TEST REPORT

ANSI/CAN/UL 9540A:2019

TÜV SÜD Test Report for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems on Unit Level

Report No.:	5061925025702-00
Date of issue:	2025-10-13
Project handler:	Zhu, Jiacheng
Supervisor:	You, Duo
Testing laboratory: Address: Testing location:	TÜV SÜD New Energy Vehicle Testing (Jiangsu) Co., Ltd. Building A, No.15 Factory, Jintong International Industrial Park, No.8, Xihu Road, Wujin National Hi-tech Industrial Development Zone, Changzhou, Jiangsu, China Chuweineng Testing Technology (Shanghai) Co., Ltd. Building 3, No. 1065, Beihe Road, Jiading District, Shanghai
Client: Client number: Address: Contact person:	Shanghai PYTES Energy Co., Ltd. 003364 No. 3492 Jinqian Road, Fengxian District, 201406 Shanghai, PEOPLE'S REPUBLIC OF CHINA Yang, Lijuan
Standard: TRF number and revision: TRF originated by:	ANSI/CAN/UL 9540A:2019 Fourth Edition (4Ed) TRF ANSI/CAN/UL 9540A:2019 Rev 0 TÜV SÜD Product Service
Copyright blank test report: General disclaimer:	This test report is based on the content of the standard (see above). The test report considered selected clauses of the a.m. standard(s) and experience gained with product testing. It was prepared by TÜV SÜD Product Service. TÜV SÜD Group takes no responsibility for and will not assume liability for damages resulting from the reader's interpretation of the reproduced material due to its placement and context. This test report may only be quoted in full. Any use for advertising purposes must be granted in writing. This report is the result of a single examination of the object in question and is not generally applicable evaluation of the quality of other products in regular production.
Scheme:	☐ TUV Mark ☐ cTUV Mark (SCC) ☐ TUVus Mark (NRTL) ☐ GS Mark ☒ without certification ☒ other:TÜV SÜD Test Report from witness test ☐ AoC/CoC for EU-Directive / EU-Regulation:
Non-standard test method: National deviations:	☒ No ☐ Yes, see details under *Summary of testing* N/A
Number of pages *(Report)*: Number of pages *(Attachments)*:	62 23 (page 40 – 62)

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Building A, No.15 Factory, Jintong International Industrial Park, No.8, Xihu Road, Wujin National Hi-tech Industrial Development Zone, Changzhou, Jiangsu, China

Test sample:	Batteries
Type of test object:	Rechargeable Li-ion Battery System
Trademark:	Pytes
Model and/ or type reference:	V10, V10α, V12, V12α
Rating(s):	V10, V10α: 51.2 Vd.c., 200 Ah V12, V12α: 51.2 Vd.c., 230 Ah
Manufacturer: Manufacturer number: Address:	Shanghai PYTES Energy Co., Ltd. 003364 No. 3492 Jinqian Road, Fengxian District, 201406 Shanghai, PEOPLE'S REPUBLIC OF CHINA
Name and address of factory(ies) Shanghai PYTES Energy Co., Ltd. No. 3492 Jinqian Road, Fengxian District, 201406 Shanghai, PEOPLE'S REPUBLIC OF CHINA	
Sub-contractors / tests (clause):	N/A
Name:	N/A
Order description:	☐ Complete test according to TRF
	☐ Partial test according to manufacturer's specifications
	☐ Preliminary test
	☐ Spot check
	☒ Others: Witness test
Date of order: Date of receipt of test item: Date(s) of performance of test:	2024-08-20 2025-08-22 2025-08-22 to 2025-08-23
Test item particulars: According to Unit Level of ANSI/CAN/UL 9540A:2019 Fourth Edition.	
Purpose of the product (description of intended use): Rechargeable Li-ion Battery System, model: V10, V10α, V12, V12α, is used for residential & non-residential applications.	

Remark:

The models V10 and V12, as well as V10α and V12α, are identical in all aspects except for:

1.Rated capacity and rated energy:
- – V10 / V10α have a rated capacity of 200 Ah and a rated energy of 9.98 kWh,
- – V12 / V12α feature a rated capacity of 230 Ah and a rated energy of 11.776 kWh.

2.Battery connectors:
- – V10α / V12α use battery connector model: C10-730189,
- – V10 / V12 use battery connector model: BPC 250 FTB.

Due to the identical product design (except as stated above) and the use of identical critical components, only one model was tested at its maximum state of charge. The results are considered representative of the performance of all models listed. The test results in this report were generated from testing model V12α.

There is no difference between the unit-level and module-level test samples. The unit-level testing is conducted under the final installation (wall-mounted) conditions.

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Characteristic data (not shown on the marking plate):		
Product name	Rechargeable Li-ion Cell	Rechargeable Li-ion Battery System
Type/model	LF230	V10, V10α, V12, V12α
Nominal voltage	3.2 Vd.c.	51.2 Vd.c.
Rated capacity	230 Ah	V10, V10α: 200 Ah V12, V12α: 230 Ah
Charging voltage specified by manufacturer	3.65 V	56.8 V
Upper limit charging voltage	3.65 V	58 V or any cell reaches 3.65 V
Charging current specified by manufacturer	115 A	100 A
Maximum continuous charging current	460 A	150 A
Discharging current specified by manufacturer	115 A	100 A
Maximum continuous discharging current	690 A	150 A
End of discharge voltage	2.5 V (T>0°C); 2.0 V (T≤0°C)	47.5 V
Operating ambient temperature range	-	0 °C to 25 °C
Standard charging method specified by manufacturer	Charge at constant current 115 A until voltage reaches 3.65 V, then charge at constant voltage 3.65 V till charge current is 11.5 A	Charge at constant current 100 A until voltage reaches 56.8 V, then charge at constant voltage 56.8 V till charge current is 9.2 A
Standard discharging method specified by manufacturer	-	Discharge at constant current 100 A until the voltage reaches 47.5 V
Dimension	L×W×H: (173.93 ± 0.5) mm x (53.85 ± 0.5) mm x (207.2 ± 0.5) mm	L×W×H: (671.2 ± 2.0) mm x (520.0 ± 2.0) mm x (260.0 ± 2.0) mm
Weight	(4.140 ± 0.124) kg	(98.6 ± 0.5) kg
Configuration	-	16S

Attachments:
Attachment 1: Product description
Attachment 2: Exploded-view drawing of module & Identification/location of cells within the module
Attachment 3: Pre-conditioning profile
Attachment 4: Photo of sample before test and test setup with thermocouple location
Attachment 5: Photo of sample after test
Attachment 6: Monitored temperature chart
Attachment 7: Flammable gas generation and composition data chart
Attachment 8: Heat release rate versus time data chart

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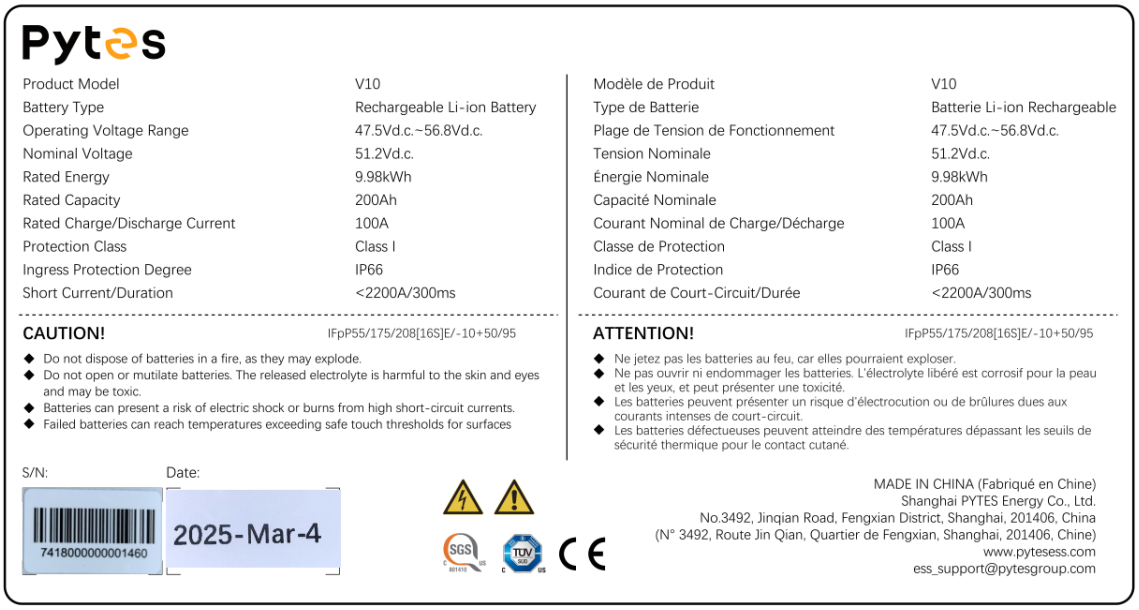
Attachment 9: Peak smoke release rate and total smoke release data chart Attachment 10: Summary of Heat release rate & Peak smoke release rate and total smoke release data
If additional information is necessary, please provide N/A

Copy of marking plate:

For Rechargeable Li-ion Battery System, model: V10



Pytes

Product Model	V10	Modèle de Produit	V10
Battery Type	Rechargeable Li-ion Battery	Type de Batterie	Batterie Li-ion Rechargeable
Operating Voltage Range	47.5Vd.c.~56.8Vd.c.	Plage de Tension de Fonctionnement	47.5Vd.c.~56.8Vd.c.
Nominal Voltage	51.2Vd.c.	Tension Nominale	51.2Vd.c.
Rated Energy	9.98kWh	Énergie Nominale	9.98kWh
Rated Capacity	200Ah	Capacité Nominale	200Ah
Rated Charge/Discharge Current	100A	Courant Nominal de Charge/Décharge	100A
Protection Class	Class I	Classe de Protection	Class I
Ingress Protection Degree	IP66	Indice de Protection	IP66
Short Current/Duration	<2200A/300ms	Courant de Court-Circuit/Durée	<2200A/300ms

CAUTION! IFpP55/175/208[16S]E/-10+50/95

- Do not dispose of batteries in a fire, as they may explode.
- Do not open or mutilate batteries. The released electrolyte is harmful to the skin and eyes and may be toxic.
- Batteries can present a risk of electric shock or burns from high short-circuit currents.
- Failed batteries can reach temperatures exceeding safe touch thresholds for surfaces

ATTENTION! IFpP55/175/208[16S]E/-10+50/95

- Ne jetez pas les batteries au feu, car elles pourraient exploser.
- Ne pas ouvrir ni endommager les batteries. L'électrolyte libéré est corrosif pour la peau et les yeux, et peut présenter une toxicité.
- Les batteries peuvent présenter un risque d'électrocution ou de brûlures dues aux courants intenses de court-circuit.
- Les batteries défectueuses peuvent atteindre des températures dépassant les seuils de sécurité thermique pour le contact cutané.

S/N: 7418000000001460 Date: 2025-Mar-4

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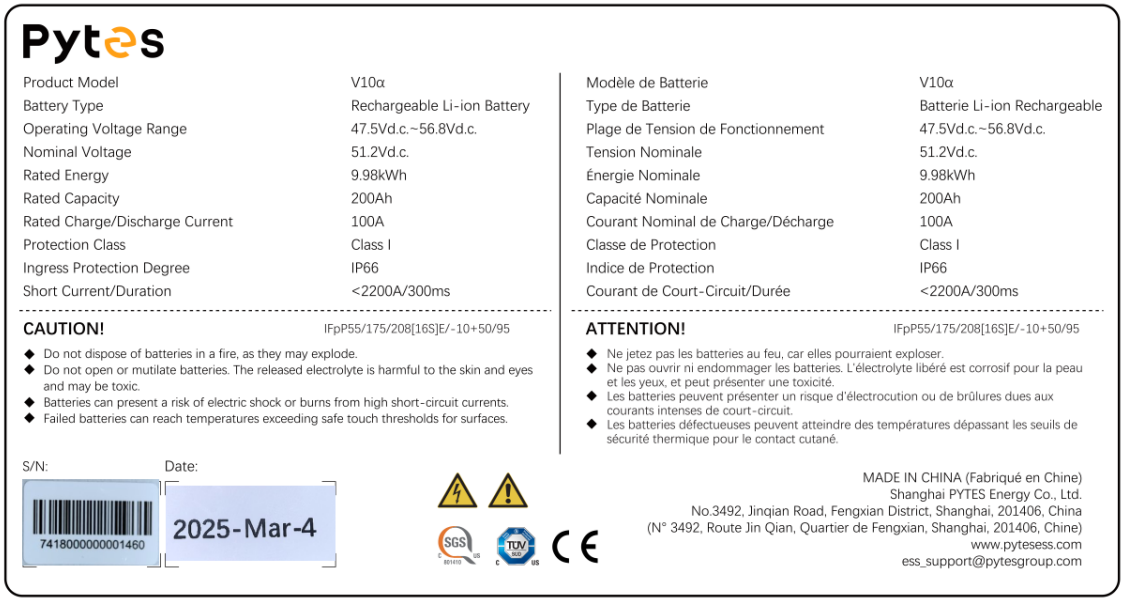
For Rechargeable Li-ion Battery System, model: V10α



Pytes

Product Model	V10α	Modèle de Batterie	V10α
Battery Type	Rechargeable Li-ion Battery	Type de Batterie	Batterie Li-ion Rechargeable
Operating Voltage Range	47.5Vd.c.~56.8Vd.c.	Plage de Tension de Fonctionnement	47.5Vd.c.~56.8Vd.c.
Nominal Voltage	51.2Vd.c.	Tension Nominale	51.2Vd.c.
Rated Energy	9.98kWh	Énergie Nominale	9.98kWh
Rated Capacity	200Ah	Capacité Nominale	200Ah
Rated Charge/Discharge Current	100A	Courant Nominal de Charge/Décharge	100A
Protection Class	Class I	Classe de Protection	Class I
Ingress Protection Degree	IP66	Indice de Protection	IP66
Short Current/Duration	<2200A/300ms	Courant de Court-Circuit/Durée	<2200A/300ms

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For Rechargeable Li-ion Battery System, model: V12

Pytes

Product Model	V12	Modèle de Produit	V12
Battery Type	Rechargeable Li-ion Battery	Type de Batterie	Batterie Li-ion Rechargeable
Operating Voltage Range	47.5Vd.c.~56.8Vd.c.	Plage de Tension de Fonctionnement	47.5Vd.c.~56.8Vd.c.
Nominal Voltage	51.2Vd.c.	Tension Nominale	51.2Vd.c.
Rated Energy	11.776kWh	Énergie Nominale	11.776kWh
Rated Capacity	230Ah	Capacité Nominale	230Ah
Rated Charge/Discharge Current	100A	Courant Nominal de Charge/Décharge	100A
Protection Class	Class I	Classe de Protection	Class I
Ingress Protection Degree	IP66	Indice de Protection	IP66
Short Current/Duration	<2200A/300ms	Courant de Court-Circuit/Durée	<2200A/300ms

CAUTION! IFpP55/175/208[16S]E/-10+50/95

- Do not dispose of batteries in a fire, as they may explode.
- Do not open or mutilate batteries. The released electrolyte is harmful to the skin and eyes and may be toxic.
- Batteries can present a risk of electric shock or burns from high short-circuit currents.
- Failed batteries can reach temperatures exceeding safe touch thresholds for surfaces.

