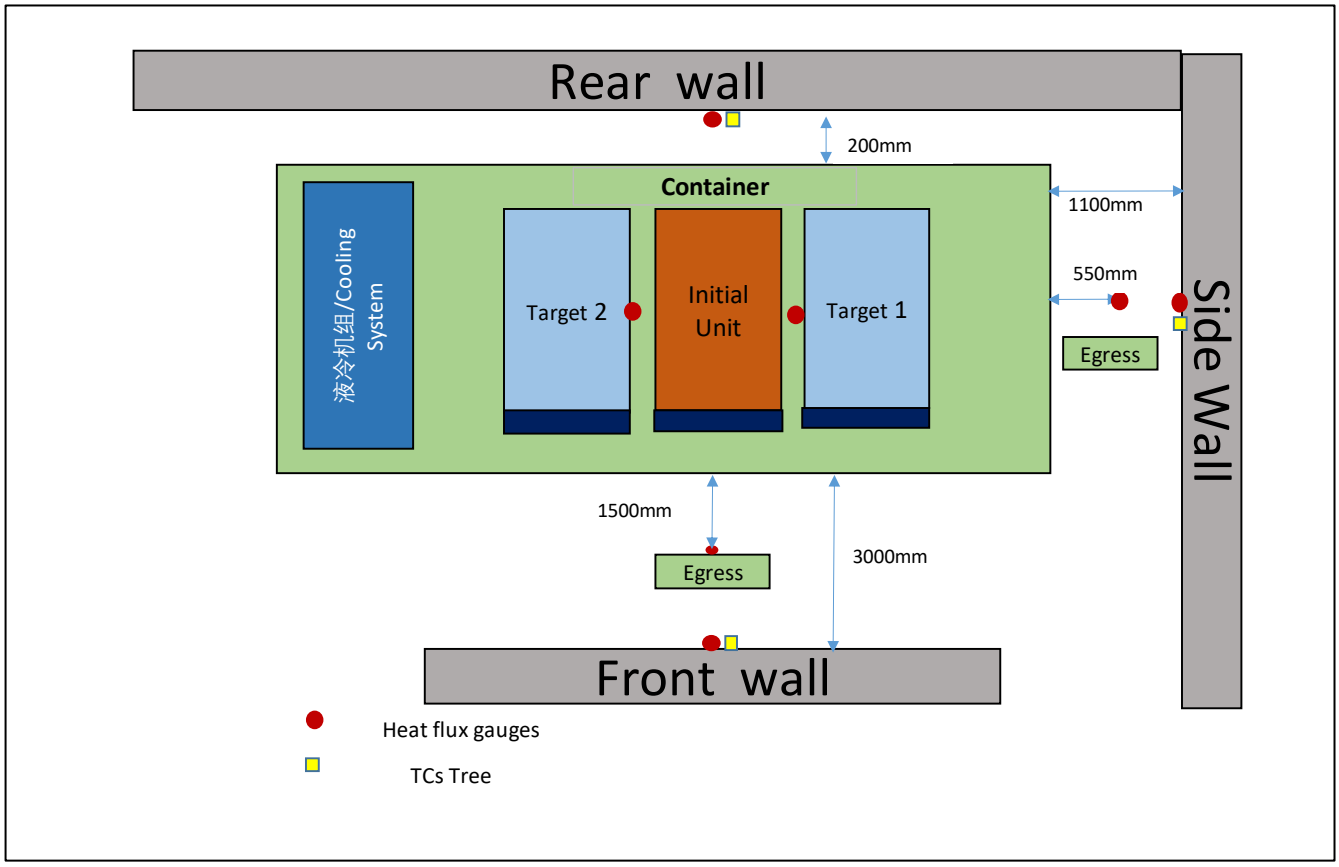
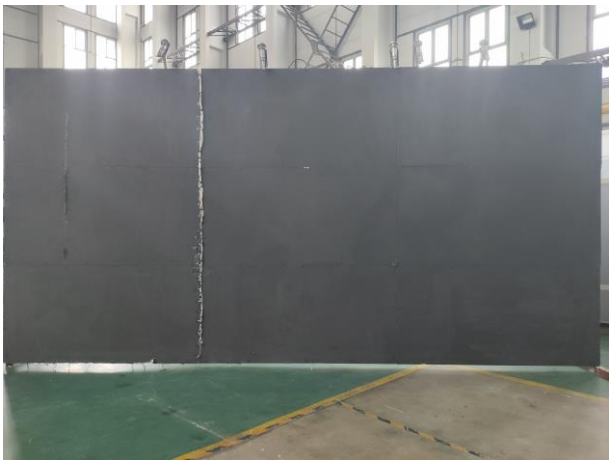


Figure 9: Test area layout

Front view - TC Location of front wall. From the bottom to up, TCs were FW-1 to FW-24



Side view - TC Location of side wall. From the bottom to up, TCs were SW-1 to SW-24

Rear view - TC Location of side wall. From the bottom to up, TCs were RW-1 to RW-24