ATTENTION! IFpP55/175/208[16S]E/-10+50/95

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- Les batteries défectueuses peuvent atteindre des températures dépassant les seuils de sécurité thermique pour le contact cutané.

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For Rechargeable Li-ion Battery System, model: V12α

Pytes

Product Model	V12α	Modèle de Produit	V12α
Battery Type	Rechargeable Li-ion Battery	Type de Batterie	Batterie Li-ion Rechargeable
Operating Voltage Range	47.5Vd.c.~56.8Vd.c.	Plage de Tension de Fonctionnement	47.5Vd.c.~56.8Vd.c.
Nominal Voltage	51.2Vd.c.	Tension Nominale	51.2Vd.c.
Rated Energy	11.776kWh	Énergie Nominale	11.776kWh
Rated Capacity	230Ah	Capacité Nominale	230Ah
Rated Charge/Discharge Current	100A	Courant Nominal de Charge/Décharge	100A
Protection Class	Class I	Classe de Protection	Class I
Ingress Protection Degree	IP66	Indice de Protection	IP66
Short Current/Duration	<2200A/300ms	Courant de Court-Circuit/Durée	<2200A/300ms

CAUTION! IFpP55/175/208[16S]E/-10+50/95

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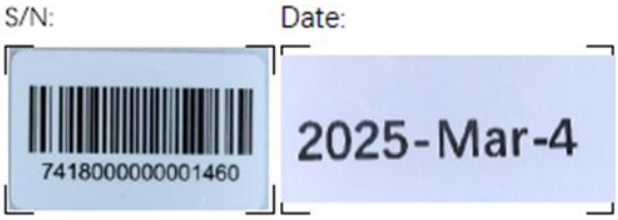
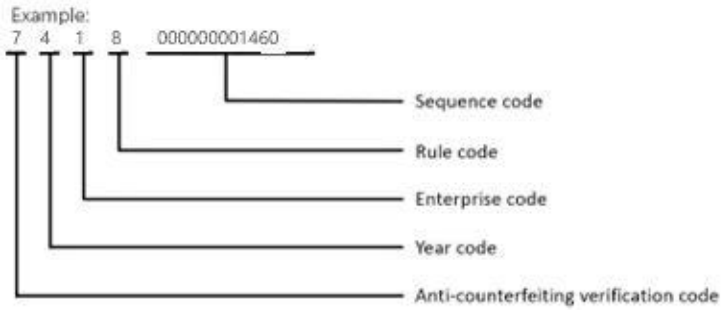
For S/N and Date



Remark:

1. “+” and “-” are marked near the connector of the battery.

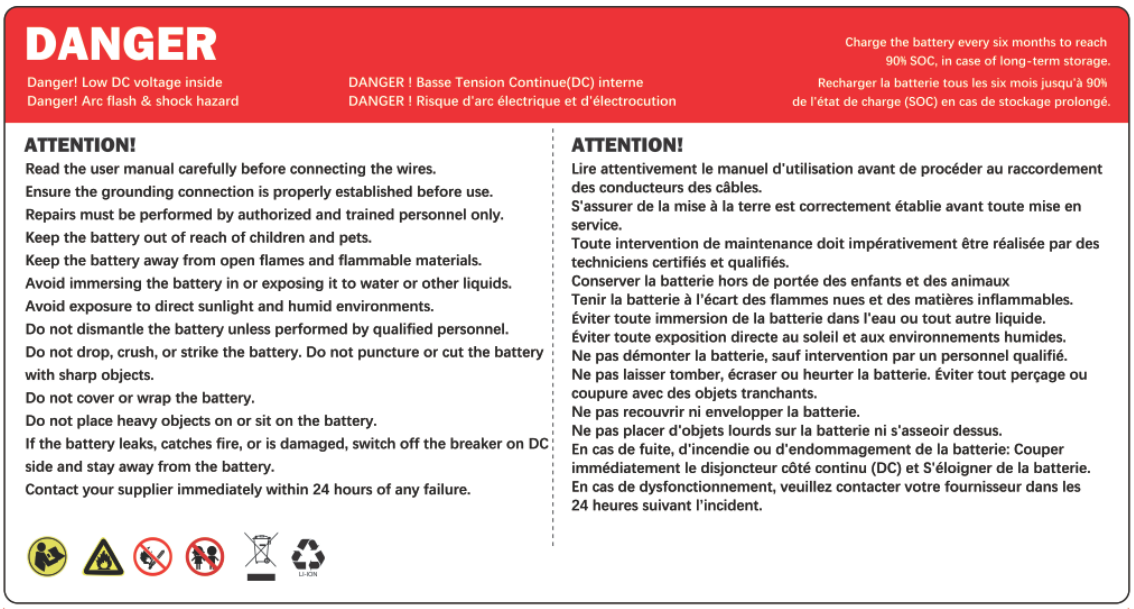
2. The code “7418000000001460” can be used to trace the manufacture information of the battery. Its interpretation for Rechargeable Li-ion Battery, which is shown as follows:



“2025-Mar-4” represents the date of manufacture, meaning the battery was produced on Mar 4th, 2025. This is not the manufacture date of actual samples and only for example.

3. The disposal and caution information are in the manual.

Label for warning



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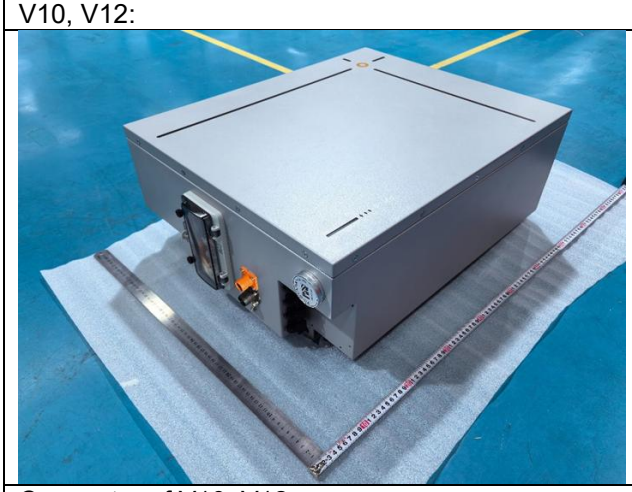
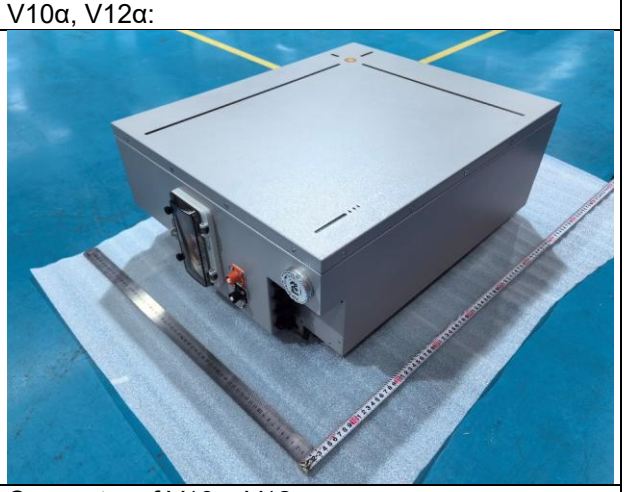
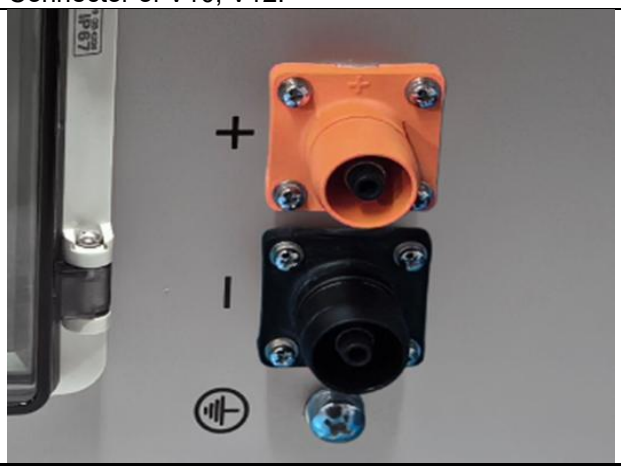
Description and pictures of the tested product:

The Rechargeable Li-ion Battery System, model: V10, V10α, V12, V12α, is used for residential & non-residential applications, consists of Rechargeable Li-ion cells, model no. LF230, connected in 16S.

V10, V12:	V10α, V12α:
	
Connector of V10, V12:	Connector of V10α, V12α:
	

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UNIT LEVEL

Summary of unit level testing:	
Unit model name	V10, V10α, V12, V12α
Ratings	V10, V10α: 51.2 Vd.c., 200 Ah V12, V12α: 51.2 Vd.c., 230 Ah
Whether UL 1973 compliant	Battery V10, V10α, V12, V12α Compliant with UL 1973. Report No.: 64.280.24.60301.02 Certificate No.: U8 003364 0032 Rev.01
Number of modules in the initiating BESS unit	1
The construction of the initiating BESS unit per 5.3	See Attachment 1
Fire protection features/detection/suppression systems within unit	No fire protection features/detection/suppression systems within unit
Module voltage(s) corresponding to the tested SOC	55.3 V (100 % SOC)
The thermal runaway initiation method used	Heating the cell with externally applied 2 pieces flexible film heaters that cover each large surface of the cell. Film heater specifications: 152.4 mm × 203.2 mm (220 V, 480 W/pc)
Location of the initiating module within the BESS unit	See Attachment 4
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 4
Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension	No flaming outside the initiating BESS enclosure observed.
Chemical and convective heat release rate versus time data	See Attachment 8, 10
Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1)	See Attachment 4
Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	See Attachment 4
The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple	See Table 3 and Attachment 4 and 6
The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple	See table 3
The maximum incident heat flux on target wall surfaces and target BESS units	Target wall surfaces: 26.04 kW/m^2 Target BESS unit: 9.20 kW/m^2
The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test	Target ceiling: 0.44 kW/m^2

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UNIT LEVEL	
Gas generation and composition data	See Table 2 and Attachment 7
Peak smoke release rate and total smoke release data	See Attachment 9, 10
Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred	No integral fire protection systems within unit
Observation of flying debris or explosive discharge of gases	No observation of flying debris or explosive discharge of gases
Observation of re-ignition(s) from thermal runaway events	N/A (no fire during test)
Observation(s) of sparks, electrical arcs, or other electrical events	No observation of sparks, electrical arcs, or other electrical events
Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits;	1) Thermal runaway was observed on all 16 cells of the initiating unit. 2) No propagation to target units and no damage to target units. 3) No damage to adjacent walls, ceilings, or soffits. see Attachment 5
Performance at unit level testing:	
☒ Non-Residential Installations: ☒ Residential Installations: ☐ Indoor Floor Mounted ☐ Outdoor Ground Mounted ☒ Indoor Wall Mounted ☒ Outdoor Wall Mounted ☐ Rooftop and Open Garages	
a) Flaming outside the initiating BESS unit is not observed; (for Indoor Floor Mounted & Indoor Wall Mounted & Outdoor Wall Mounted)	No flaming outside the initiating BESS unit during test.
a) If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test. (for Outdoor Ground Mounted & Rooftop and Open Garages)	No flaming outside the initiating BESS unit during test.
b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	Maximum temperature of target BESS units adjacent to the initiating BESS unit: 138.0 °C.
c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15; (for Indoor Floor Mounted & Indoor Wall Mounted & Rooftop and Open Garages)	Maximum temperature of wall surface: 119.2 °C.
c) For BESS units intended for installation near exposures, surface temperature measurements on wall	Maximum temperature of wall surface: 119.2 °C

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UNIT LEVEL	
surfaces do not exceed 97K of temperature rise above ambient per 9.2.15; (for Outdoor Ground Mounted)	
d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	No explosion hazards were observed.
e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	0.35 kW/m^2
e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size. (for Indoor Floor Mounted)	Volume of flammable gas measured during this test: 5619.9 L. LFL from cell level test report: 6.75 % at the venting temperature. (External report with Project No. 4791504604) Resulting minimum room size: 333.1 m^3 to not exceed 25% LFL in air, at venting temperature.
Performance - module level test:	
a) Thermal runaway is contained by module design; and	Thermal runaway was contained by module design.
b) Cell vent gas is non-flammable as determined by the cell level test.	Cell vent gas is flammable according to cell level test report (external report with Project No. 4791504604).
Performance - cell level test:	
a) Thermal runaway cannot be induced in the cell; and	Thermal runaway occurred according to cell level test report (external report with Project No. 4791504604).
b) The cell vent gas does not present a flammability hazard when mixed with any volume of air, as determined in accordance with ASTM E918 at both ambient and vent temperatures.	Cell vent gas present flammability hazard according to cell level test report (external report with Project No. 4791504604).

Additional information on non-standard test method(s)	
Sub clause:	N/A
Page:	N/A
Rational:	N/A

Possible test case verdicts:	
test case does not apply to the test object:	N/A (not applicable / not included in the order)
test object does meet the requirement:	P (Pass)
test object does not meet the requirement:	F (Fail)

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UNIT LEVEL

General remarks:

"(see remark #)" refers to a remark appended to the report.

"(see appended table)" refers to a table appended to the report.

Throughout this report ***a*** ☐ ***Comma*** */* ☒ ***Point*** *is used as the decimal separator.*

The test results presented in this report relate only to the object tested.

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INTRODUCTION

1.	**Scope**	—
2	**Units of Measurement**	—
3	**Normative References**	—
4	**Glossary**	—

CONSTRUCTION

5.	**General**		
5.1	**Cell**		
5.1.1	The cells associated with the BESS that were tested shall be documented in the test report, including cell chemistry (e.g. NMC, LFP), the physical format of the cell (i.e. prismatic, cylindrical, pouch), cell electrical rating in capacity and nominal voltage, the overall dimensions of the cell, and weight.	Cell chemistry: LFP Physical cell format: Prismatic	P
5.1.2	The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973.	Note: Cell complies with UL 1973; Certificate Number: UL-US-2441492-0	P
5.1.3	Refer to 7.6.1 for further details to be included in the cell level test report		P
5.2	**Module**		
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report, including the generic (e. g., metallic or nonmetallic) enclosure material, the general layout of the module contents and the electrical configuration of the cells in the modules and the modules in the BESS.	Module consists of a metallic enclosure material. Further details of the layout and module contents see Attachment 2.	P

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5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973.	Comply with UL 1973. Report No.: 64.280.24.60301.02 Certificate No.: U8 003364 0032 Rev.01	P
5.2.3	Refer to 8.3 for further details to be included in the module level test report.		P
5.3	**Battery energy storage system unit**		
5.3.1	The BESS unit documentation included in the test report shall indicate the units that comply with UL 9540 and include the manufacturer, model, electrical ratings, and energy capacity of all BESS.	Unit manufacturer name: Shanghai PYTES Energy Co., Ltd. V10, V10α: 51.2 Vd.c., 200 Ah V12, V12α: 51.2 Vd.c., 230 Ah Unit is not tested or certified, or verified with UL 9540.	N/A
5.3.2	For BESS units for which UL 9540 compliance cannot be determined, the documentation included in the test report shall include the number of modules in the BESS, electrical configuration of the module, and physical layout of the modules in the BESS, battery management system (BMS) and other major components of the BESS. The BESS enclosure overall dimensions and generic (e. g., metallic or nonmetallic) material used for the enclosure shall be documented. Depending upon the configuration of the BESS (e.g. the power conditioning system is external to the BESS enclosure), a battery system(s) can be tested as representative of the BESS. It shall be documented as to whether the battery system complies with UL 1973 in addition to the overall BESS compliance to UL 9540.	Unit (model: V10, V10α, V12, V12α) is not tested or certified, or verified with UL 9540. Unit (model: V10, V10α, V12, V12α) is compliant with UL 1973. Report No.: 64.280.24.60301.02 Certificate No.: U8 003364 0032 Rev.01	N/A
5.3.3	If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report.	No fire detection and suppression systems are within unit.	N/A
5.3.4	Refer to 9.7, 10.4 and 10.7 for further details to be included in the unit level and if applicable, installation level test reports.	9.7 considered.	N/A
5.4	**Flow Batteries**		

PERFORMANCE

6	**General**		
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires, explosions, smoke, off gassing of flammable and toxic materials,		P

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	exposure to toxic and corrosive liquids, and potential exposure to hazardous voltages and electrical energy. See Annex B for recommended testing practices.		
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications. All samples shall be disposed of in accordance with local regulations.		P
7	**Cell Level**		—
8	**Module Level**		—
9	**Unit Level**		
9.1	**Sample and test configuration**		
9.1.1	The unit level test shall be conducted with BESS units installed as described in the manufacturer's instructions and this section. Test configurations include the following:		P
	a) Indoor floor mounted non-residential use BESS;		N/A
	b) Indoor floor mounted residential use BESS;		N/A
	c) Outdoor ground mounted non-residential use BESS;		N/A
	d) Outdoor ground mounted residential use BESS;		N/A
	e) Indoor wall mounted non-residential use BESS;		P
	f) Indoor wall mounted residential use BESS;		P
	g) Outdoor wall mounted non-residential use BESS;		P
	h) Outdoor wall mounted residential use BESS; and		P
	i) Rooftop and open garage non-residential use BESS installations.		N/A
9.1.2	The unit level test requires one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation. Tests conducted for indoor floor mounted installations shall be considered representative of both indoor floor mounted and outdoor ground mounted installations with fire propagation hazards and separation distances between initiating and target units representative of the installation. Tests shall be conducted indoors with fire propagation hazards and separation distances between initiating and target units representative of the installation. The results of such tests shall be considered to also represent an		P

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	outdoor installation. Examples of potential test configurations are shown in Figure 9.1, Figure 9.2, Figure 9.3, and Figure 9.4.		
	Exception: *Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place:* *a) Wind screens are utilized with a maximum wind speed maintained at ≤ 12 mph;* *b) The temperature range is within 10°C to 40°C (50°F to 104°F);* *c) The humidity is < 90% RH;* *d) There is sufficient light to observe the testing;* *e) There is no precipitation during the testing;* *f) There is control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; and* *g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing.*		N/A
9.1.3	Depending upon the configuration and design of the BESS (e.g. the BESS is composed of multiple separate parts within separate enclosures), this testing to determine fire characterization can be done at the battery system level. The suitability of this approach shall be determined based upon the overall design of the BESS and an analysis of the battery system as representative of the overall BESS for fire characterization concerns.		P
9.1.4	The initiating BESS unit shall contain components representative of a BESS unit in a complete installation. Combustible components that interconnect the initiating and target BESS units shall be included.		P
9.1.5	Target BESS units shall include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components. The target BESS unit module enclosures do not need to contain cells.		P
9.1.6	The initiating BESS unit shall be at the maximum operating state of charge (MOSOC), in accordance with the manufacturer's specifications, for conducting the tests in this standard. After charging and prior to testing, the initiating BESS shall rest for a maximum period of 8 h at room ambient.	See Attachment 3: Pre-conditioning profile. Charge at constant current 100 A until the voltage reaches 56.8 V, then charge at constant voltage 56.8 V until current drops to 9.2 A.	P

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9.1.7	If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT. If the BESS unit is provided with an optional integral fire suppression system, the system shall not be provided on the DUT.	No fire detection and suppression systems are within the unit.	N/A
9.1.8	Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing. This does not include a fire suppression control in accordance with UL 840 that is external to the BESS, but provided as part of an integral fire suppression system per 9.1.7.		P
9.2	**Test method – Indoor floor mounted BESS units**		
9.2.1	Samples and test configurations are in accordance with 9.1. During the test, the test room environment shall be controlled to prevent drafts that may affect test results. At the start of the test, the room ambient temperature shall not be less than 10°C (50°F) nor more than 32°C (90°F).		P
9.2.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units shall be closed, latched and locked at the beginning and duration of the test.		P
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections.		P
9.2.4	Instrumented wall sections shall extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.		P
9.2.5	Instrumented wall sections shall be at least 0.61-m (2-ft) taller than the BESS unit height, but not less than 3.66 m (12 ft) in height above the bottom surface of the unit.		P
9.2.6	The surface of the instrumented wall sections shall be covered with 16-mm (5/8-in) gypsum wall board and painted flat black.		P
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.		P
9.2.8	The light transmission in the calorimeter's exhaust duct shall be measured using a white light source and photo detector for the duration of the test, and the smoke release rate shall be calculated as described in 8.2.15.		P
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, using the methodologies specified in 8.2.11 and 9.2.12, respectively.		P

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9.2.10	With reference to 9.2.9, the heat release rate measurement system shall be calibrated using an atomized heptane diffusion burner. The calibration shall be performed using flows of 3.8, 7.6, 11.4 and 15.2 L/min (1, 2, 3 and 4 gpm) of heptane.		P
9.2.11	With reference to 9.2.9, the convective heat release rate shall be measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct. See 9.2.12.		P
9.2.12	With reference to 9.2.9, the convective heat release rate shall be calculated using the following equation: $HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$		P
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation as noted in 9.1.	See Attachment 4	P
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		P
	a) The BESS units and the instrumented wall sections; and		P
	b) Adjacent BESS units.		P
9.2.15	Wall surface temperature measurements shall be collected for BESS intended for installation in locations with combustible construction. If the intended installation is composed completely of noncombustible construction in which wall assemblies, cables, wiring and any other combustible materials are not to be present in the BESS installation, then the report should note that the installation shall contain no combustible construction and that surface temperature rises can be deemed not applicable.		P
9.2.16	Wall surface temperatures shall be measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller, Type-K exposed junction thermocouples. The thermocouples for measuring the temperature on wall surfaces shall be horizontally positioned in the wall locations anticipated to receive the greatest thermal exposure from the initiating BESS unit.		P
9.2.17	Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires. The thermocouple tip shall be depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement and		P

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	held in thermal contact with the surface at that point by the use of pressure-sensitive paper tape.		
9.2.18	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall: a) Both are collinear with the vertical thermocouple array; b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.		P
9.2.19	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit: a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		P
9.2.20	For non-residential use BESS, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge positioned at the mid height of the initiating unit in the center of the accessible means of egress.		P
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples shall be installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module. Each non-initiating module enclosure within the initiating BESS unit shall be instrumented with at least one No. 24-gauge or smaller Type-K thermocouple(s) to provide data to monitor the thermal conditions within non-initiating modules. Additional thermocouples shall be placed to account for convoluted enclosure interior geometries.		P
9.2.22	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator. The cheesecloth shall be untreated cotton cloth running 26 – 28 m^2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in2) area.		P
9.2.23	An internal fire condition in accordance with the module level test shall be created within a single module in the initiating BESS unit:		P

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	a) The position of the module shall be selected to present the greatest thermal exposure to adjacent modules (e.g. above, below, laterally), based on the results from the module level test; and b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same as that used to initiate and propagate thermal runaway within the module level test (Section 8).		
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct. Gas composition shall be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2.0 m (6.6 ft), or equivalent gas analyzer. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.		P
9.2.25	The hydrocarbon content of the vent gas shall be measured using flame ionization detection.		P
9.2.26	The test shall be terminated if:		P
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;		P
	b) The fire propagates to adjacent units or to adjacent walls; or		N/A
	c) A condition hazardous to test staff or the test facility requires mitigation.		N/A
9.2.27	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.	Volume of flammable gas measured during this test: 5619.9 L. LFL from cell level test report: 6.75 % at the venting temperature. (External report with Project No. 4791504604) Resulting minimum room size: 333.1 m^3 to not exceed 25% LFL in air, at venting temperature.	P

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9.3	**Test method – Outdoor ground mounted units**		
9.3.1	Outdoor ground mounted non-residential use BESS being evaluated for installation in close proximity to buildings and structures shall use the test method described in Section 9.2. If intended for outdoor use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		N/A
9.3.2	Outdoor ground mounted residential use BESS being evaluated for installation in close proximity to buildings and structures shall use the test method described in Section 9.2 except as noted in 9.3.3 and 9.3.4. Heat flux measurements for the accessible means of egress shall be measured in accordance with 9.2.20. If intended for outdoor use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		N/A
9.3.3	Test samples shall be installed as shown in Figure 9.2 in proximity to an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (undersurface of the eave shown in Figure 9.2). The sample shall be mounted on a support substrate and spaced from the wall in accordance with the minimum separation distances specified by the manufacturer. The wall and soffit shall be constructed with 19.05-mm (3/4-in) plywood installed on wood studs and painted flat black. The instrumented wall shall extend not less than 0.49-m (1.6-ft) horizontally beyond the exterior of the target BESS units. The No. 24-gauge or smaller, Type-K exposed junction thermocouple array on the walls as noted in 9.2.16 shall extend to the surface of the soffit as shown in Figure 9.2.		N/A
	Exception: *If the manufacturer requires installation against non-flammable material, the test setup may include manufacturer recommended backing material between the unit and plywood wall.*		N/A
9.3.4	Target BESS shall be installed on each side of the initiating BESS in accordance with the manufacturer's installation specifications. The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		N/A

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9.4	**Test Method – Indoor wall mounted units**		
9.4.1	Testing of indoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.3.		P
9.4.2	The test shall be conducted in a standard NFPA 286 fire test room, 3.66 × 2.44 × 2.44-m (12 × 8 × 8-ft) high, with a 0.76 × 2.13-m (2-1/2 × 7-ft) high opening. The room shall be constructed with 16-mm (5/8-in) gypsum wall board installed on wood studs and painted flat black.		P
9.4.3	The initiating BESS unit shall be positioned on the wall opposite of the door opening, with the center located 1.22-m (4-ft) above the floor, and halfway between adjacent walls.		P
9.4.4	Target BESS shall be installed on the wall on each side of the initiating BESS, at the same height above the floor as the initiating BESS. The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		P
9.4.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		P
9.4.6	The gas collection methods shall be in accordance with 9.2. 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.	Volume of flammable gas measured during this test: 5619.9 L. LFL from cell level test report: 6.75 % at the venting temperature. (External report with Project No. 4791504604) Resulting minimum room size: 333.1 m^3 to not exceed 25% LFL in air, at venting temperature.	P
9.4.7	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator. The cheesecloth shall be untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm2 (1 in2) area.		P
9.5	**Test Method – Outdoor wall mounted units**		
9.5.1	Testing of outdoor wall mounted BESS shall be in accordance with Section 9.2, except as modified in this section. See Figure 9.4. If intended for outdoor use only wall mount installations, the smoke release rate, the convective and chemical heat release rate;		P