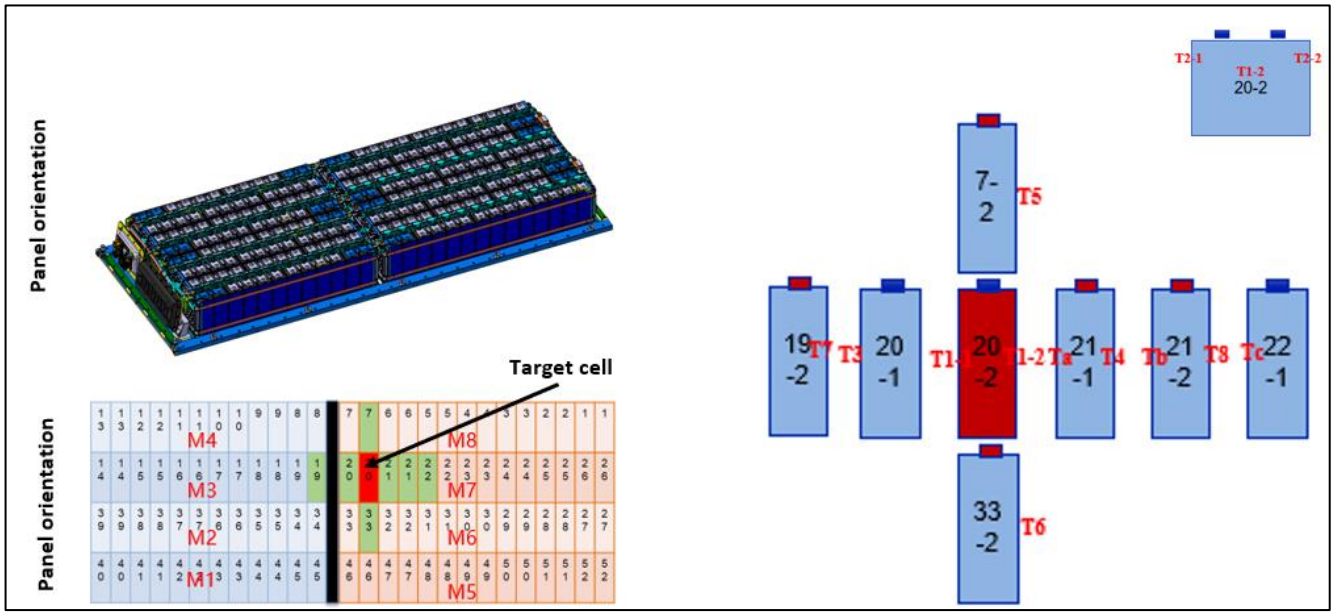


Figure 10: TC Location in the initiating module and above module. TCs were on the cells' large side body

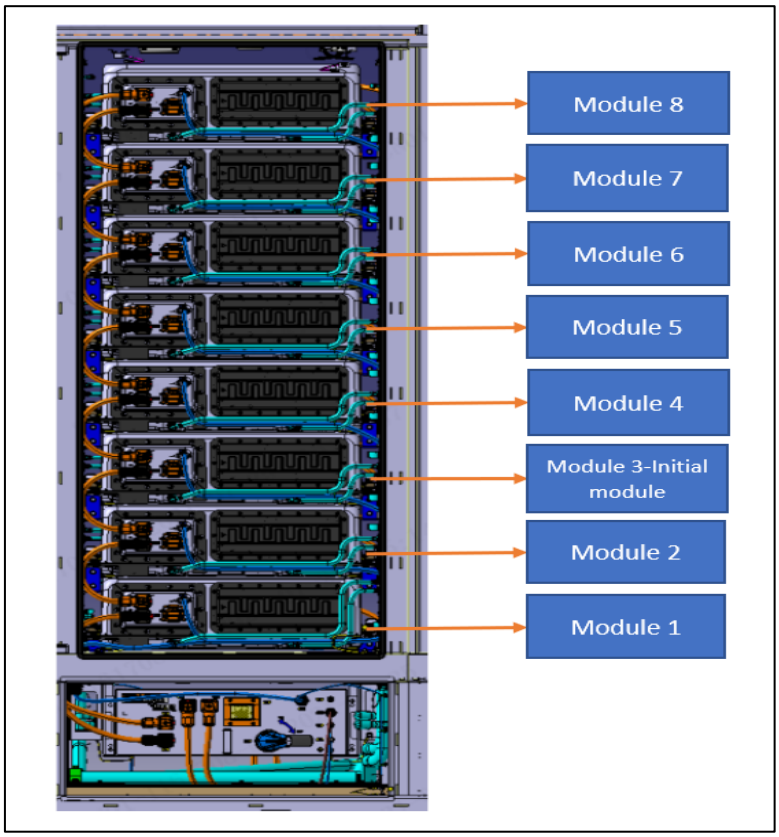


Figure 11: The initiating module 3 location in the initiating unit

Initiating unit	Target unit - 1	Target unit - 2

Figure 12: TC location in the initiating and target units, T16 series for target unit-1, T17 series for target unit-2

(Note: Except T15 affixed to the top frame of the initiating module, other T14 affixed to the middle height of the module frame.)

Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. - (*Pages **36** through **39***)

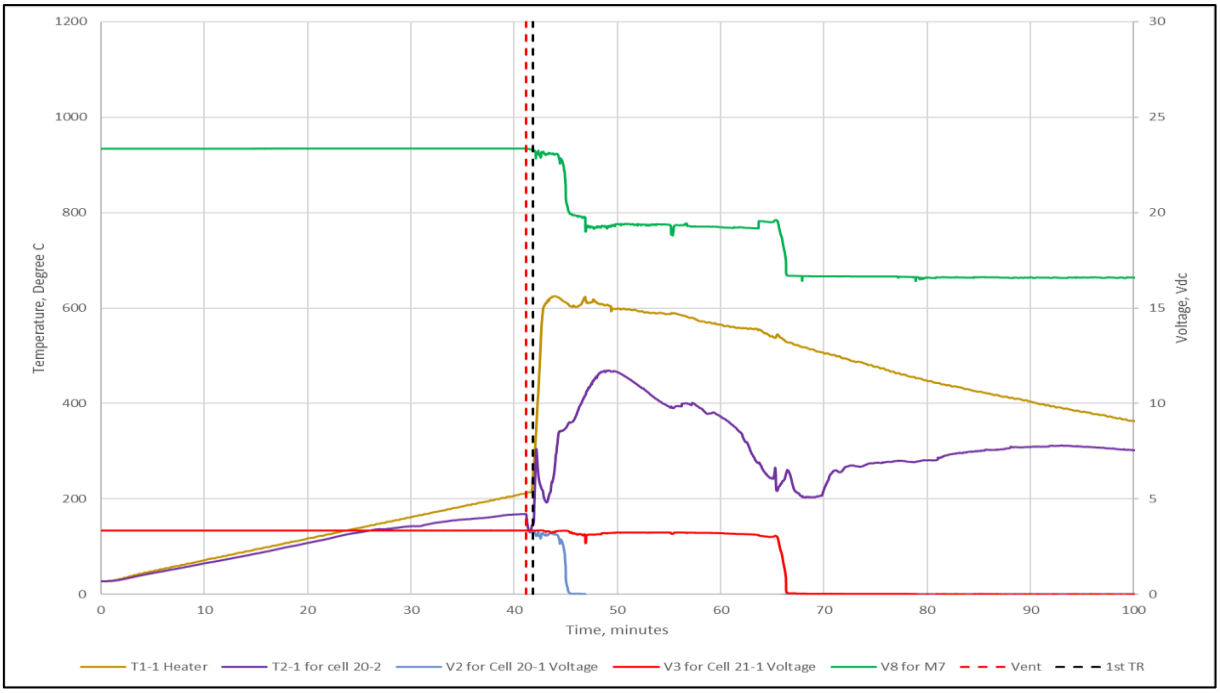


Figure 13: Initiating cells vent, Thermal runaway Initiating cell Temperature and Voltage Profiles During Testing