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	and the content, velocity and temperature of the released vent gases need not be measured.		
9.5.2	Test samples shall be mounted on an instrumented wall section that is 3.66-m (12-ft) tall with a 0.3-m (1-ft) wide horizontal soffit (undersurface of the eave shown in Figure 9.4). The wall and soffit shall be constructed with 19.05-mm (3/4-in) plywood installed on wood studs and painted flat black. The instrumented wall shall extend not less than 0.49-m (1.6-ft) horizontally beyond the exterior of the target BESS units. The No. 24-gauge or smaller, Type-K exposed junction thermocouple array on the walls as noted in 9.2.16 shall extend to the surface of the soffit as shown in Figure 9.4.		P
9.5.3	The initiating BESS unit shall be positioned on the instrumented wall, with its center located 1.22-m (4-ft) above the floor, and halfway between wall edges.		P
9.5.4	Target BESS shall be installed on the wall on each side of the initiating BESS, at the same height above the floor as the initiating BESS. The physical spacing between BESS units (both initiating and target) shall be the minimum separation distances specified by the manufacturer.		P
9.5.5	The wall on which the initiating and target BESS units are mounted shall be instrumented in accordance with Section 9.2.		P
9.5.6	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator. The cheesecloth shall be untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm2 (1 in2) area .		P
9.6	**Rooftop and open garage installations**		N/A
9.6.1	Testing of BESS intended for non-residential use rooftop or open garage installations shall be in accordance with 9.2.		N/A
9.6.2	If intended for rooftop and open garage use only installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		N/A
9.7	**Unit level test report**		
9.7.1	The report on the unit level testing shall identify the type of installation being tested, as follows:		P
	a) Indoor floor mounted non-residential use BESS;		N/A
	b) Indoor floor mounted residential use BESS;		N/A

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	c) Outdoor ground mounted non-residential use BESS;		N/A
	d) Outdoor ground mounted residential use BESS;		N/A
	e) Indoor wall mounted non-residential use BESS;		P
	f) Indoor wall mounted residential use BESS;		P
	g) Outdoor wall mounted non-residential use BESS;		P
	h) Outdoor wall mounted residential use BESS;		P
	i) Rooftop installed non-residential use BESS; or		N/A
	j) Open garage installed non-residential use BESS.		N/A
9.7.2	With reference to 9.7.1, if testing is intended to represent more than one installation type, this shall be noted in the report.	Testing is intended to represent Indoor wall mounted non-residential use BESS and Indoor wall mounted residential use BESS and Outdoor wall mounted non-residential use BESS and Outdoor wall mounted residential use BESS	P
9.7.3	The report shall include the following, as applicable:		P
	a) Unit manufacturer name and model number (and whether UL 9540 compliant);	Unit manufacturer name: Shanghai PYTES Energy Co., Ltd. Model: V10, V10α, V12, V12α Unit is not tested or certified, or verified with UL 9540.	N/A
	b) Number of modules in the initiating BESS unit;	1 module	P
	c) The construction of the initiating BESS unit per 5.3;	See Attachment 1	P
	d) Fire protection features / detection / suppression systems within unit;	No fire suppression system within unit.	N/A
	e) Module voltage(s) corresponding to the tested SOC;	See Table 1	P
	f) The thermal runaway initiation method used;	See Table 1	P
	g) Location of the initiating module within the BESS unit;	See Attachment 4	P
	h) Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	See Attachment 4	P
	i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	No flaming during the test	P

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UNIT LEVEL			
	j) Chemical and convective heat release rate versus time data;	See Attachment 8, 10	P
	k) Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1);	See Attachment 4	P
	l) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	See Attachment 4	P
	m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	See Table 3 and Attachment 4 and 6	P
	n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;	Testing is intended to represent Indoor wall mounted and Outdoor wall mounted.	N/A
	o) The maximum incident heat flux on target wall surfaces and target BESS units;	Target wall surfaces: 26.04 kW/m^2 Target BESS unit: 9.20 kW/m^2	P
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;		N/A
	q) Gas generation and composition data;	See Table 2 and Attachment 7	P
	r) Peak smoke release rate and total smoke release data;	See Attachment 9, 10	P
	s) Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	No fire detection and suppression systems are within unit.	N/A
	t) Observation of flying debris or explosive discharge of gases;	No observation of flying debris or explosive discharge of gases.	P
	u) Observation of re-ignition(s) from thermal runaway events;	No fire during test	N/A
	v) Observation(s) of sparks, electrical arcs, or other electrical events;	No observation(s) of sparks, electrical arcs, or other electrical events.	P
	w) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits; and	see Attachment 5	P
	x) Photos and video of the test.		P

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UNIT LEVEL			
9.8	**Performance at unit level testing**		
9.8.1	Installation level testing in Section 10 is not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.		P
Table 9.1	**Unit Level Performance Criteria**		
	Non-Residential Installations: **Indoor Floor Mounted**		
	Non-Residential Installations: **Outdoor Ground Mounted**		
	Non-Residential Installations: **Indoor Wall Mounted**		P
	a) Flaming outside the initiating BESS unit is not observed;	No flaming outside the initiating BESS unit during test.	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	Maximum temperature of target BESS units adjacent to the initiating BESS unit: 138.0 °C.	P
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	Maximum temperature of wall surface: 119.2 °C.	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; and	Explosion hazards are not observed.	P
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	0.35 kW/m^2	P
	Non-Residential Installations: **Outdoor Wall Mounted**		
	a) If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.	No flaming outside the initiating BESS unit during test.	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	Maximum temperature of target BESS units adjacent to the initiating BESS unit: 138.0 °C	P

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UNIT LEVEL			
	c) For BESS units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	Maximum temperature of wall surface: 119.2 °C	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; and	Explosion hazards are not observed.	P
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	0.35 kW/m^2	P
	Non-Residential Installations: **Rooftop and Open Garages**		
	Residential Installations: **Indoor Floor Mounted**		
	Residential Installations: **Outdoor Ground Mounted**		
	Residential Installations: **Indoor Wall Mounted**		
	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;	No flaming outside the initiating BESS unit during test.	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	Maximum temperature of target BESS units adjacent to the initiating BESS unit: 138.0 °C.	P
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	Maximum temperature of wall surface: 119.2 °C.	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; and	Explosion hazards are not observed.	P
	e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size.	Volume of flammable gas measured during this test: 5619.9 L. LFL from cell level test report: 6.75 % at the venting temperature. (External report with Project No. 4791504604)	P

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UNIT LEVEL			
		Resulting minimum room size: 333.1 m^3 to not exceed 25% LFL in air, at venting temperature.	
	Residential Installations: **Outdoor Wall Mounted**		
	a) If flaming outside the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.	No flaming outside the initiating BESS unit during test.	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	Maximum temperature of target BESS units adjacent to the initiating BESS unit: 138.0 °C.	P
	c) For BESS units intended for near exposures, surface temperature measurements on wall surfaces do not exceed 97K of temperature rise above ambient per 9.2.15;	Maximum temperature of wall surface: 119.2 °C.	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; and	Explosion hazards are not observed.	P
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2.	0.35 kW/m^2	P
10	**Instalaton Level**		—
ANNEX A	**Test Concepts And Application Of Test Results To Installations** (informative)		—
A1	Introduction		N/A
A2	Test Methodology and Purpose		N/A
A3	Evaluating the Results		N/A
ANNEX B	**Safety Recommendations for Testing** (informative)		—
B1	General		P

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UNIT LEVEL

	TABLE: Critical components information				
Object/part no.	**Manufacturer/ trademark**	**Type/model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Lithium-ion Cell	EVE Power Co., Ltd.	LF230	3.2 Vd.c., 230 Ah	ANSI/CAN/UL 1973: 2022	UL MH63503-20241022
Lithium-ion Cell	EVE Power Co., Ltd.	LF230	3.2 Vd.c., 230 Ah	ANSI/CAN/UL 9540A: 2019	External report with project number 4791504604
Rechargeable Li-ion Battery	Shanghai PYTES Energy Co., Ltd.	V10, V10α V12, V12α	51.2 Vd.c., 200 Ah 51.2 Vd.c., 230 Ah	ANSI/CAN/UL 1973: 2022	Report No.: 64.280.24.60301.02 Certificate No.: U8 003364 0032 Rev.01
Rechargeable Li-ion Battery	Shanghai PYTES Energy Co., Ltd.	V10, V10α V12, V12α	51.2 Vd.c., 200 Ah 51.2 Vd.c., 230 Ah	ANSI/CAN/UL 9540A: 2019	Report No.: 5061725025703-00
Supplementary information: N/A					

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UNIT LEVEL

UNIT LEVEL TEST RESULT:

Table 1: Thermal runaway test result	
Summary of initiating module	
Initial ambient temperature:	27.0 °C
Initial relative humidity:	71% RH
Pre-conditioning time	From 2025-08-22 09:17:54 to 2025-08-22 09:20:39
Thermal runwaway test start time	2025-08-22 15:55:35
Module voltage before test:	55.3 V
Methods used to initiate thermal runaway	Heating the cell with two externally applied flexible film heaters with 4.5 K/min heating rate until thermal runaway occurs.
Average heating rate:	T1: 4.5 K /min, T2: 4.5 K /min
Surface temperature when gases were first vented:	T1: 173.0 °C, T2: 233.4 °C The valve opening of the initiating cell may have affected the temperature sensor, and after the valve opened, a significant temperature difference appeared between the two sides of the initiating cell.
Time when gases were first vented:	Cell 4: 2025-08-22 16:41:10
Surface temperature when thermal runaway:	T1: 256.3 °C, T2: 289.2 °C
Time when thermal runaway:	Cell 4: 2025-08-22 16:54:49
Module voltage after test:	0 V
Location of cell(s) for initiating thermal runaway	Cell 4 (see Attachment 1)
Thermal runaway of other cells within module:	Thermal runaway was observed on all 16 cells in the module
Observation(s) of flying debris:	No
Observation(s) of explosive discharge of gas:	No
Observation(s) of sparks, electrical arcs or other electrical events:	No
Locations and visual estimations of flame	N/A, no flames observed.
Module weight before test:	98.0 kg
Module weight after test:	84.7 kg
Module weight loss:	13.3 kg
Summary of other modules	
Status of other modules	No thermal runaway observed
Supplementary information:	N/A

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UNIT LEVEL

Timeline of thermal runaway		
Time (hh:mm:ss)	Event	Description
2025-08-22 15:55:35	Start testing	
2025-08-22 16:41:10	The initiating cell 4 first vented.	
2025-08-22 16:43:03	The cell 5 vented.	

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UNIT LEVEL		
2025-08-22 16:54:49	Gas is observed from the bottom of the battery and the temperature of cell 4 started to rise sharply, thermal runaway occurred.	 
2025-08-22 16:55:18	The cell 3 vented.	

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UNIT LEVEL		
2025-08-22 16:56:35	The cell 3 went into thermal runaway based on the temperature measurement data.	 
2025-08-22 16:56:55	The cell 5 went into thermal runaway based on the temperature measurement data.	

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UNIT LEVEL		
2025-08-22 17:05:09	The cell 6 vented.	
2025-08-22 17:12:03	The cell 2 vented.	
2025-08-22 17:15:00	The cell 7 vented.	

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UNIT LEVEL		
2025-08-22 17:18:05	The cell 6 went into thermal runaway based on the temperature measurement data.	 
2025-08-22 17:22:59	The cell 5 went into thermal runaway based on the temperature measurement data.	

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UNIT LEVEL		
		
2025-08-22 18:01:09	The last cell experienced thermal runaway; at this point, all 16 cells inside the system had also undergone thermal runaway.	 

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UNIT LEVEL		
2025-08-22 19:09:10	Based on observations, no more gas or smoke was released.	
2025-08-22 23:59:55	Stop video recording.	 
Remark: Refer to attachment 4 for details of sample before test and test setup with thermocouple location.		

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UNIT LEVEL

Table 2: Vent gas composition			
Composition	Chemical formula	Measurement peak (L/min)	Analysis Method
Carbon monoxide	CO	45.36	NDIR
Carbon dioxide	CO2	88.20	NDIR
Methane	CH4	7.42	FTIR
Acetylene	C2H2	0.75	FTIR
Ethene	C2H4	8.20	FTIR
Ethane	C2H6	1.19	FTIR
Propane	C3H8	1.13	FTIR
Butane	C4H10	/	FTIR
Pentane	C5H12	/	FTIR
Benzene	C6H6	/	FTIR
Hexane	C6H14	/	FTIR
Hydrofluoric acid	HF	/	FTIR
Hydrogen chloride	HCl	/	FTIR
Hydrogen	H2	35.28	Hydrogen sensor
Total Hydrocarbons	(Methane Equivalent)	249.77	FID
Flow rate in exhaust duct (m^3/s)		2.1	

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UNIT LEVEL

Table 3: Monitored temperature result			
Number	Thermocouple location	Measured maximum temperature, °C	Limit, °C
T1	Under Film heater 1, between Cell 3 and Cell 4	1247.7	-
T2	Under Film heater 2, between Cell 4 and Cell 5	1242.5	-
T3	Between Cell 2 and Cell 3	635.3	-
T4	Between Cell 5 and Cell 6	1178.3	-
T5	Between Cell 1 and Cell 2	776.7	-
T6	Between Cell 6 and Cell 7	1281.8	-
T7	Left side of Cell 1	482.1	-
T8	Right side of Cell 8	1086.0	-
T9	Between Cell 11 and Cell 12	634.4	-
T10	Between Cell 12 and Cell 13	765.9	-
T11	Left side of Cell 9	574.8	-
T12	Right side of Cell 16	514.3	-
T13	Top cover closest to the inititating cell - Initiating Unit	332.6	-
T001	Top case - Initiating Unit	215.4	-
T002	Bottom case - Initiating Unit	164.6	-
T003	Left case - Initiating Unit	54.1	-
T004	Right case - Initiating Unit	1299.6	-
T005	Front case - Initiating Unit	208.3	-
T006	Rear case - Initiating Unit	200.3	-
T007	Top case -Target Unit 1	47.9	173.0
T008	Bottom case - Target Unit 1	35.0	173.0
T009	Left case - Target Unit 1	33.8	173.0
T010	Right case - Target Unit 1	36.5	173.0
T011	Front case - Target Unit 1	34.7	173.0
T012	Back case - Target Unit 1	33.9	173.0
T013	Top case -Target Unit 2	38.0	173.0
T014	Bottom case - Target Unit 2	36.0	173.0
T015	Left case - Target Unit 2	138	173.0
T016	Right case - Target Unit 2	35.8	173.0
T017	Front case - Target Unit 2	39.2	173.0
T018	Back case - Target Unit 2	38.0	173.0
T019	Top case -Target Unit 3	49.1	173.0

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T020	Bottom case - Target Unit 3	55.8	173.0
T021	Left case - Target Unit 3	46.3	173.0
T022	Right case - Target Unit 3	81.8	173.0
T023	Front case - Target Unit 3	73.1	173.0
T024	Back case - Target Unit 3	112.0	173.0
T025	At the centre of the internal right surface of target unit 1	42.5	173.0
T026	At the centre of the internal left surface of target unit 2	78.9	173.0
T027	At the centre of the internal bottom surface of target unit 3	92.1	173.0
T028	Upper positions on the external right surface of target 1	63.0	173.0
T029	Lower positions on the external right surface of target 1	41.5	173.0
T030	Upper positions on the external left surface of target 2	80.1	173.0
T031	Lower positions on the external left surface of target 2	108.1	173.0
T032	Upper positions on the external bottom surface of target 3	91.3	173.0
T033	Lower positions on the external bottom surface of target 3	130.4	173.0
TA35	Wall surface 1	93.7	124.0
TA36	Wall surface 2	119.2	124.0
TA37	Wall surface 3	90.3	124.0
TA38	Wall surface 4	37.0	124.0
TA39	Wall surface 5	39.6	124.0
TA40	Wall surface 6	39.2	124.0
TA41	Wall surface 7	36.6	124.0
TA42	Wall surface 8	34.5	124.0
TA43	Wall surface 9	35.2	124.0
TA44	Wall surface 10	40.2	124.0
TA45	Wall surface 11	40.5	124.0
TA46	Wall surface 12	49.8	124.0
TA47	Wall surface 13	49.8	124.0
TA48	Wall surface 14	111.9	124.0
TA49	Wall surface 15	118.3	124.0
TA50	Wall surface 16	114.1	124.0
TA51	Wall surface 17	112.0	124.0
TA52	Wall surface 18	37.8	124.0
TA53	Wall surface 19	81.3	124.0
TA54	Wall surface 20	68.7	124.0
TA55	Wall surface 21	84.0	124.0
TA56	Wall surface 22	57.9	124.0

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UNIT LEVEL			
TA57	Wall surface 23	39.8	124.0
TA58	Wall surface 24	38.2	124.0
TA59	Wall surface 25	47.5	124.0
TA60	Wall surface 26	43.9	124.0
TA61	Wall surface 27	32.6	124.0
TA62	Wall surface 28	37.7	124.0
TA63	Wall surface 29	43.5	124.0
TA64	Wall surface 30	38.3	124.0
TA65	Wall surface 31	30.2	124.0
	Ambient	29.8	-
Remark: please see Attachment 4 for thermocouple locations and Attachment 6 for monitored temperature charts.			

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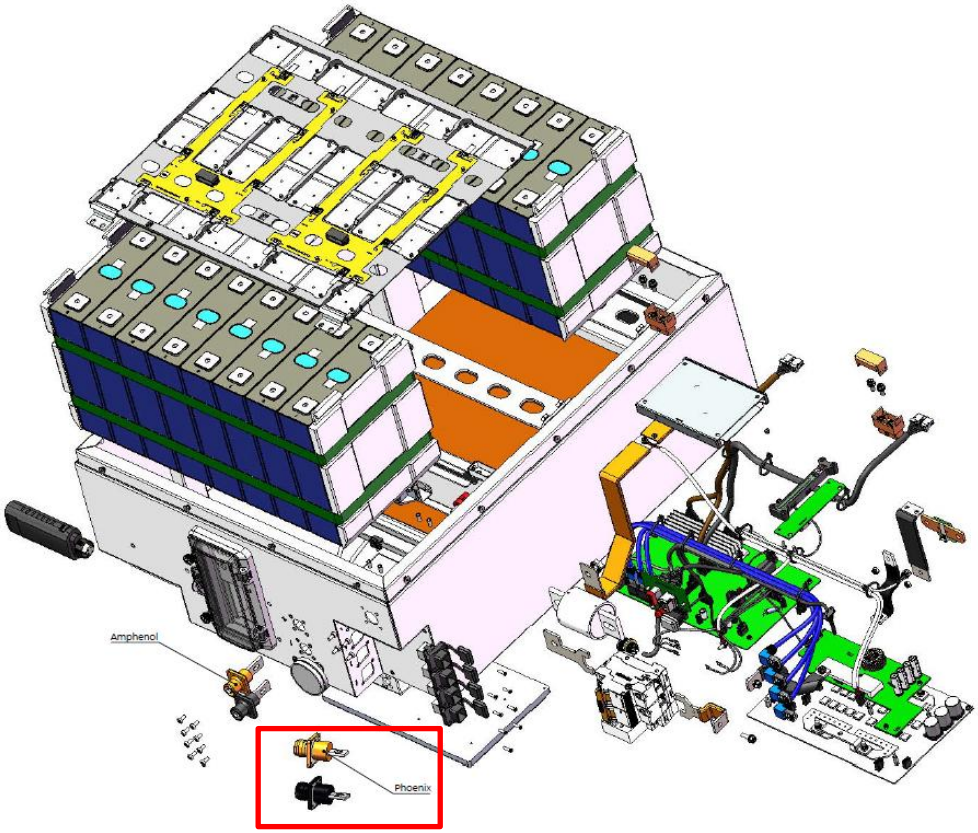
UNIT LEVEL

Attachment 1: Product description

Exploded-view drawing of system V12α as below:



Remark:
The models V10 and V12, as well as V10α and V12α, are identical in all aspects except for:
1.Rated capacity and rated energy:
– V10 / V10α have a rated capacity of 200 Ah and a rated energy of 9.98 kWh,
– V12 / V12α feature a rated capacity of 230 Ah and a rated energy of 11.776 kWh.
2.Battery connectors:
– V10α / V12α use battery connector model: C10-730189,
– V10 / V12 use battery connector model: BPC 250 FTB.

Due to the identical product design (except as stated above) and the use of identical critical components, only one model was tested at its maximum state of charge. The results are considered representative of the performance of all models listed. The test results in this report were generated from testing model V12α.

The differences of battery connectors have been highlighted with red box.

There is no difference between the unit-level and module-level test samples. The unit-level testing is conducted under the final installation (wall-mounted) conditions.

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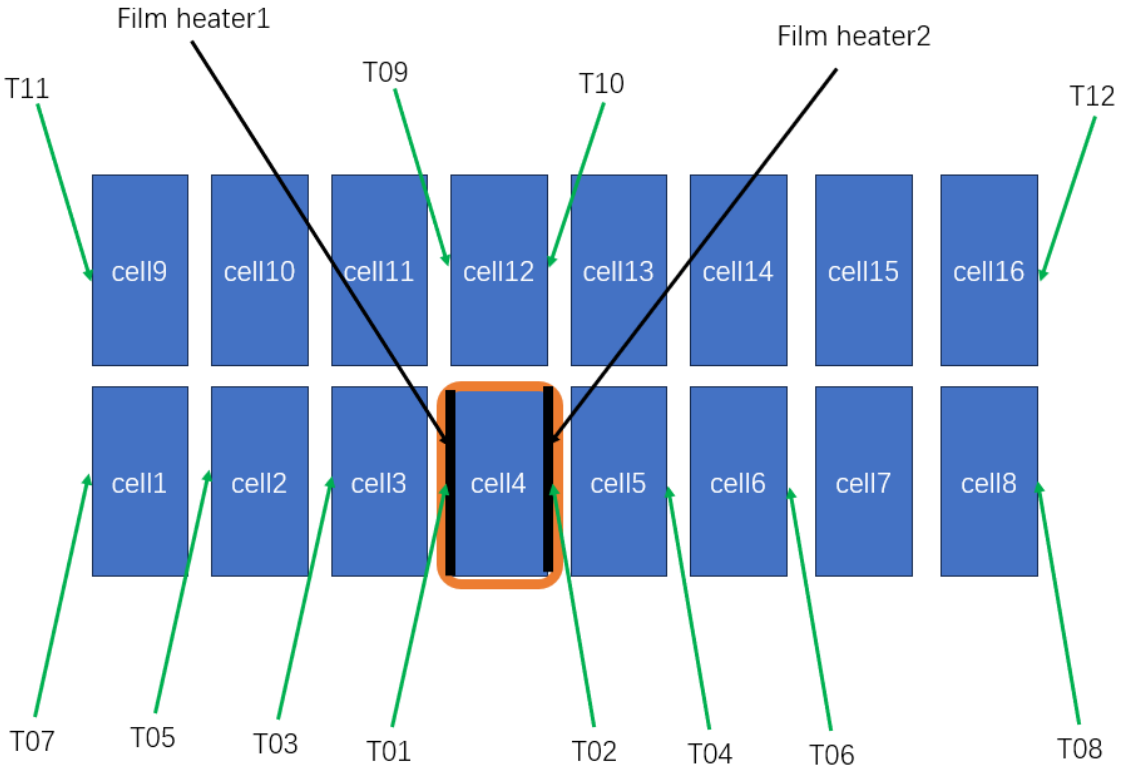
UNIT LEVEL

Attachment 2: Exploded-view drawing of module & Identification/location of cells within the module

Exploded-view drawing of module same with exploded-view drawing of system V12α.

Identification/location of cells within the module as below (Cell 4 as initiating cell):



Schematic Illustration of film heaters and thermocouple locations in DUT.

Cell 4 is the initiating cell. T1 to T12 means thermocouples T1 to T12.

Thermocouples T1 and T2 are centred under the film heaters

For detailed thermocouple locations, refer to Table 3 below:

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UNIT LEVEL

Attachment 3: Pre-conditioning profile

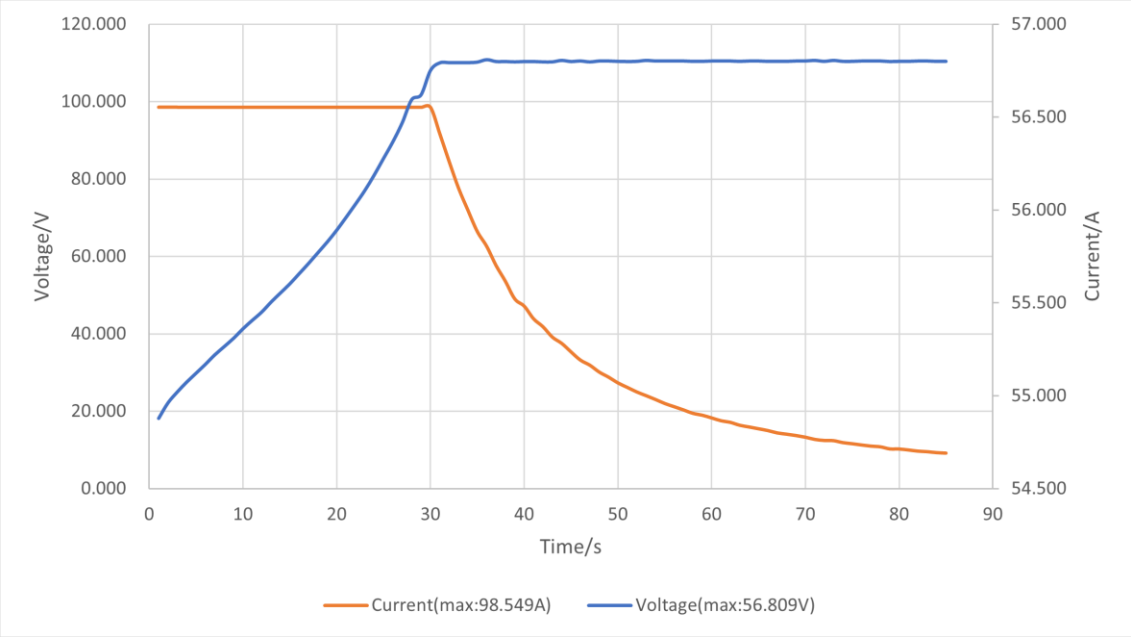

Figure 1 of Attachment 3: Pre-condition for the initiating unit

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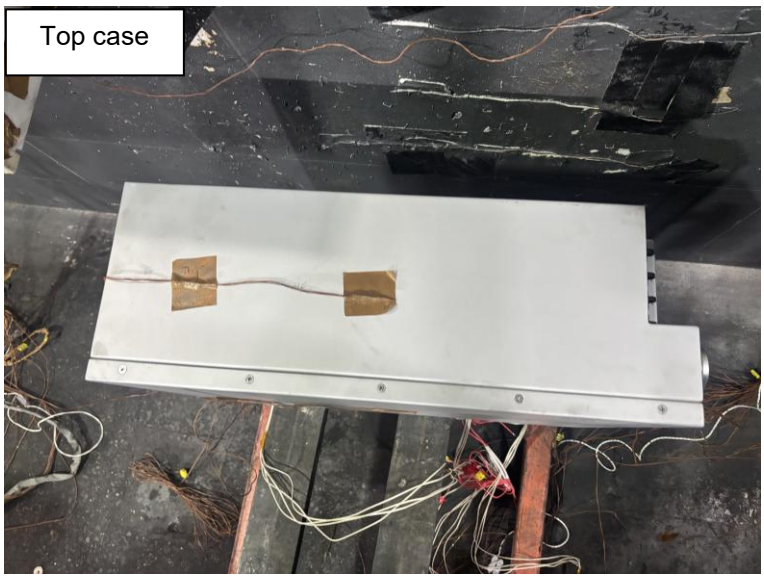
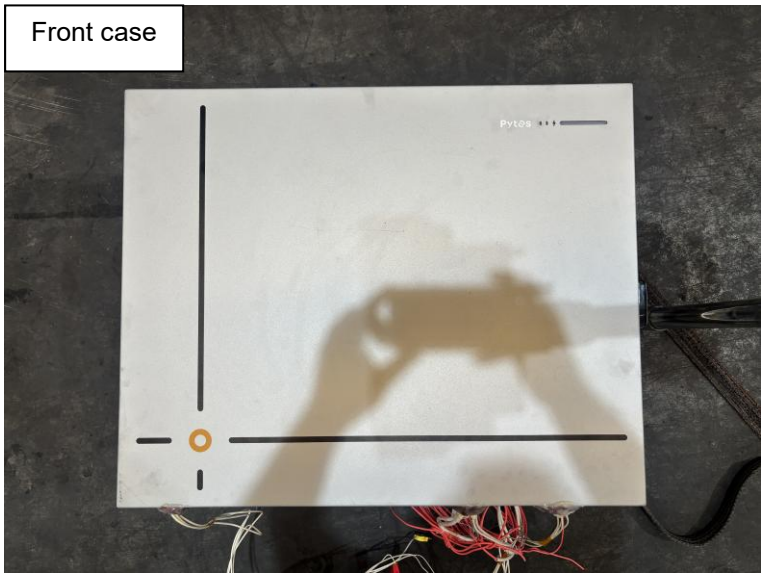
UNIT LEVEL