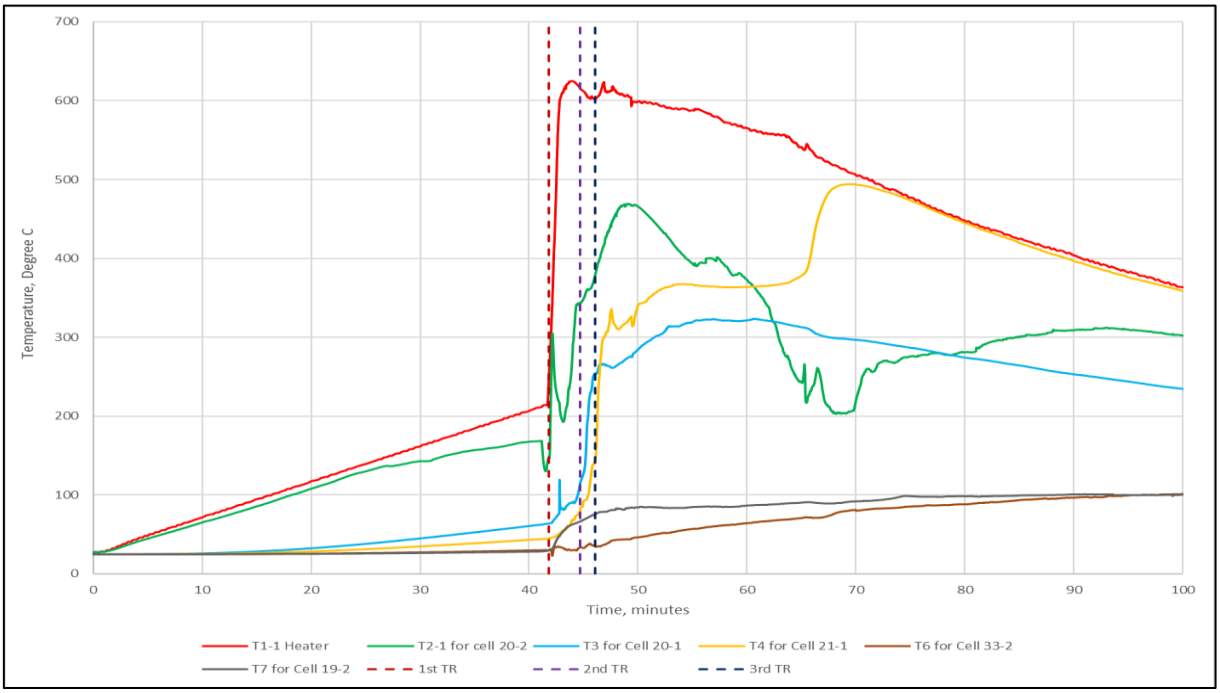


Figure 14: Initiating module temperature

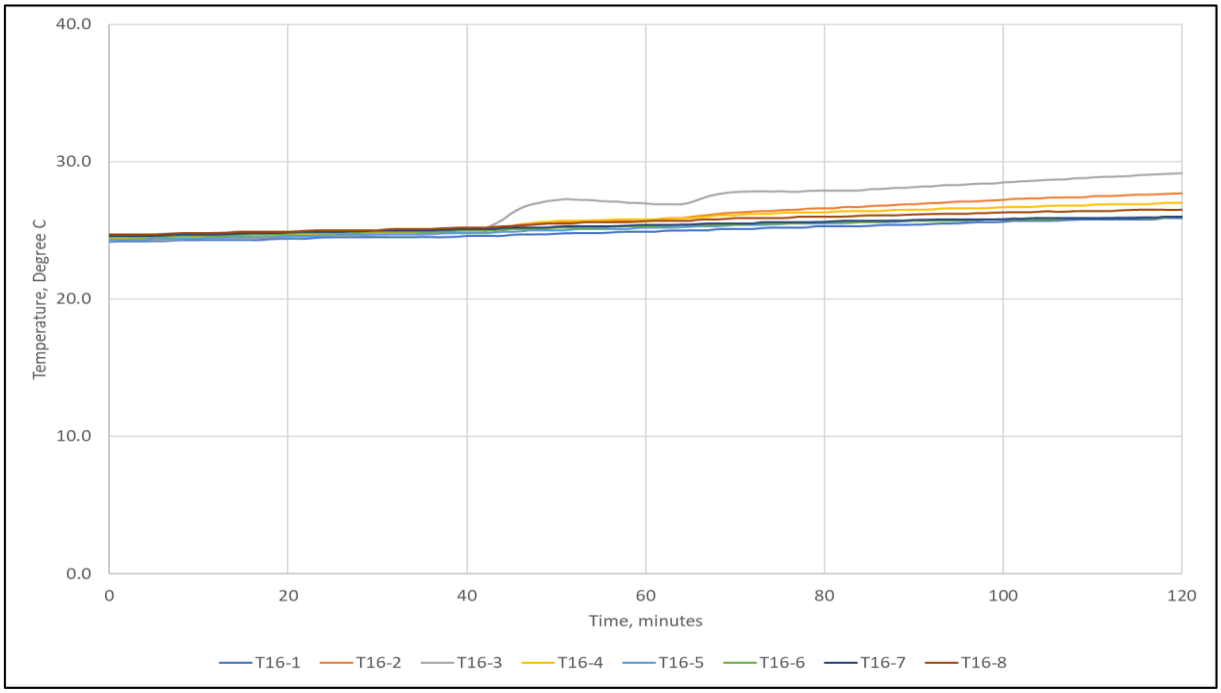


Figure 15: Target unit-1 temperature

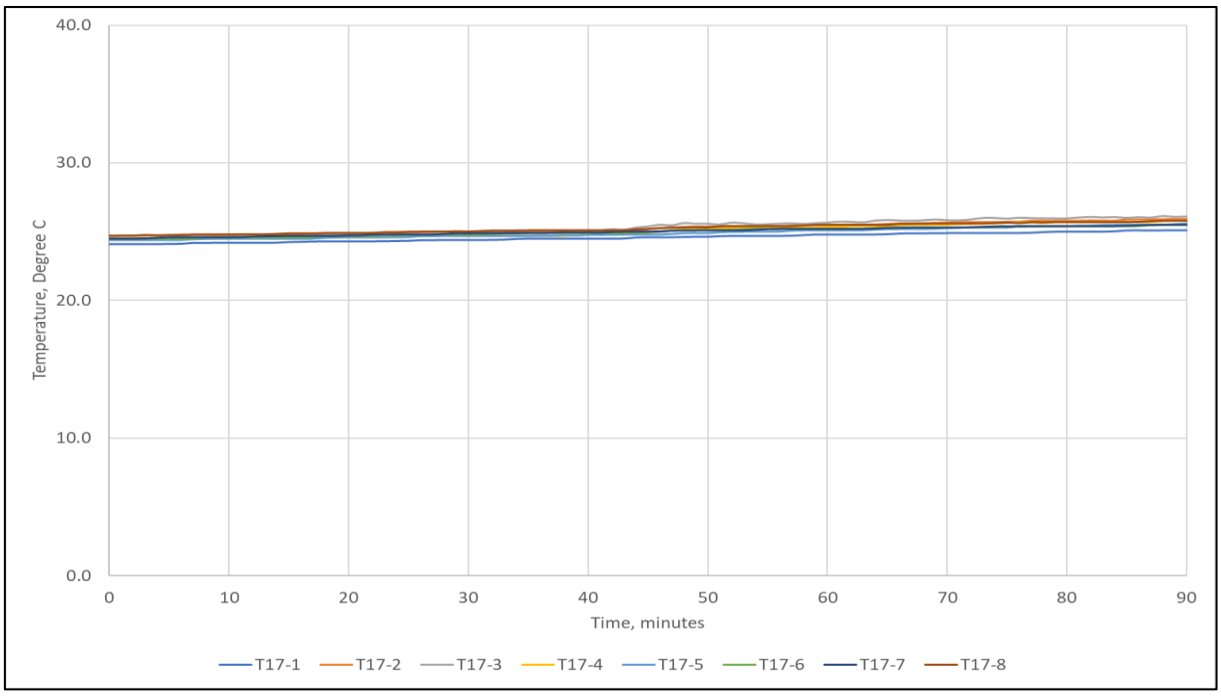


Figure 16: Target unit-2 temperature

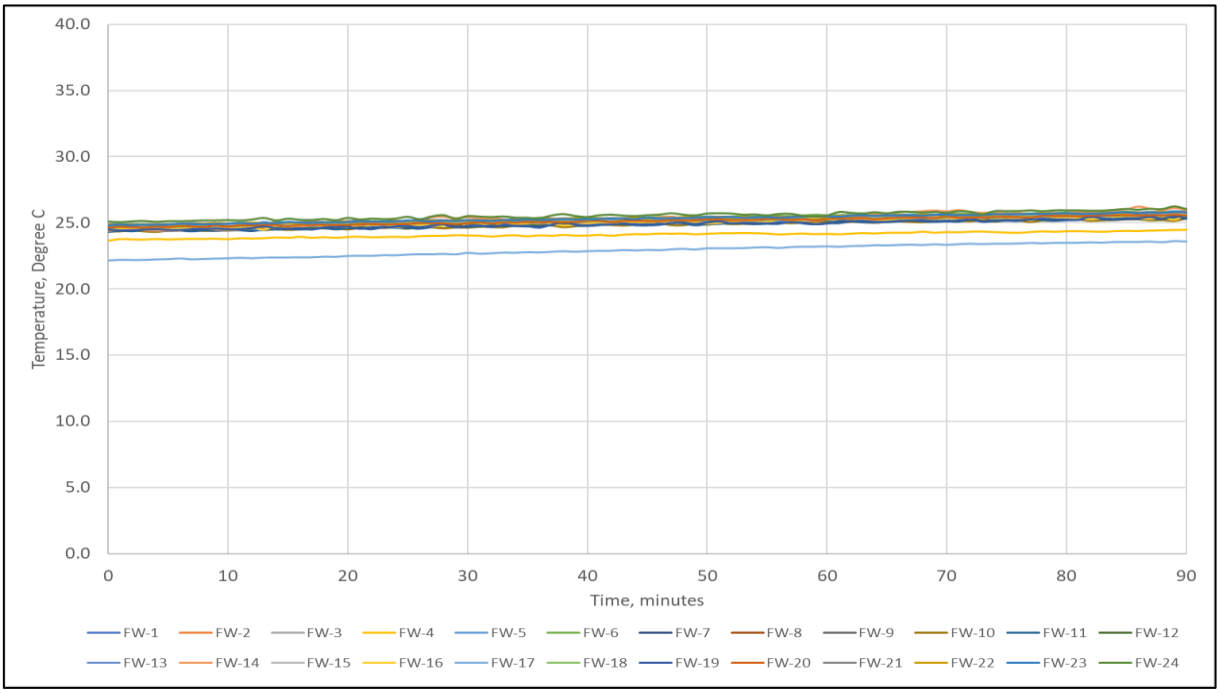


Figure 17: Front wall temperature

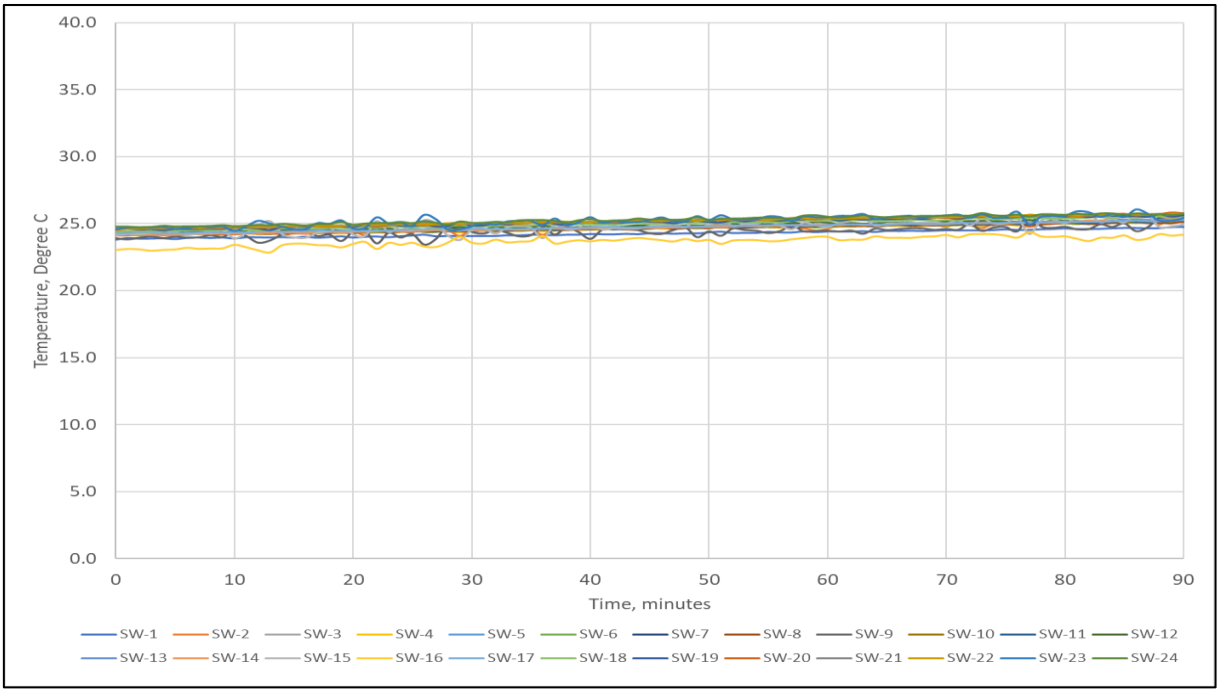