Attachment 4: Photo of sample before test and test setup with thermocouple location

Details of:	Figure 1 of Attachment 4: Overview of initiating unit before test
	

Details of:	Figure 2 of Attachment 4: Overview of initiating unit before test
	

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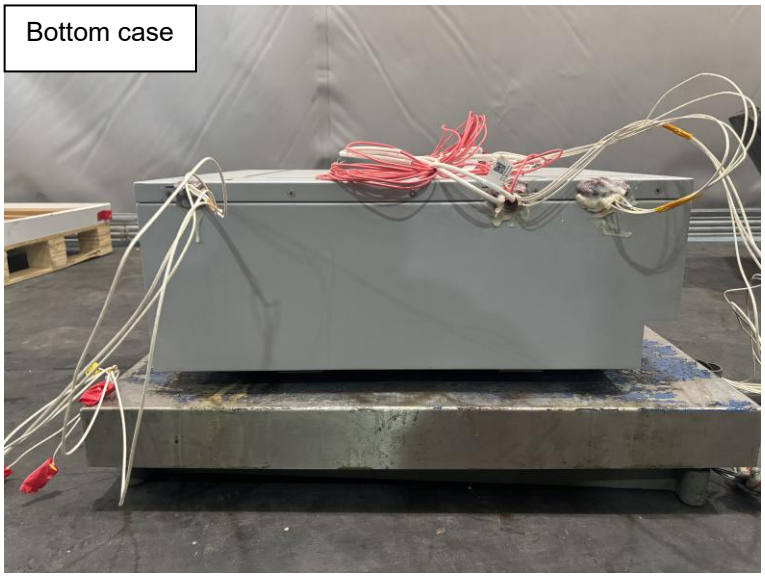
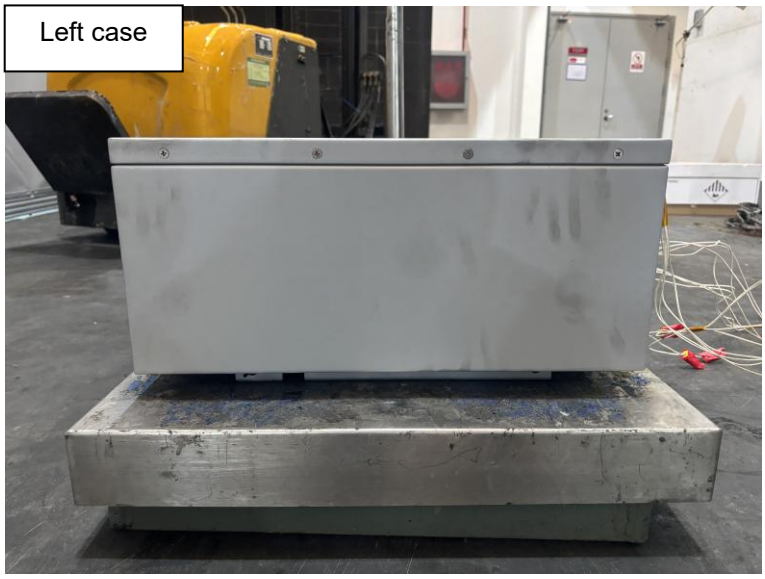
UNIT LEVEL

Details of:	Figure 4 of Attachment 4: Overview of initiating unit before test
	Bottom case 

Details of:	Figure 5 of Attachment 4: Overview of initiating unit before test
	Left case 

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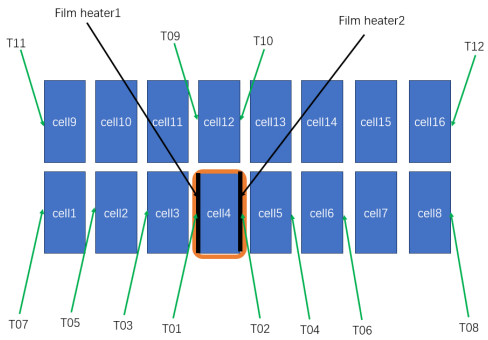
UNIT LEVEL

Details of:	Figure 6 of Attachment 4: Overview of initiating unit before test
	

Details of:	Figure 7 of Attachment 4: Overview of sample & thermocouple location of initiating unit _before test
	  Schematic Illustration of film heaters and thermocouple locations in DUT. Cell 4 is the initiating cell. T1 to T12 means thermocouples T1 to T12.

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Details of:	Figure 8 of Attachment 4: Overview of instrumented walls before test

Remark: thermocouple locations of wall surface (one vertical array at 152mm intervals for the full height)

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UNIT LEVEL

Details of:	Figure 9 of Attachment 4: Thermocouple location of initiating unit case before test
	

Details of:	Figure 10 of Attachment 4: Overview of sample & test setup before test
	

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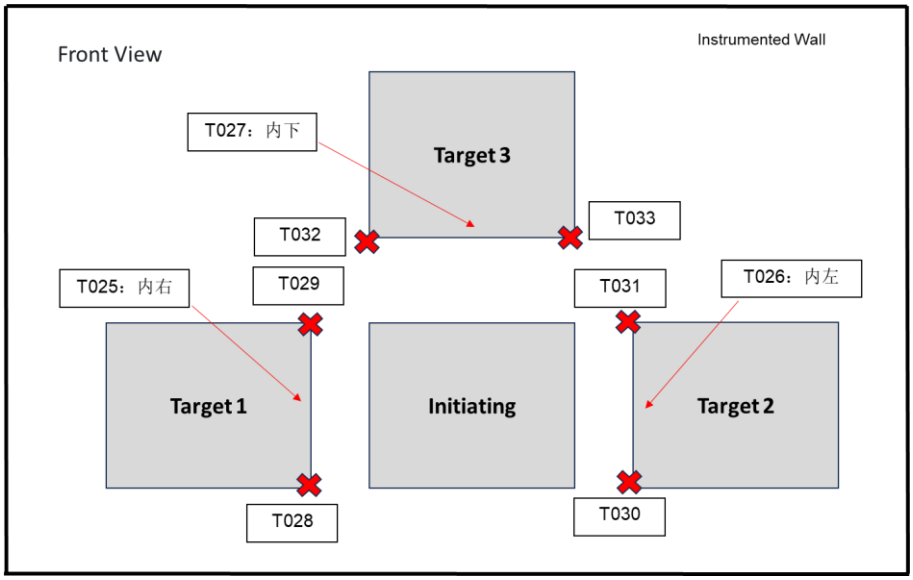
UNIT LEVEL

Details of:	Figure 11 of Attachment 4: Thermocouple location for neighbour units and other locations for samples before test



T025 At the centre of the internal right surface of target unit 1
T026 At the centre of the internal left surface of target unit 2
T027 At the centre of the internal bottom surface of target unit 3
T028 Upper positions on the external right surface of target 1
T029 Lower positions on the external right surface of target 1
T030 Upper positions on the external left surface of target 2
T031 Lower positions on the external left surface of target 2
T032 Upper positions on the external bottom surface of target 3
T033 Lower positions on the external bottom surface of target 3

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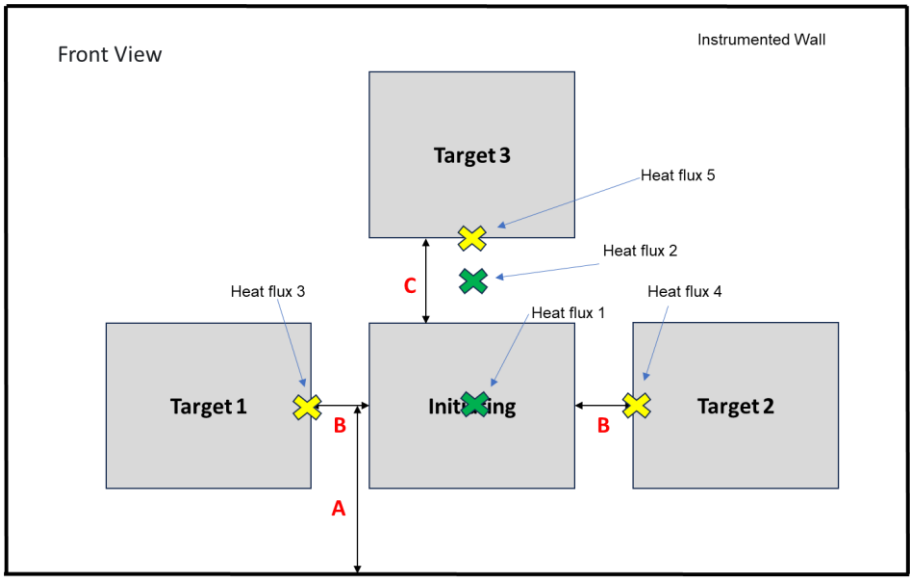
Details of:	Figure 12 of Attachment 4: Location of the heat flux sensors



Remark:
Heat flux 1: Positioned one the wall, at the central height of the initiating unit

Heat flux 2: Positioned one the wall, at the central height between the initiating unit and Target 3

Heat flux 3: Positioned at the centre of the right surface of Target unit 1, the height is the same as that of the initiating unit

Heat flux 4: Positioned at the centre of the left surface of Target unit 2, the height is the same as that of the initiating unit

Heat flux 5: Positioned at the centre of the bottom surface of Target unit 3

Heat flux 6: Positioned at the middle of the egress

Heat flux 7: Positioned at the the ceiling

Remark: A=1.22m; B=7.62cm; C=15.24cm

Item	Height, mm	Distance to Instrumented wall, mm
Heat flux 1	1220	0
Heat flux 2	1556.2	0
Heat flux 3	1220	130
Heat flux 4	1220	130
Heat flux 5	1632.4	130
Heat flux 6	1220	760
Heat flux 7	3660	0

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UNIT LEVEL

Attachment 5: Photo for sample after test

Details of:	Figure 1 of Attachment 5: Overview of sample after test

Front view

Side view

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Details of:	Figure 2 of Attachment 5: Overview of the cheesecloth after test
	

Details of:	Figure 3 of Attachment 5: Top view of initiating unit after test
	

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Details of:	Figure 4 of Attachment 5: Bottom view of initiating unit after test
	

Details of:	Figure 5 of Attachment 5: Front view of initiating unit after test
	

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Details of:	Figure 6 of Attachment 5: Left side view of initiating unit after test
	

Details of:	Figure 7 of Attachment 5: Right side view of initiating unit after test
	

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Details of:	Figure 8 of Attachment 5: Internal view of initiating unit after test.

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UNIT LEVEL

Attachment 6: Monitored voltage and temperature chart

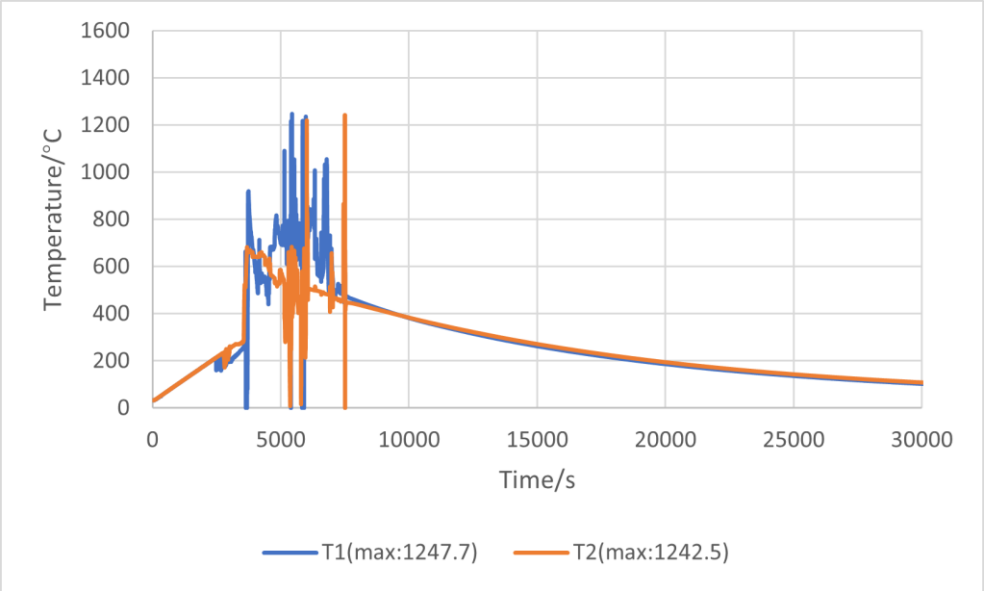

Figure 1 of Attachment 6: Temperatures of initiating cell in initiating unit.
Remark: Measurement errors observed, probably caused due to electrolyte leakage.

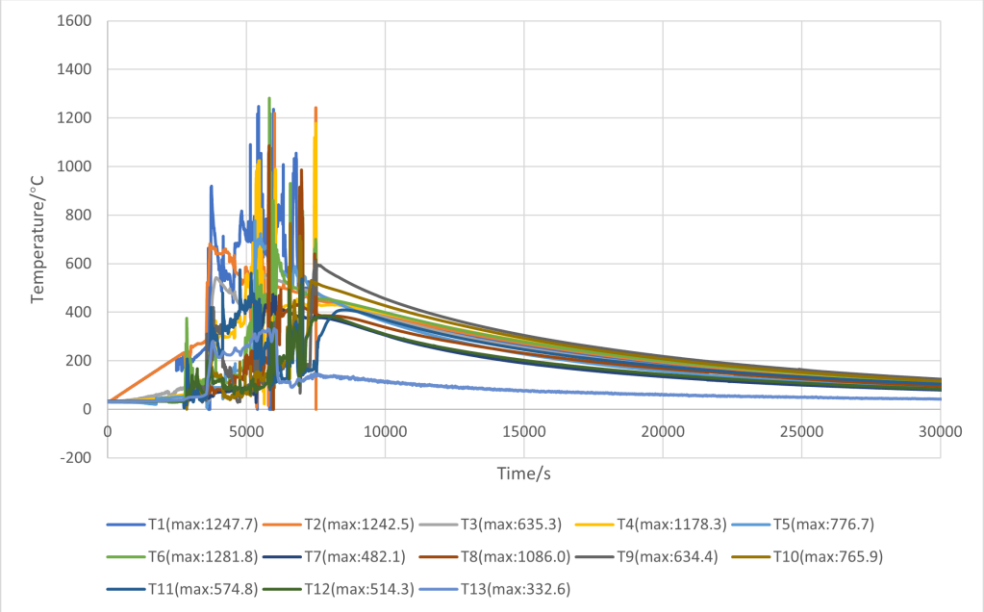

Figure 2 of Attachment 6: Temperatures of other cells in initiating unit.
Remark: Measurement errors observed, probably caused due to electrolyte leakage.

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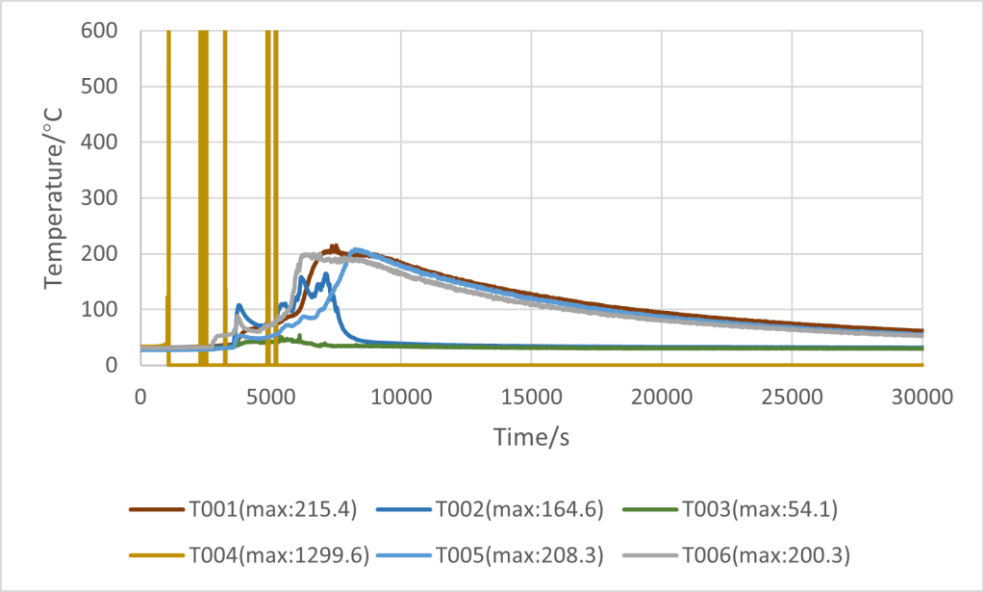

Figure 3 of Attachment 6: Temperatures of external surface temperature of initiating unit.

Remark: Measurement errors observed on T004, probably caused due to the pressure relief valve releasing gas..

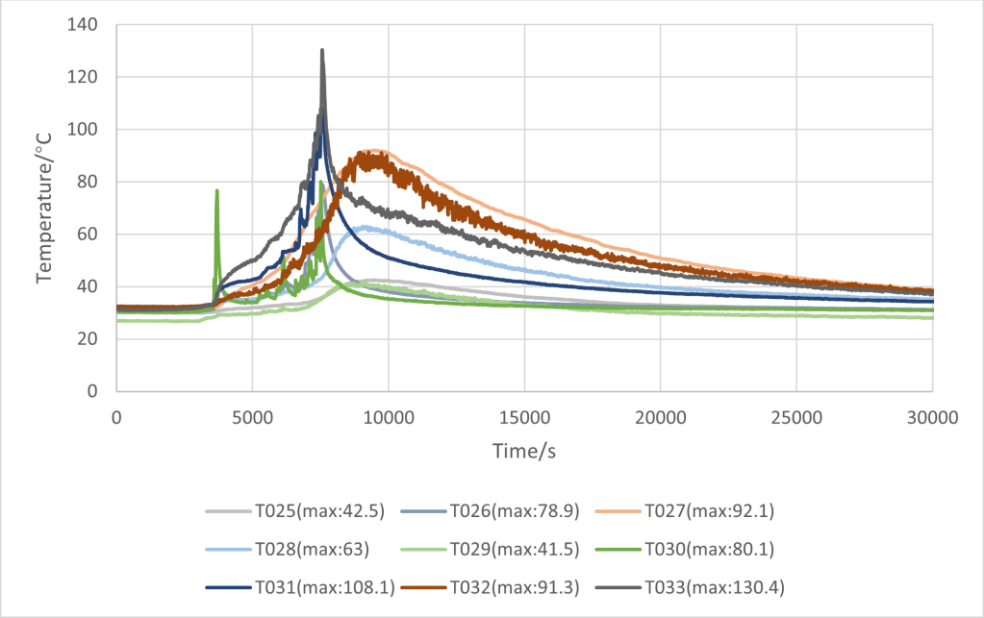

Figure 4 of Attachment 6: Internal temperature of the target unit.

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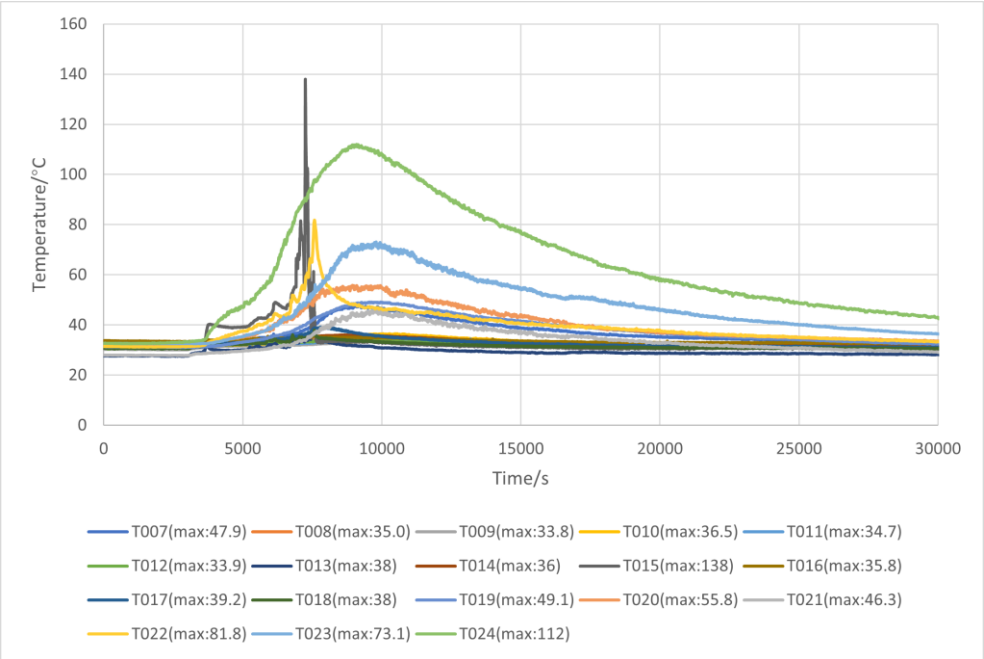

Figure 5 of Attachment 6: Temperatures of the surface of target units.

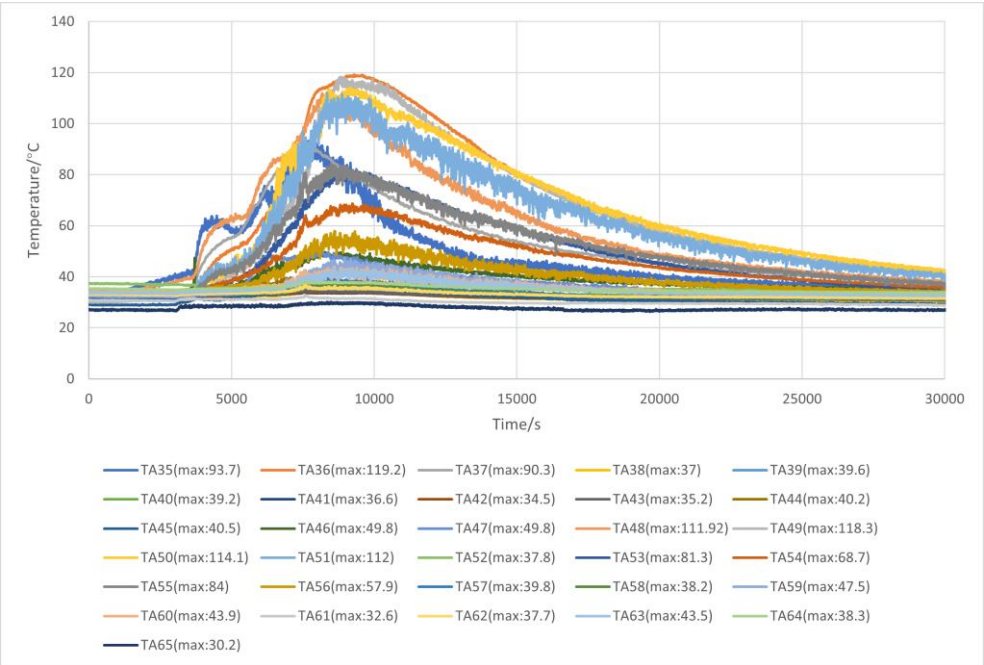

Figure 6 of Attachment 6: Temperatures of wall surface.

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UNIT LEVEL

Attachment 7: Flammable gas generation and composition data chart

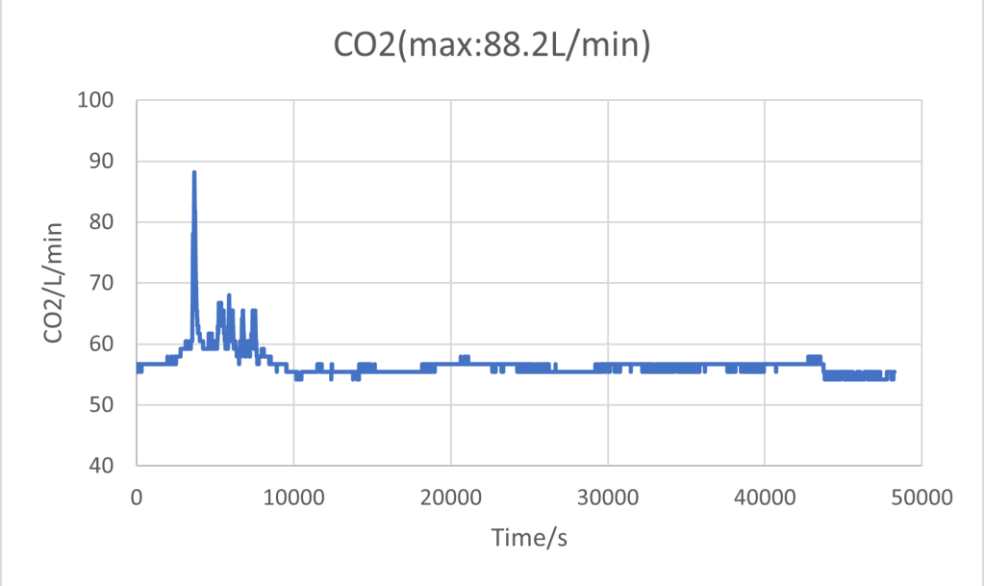

Figure 1 of Attachment 7: Gas generation and composition data chart (detected by NDIR).

Remark: Flow rate in exhaust duct was 2.1 m^3/s.

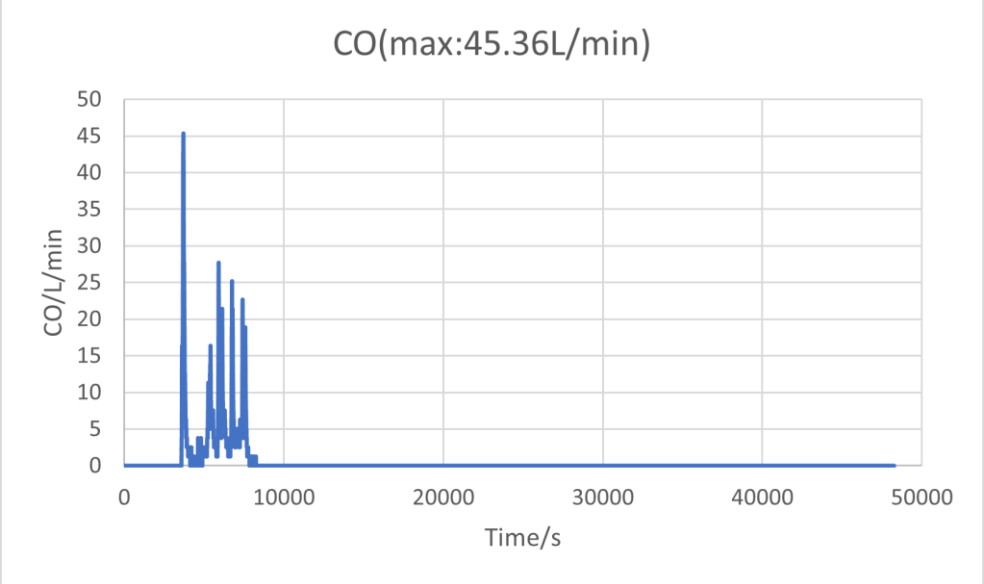

Figure 2 of Attachment 7: Gas generation and composition data chart (detected by NDIR).

Remark: Flow rate in exhaust duct was 2.1 m^3/s.