Figure 18: Side wall temperature

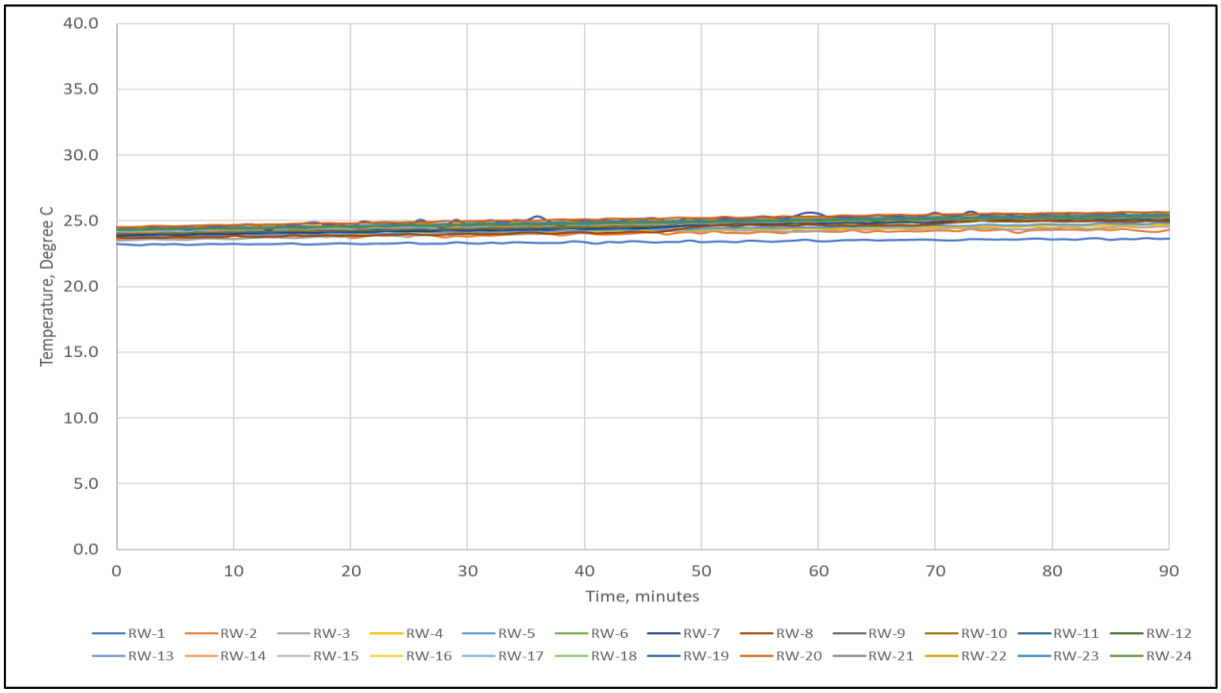


Figure 19: Rear wall temperature

Attachment E: BESS Unit Testing and Post Testing Photos - (*Pages **40** through **41***)

(a) Start Heating
[00:00:00]

(b) Vent initiating cell 20-2
[00:41:08]

(c) Initiating cell 20-2 Thermal runaway
[00:41:48]

(d) Cell 20-1 Thermal runaway
[00:44:40]

(e) Cell 21-1 Thermal runaway
[00:46:03]

(f) Thermal runaway of adjacent cell
Approximately [01:05:26]

(g) Test Termination
[01:25:00]

Figure 20: BESS Unit Testing Photos

Figure 21: BESS Unit Photos after test

Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles - (*Pages **42** through **44***)