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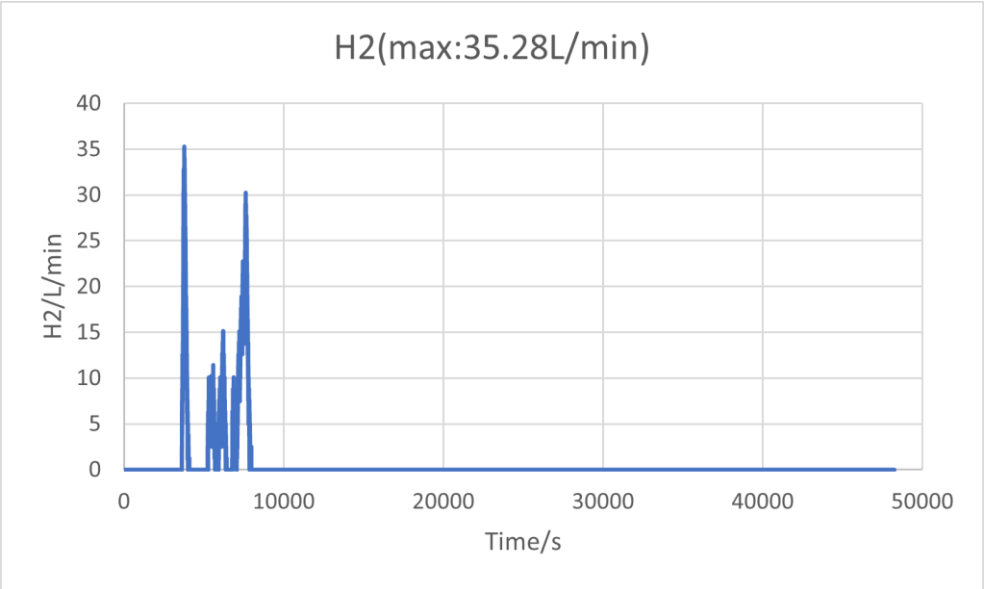

Figure 3 of Attachment 7: H_2 data chart (detected by Hydrogen sensor).

Remark: Flow rate in exhaust duct was 2.1 m^3/s.

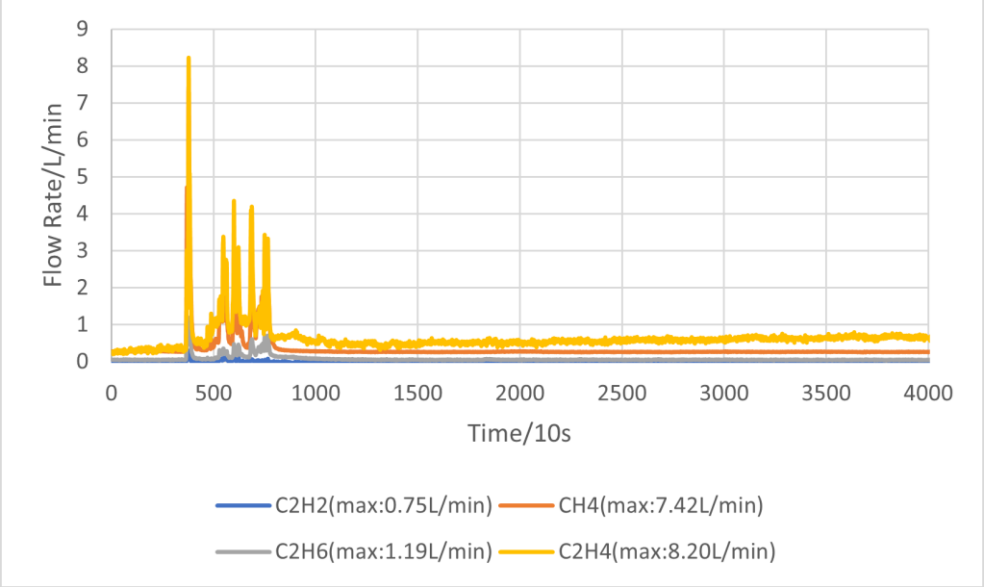

Figure 4 of Attachment 7: Gas generation and composition data chart (detected by FTIR).

Remark: Flow rate in exhaust duct was 2.1 m^3/s.

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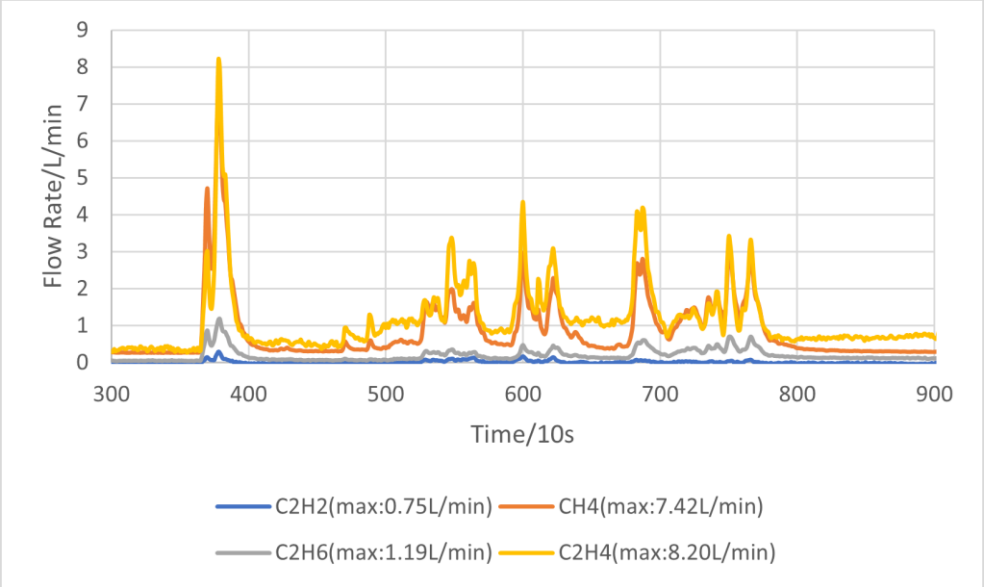

Figure 4 of Attachment 7: Zoom view of gas generation and composition data chart (detected by FTIR).

Remark: Flow rate in exhaust duct was 2.1 m^3/s.

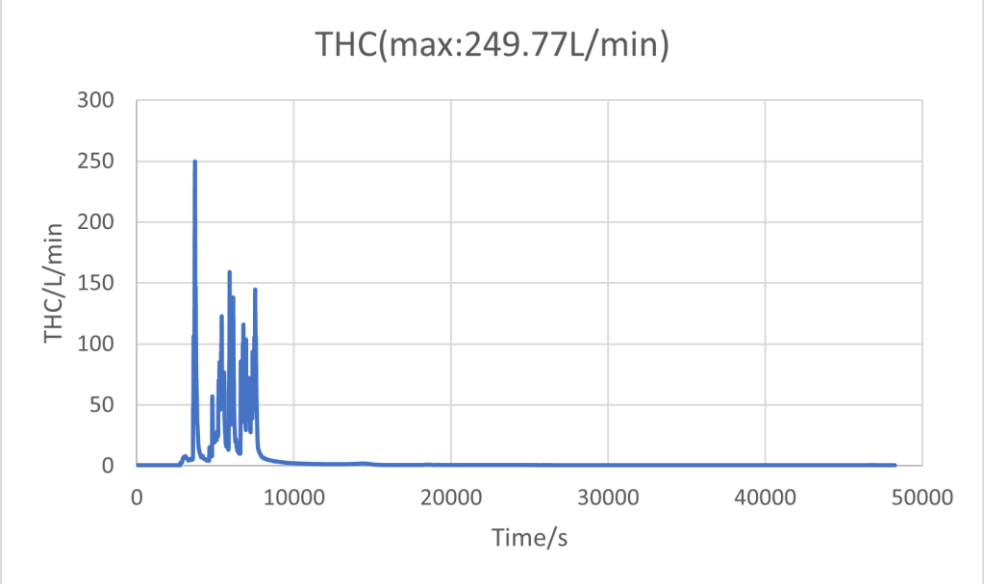

Figure 5 of Attachment 7: THC (Total Hydrocarbons) chart (detected by FID).

Remark: Flow rate in exhaust duct was 2.1 m^3/s.

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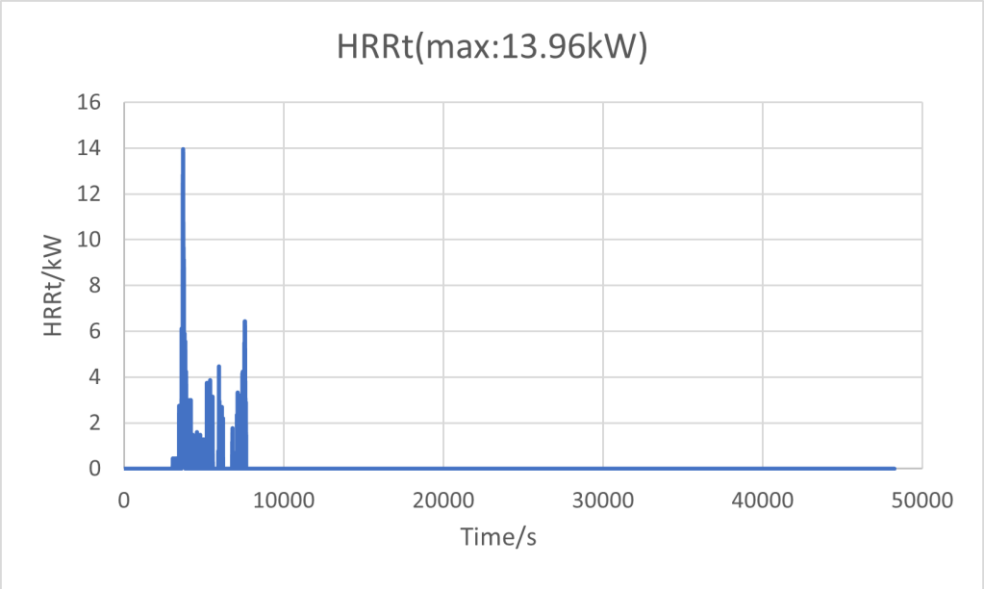
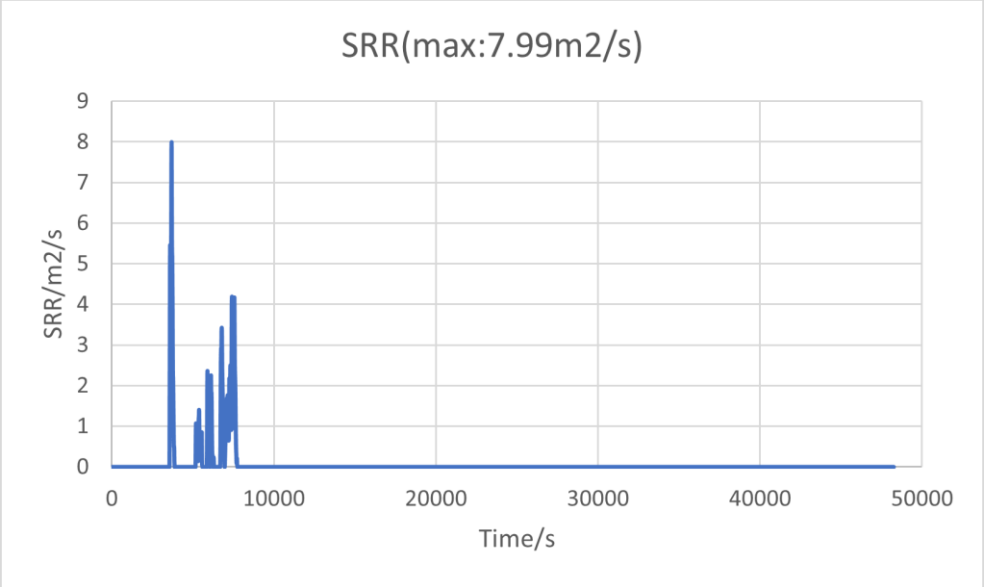
Attachment 8: Heat release rate versus time data chart



Remark: No fire was detected.

Attachment 9: Peak smoke release rate and total smoke release data chart



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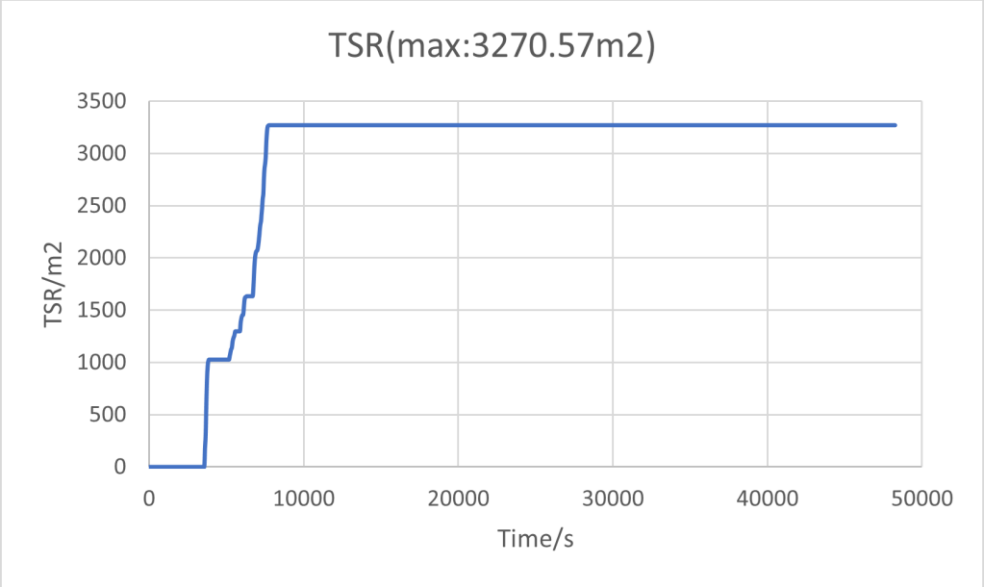

Attachment 10: Summary of Heat release rate & Peak smoke release rate and total smoke release data

Peak heat release rate	13.96 kW
Peak convective heat release rate	0 kW
Total smoke released	3270.57 m^2
Peak smoke release rate	7.99 m^2/s

Remark: No fire was detected.

---------- END REPORT ----------

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