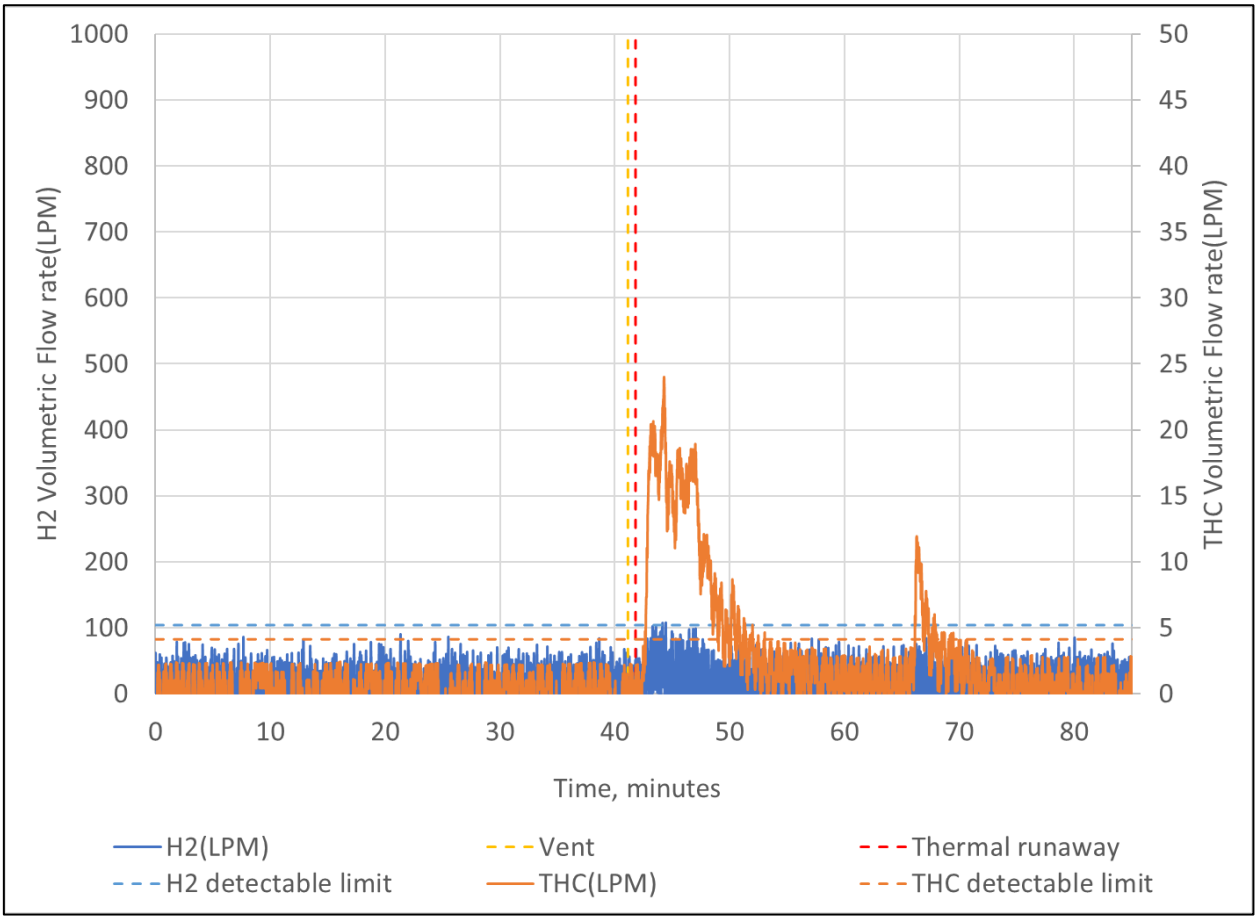


Figure 22: THC, H2 flow rates

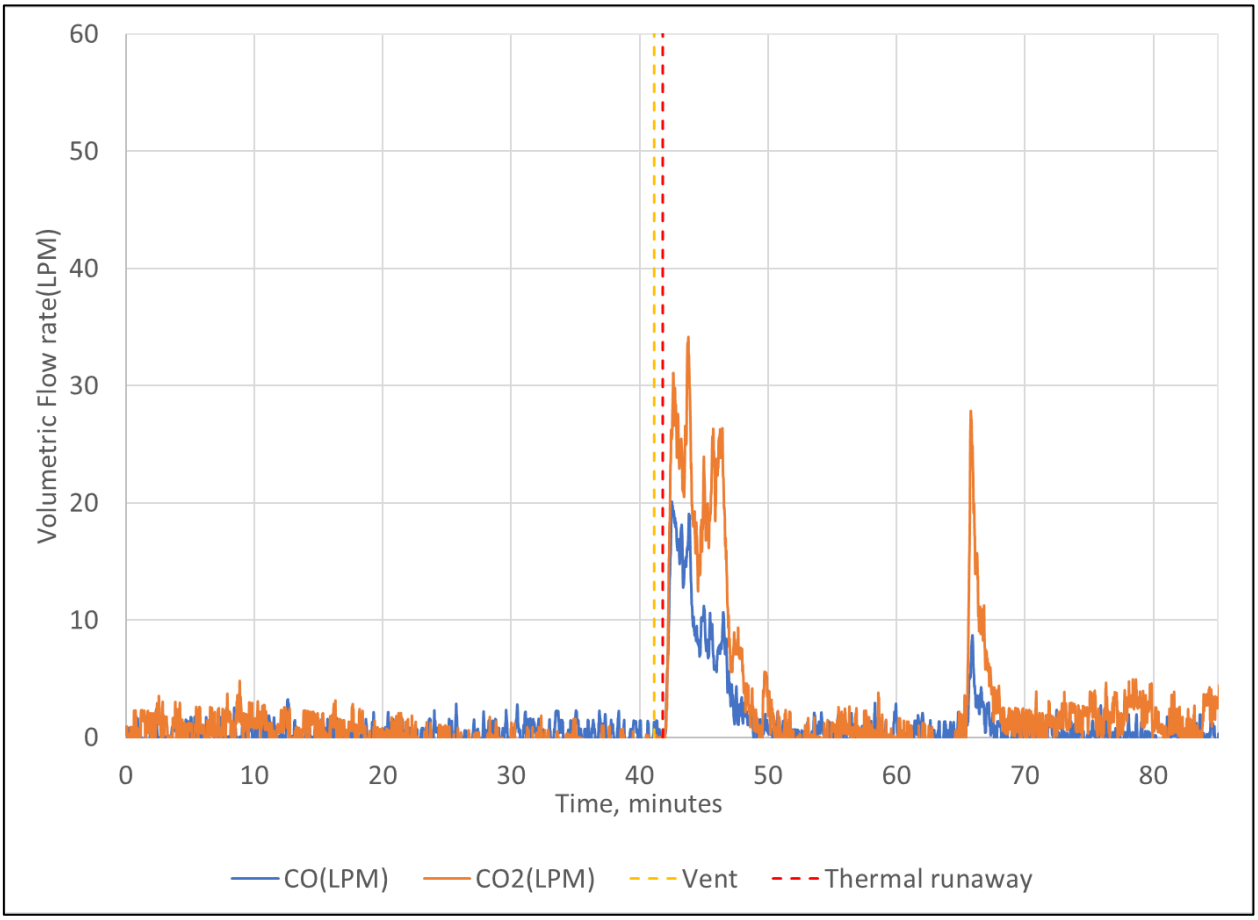


Figure 23: CO, CO2 flow rates

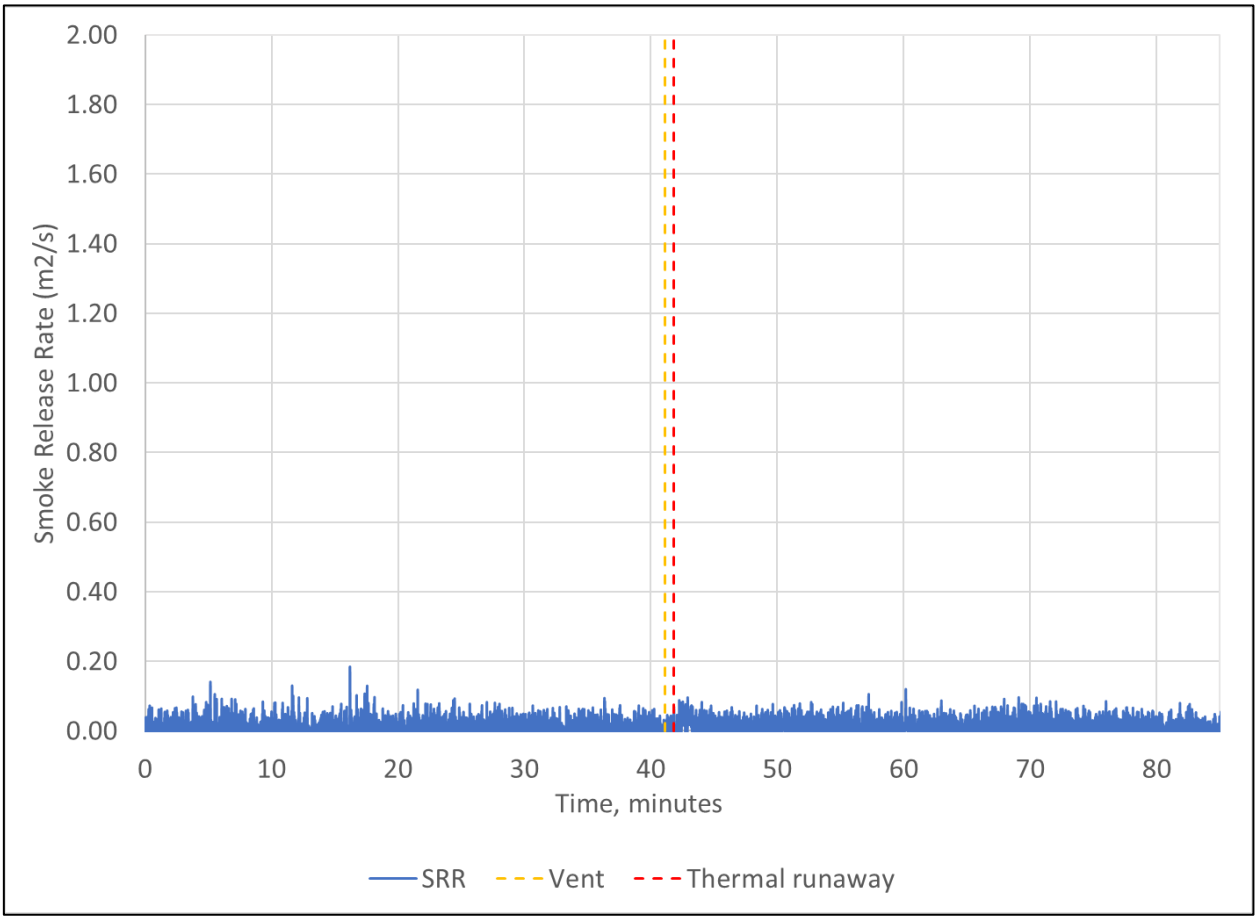


Figure 24: Smoke release rate