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

Report Reference No..... :	230510114GZU-001	
Tested by (name + signature) ..... :	Joss Huang Engineer	Joss Huang. .....
Approved by (name + signature) ..... :	Grady Ye Manager	.....
Total number of pages..... :	56	
Date of issue..... :	03 July., 2023	

Testing Laboratory..... :	Intertek Testing Services Shenzhen Ltd. Zengcheng Branch
Address..... :	C2-1, Heping Xu, Yongning Street, Zengcheng District, Guangzhou, China
Testing location/ procedure ..... :	Lab test
Testing location/ address..... :	Intertek Testing Services Shenzhen Ltd. Zengcheng Branch C2-1, Heping Xu, Yongning Street, Zengcheng District, Guangzhou, China
Applicant's name ..... :	Guangzhou Sanjing Electric Co., Ltd.
Address..... :	No.9, Lizhishan Road, Science City, Guangzhou High-tech Zone, Guangdong - CHINA
Test specification:	
Standard ..... :	ANSI/CAN/UL 9540A:2019 (Fourth Edition) + UL CRD's
Test procedure..... :	Unit level test (clause 9.1-9.8)
Non-standard test method……..... :	N/A
Test Report Form No. ..... :	ANSI/CAN/UL 9540A_Unit
Test Report Form(s) Originator ..... :	Intertek
Master TRF..... :	2022-01

Test item description ..... :	Lithium battery
Trade Mark ..... :	SAJ
Manufacturer..... :	Jiangxi Sanjing Electric C., Ltd.
Model/Type reference..... :	B2-7.3-HV5, B2-14.6-HV5, B2-21.9-HV5
Ratings..... :	See Unit information for detail.

General disclaimer:

List of attachments:

Attachment 1 – Photos

Attachment 2 – Sample preparation

Attachment 3 – Arrangement of the unit

Attachment 4 – Thermal runaway preparation

Attachment 5 – Observations and records

Attachment 6 – Temperature measurements

Attachment 7 – Heat flux measurements

Attachment 8 – Chemical heat release rate measurement

Attachment 9 – Convective heat release rate measurement

Attachment 10 – Gas generation measurement

Attachment 11 – Smoke release rate measurement

Attachment 12 – Equipment list

Test video 20230510-1.mp4 and 20230510-2.mp4 were provided in addition to this test report.

Summary of testing:

Thermal Runaway Propagation.....:	32 cells vented and thermal runaway due to thermal runaway propagation in the initiating module. No thermal runaway propagation from initiating module to other modules in initiating unit.
Maximum Target BESS Temperature (°C) .....:	97.5°C
Maximum Wall Surface Temperature (°C) .....:	195°C
Maximum Heat Flux on target wall surfaces (kW/m^2) ..:	N/A
Maximum Heat Flux on target BESS units (kW/m^2) .....:	N/A
Peak Chemical Heat Release Rate (kW) .....:	102.93kW
Peak Convective Heat Release Rate (kW) .....:	0kW
Peak Smoke Heat Release Rate (m^2/s) .....:	7.216 m^2/s
Total Smoke Release (m^2) .....:	4659.74m^2
Maximum Heat Flux on Egress Path (kW/m^2) .....:	0.034KW/s^2
External Flaming from BESS .....:	Not observed
Flying debris or explosive discharge of gases .....:	Not observed
Sparks, electrical arcs, or other electrical events .....:	Not observed
Re-ignitions .....:	Not observed

Conclusion:

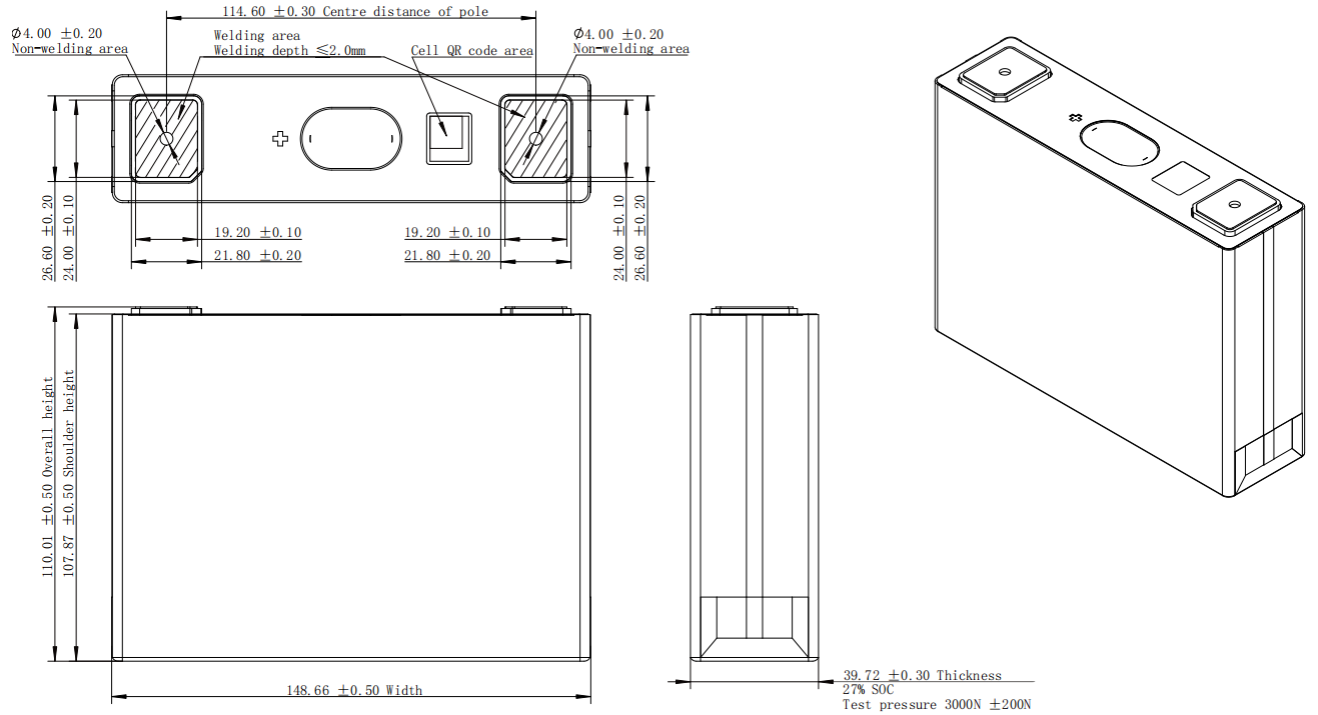
The performance criteria of the unit level test as indicated in 9.8 of UL 9540A 4th edition has been met.

Installation level testing in Section 10 is not required because the performance conditions outlined in Table 9.1 are met during the unit level test.

Possible test case verdicts:
- test case does not apply to the test object.....: N/A
- test object was not evaluated for the requirement.....: N/E
- test object does meet the requirement..... : Pass (P)
- test object does not meet the requirement .....: Fail (F)
Testing:
Date of receipt of test items .....: 10 May. 2023
Date(s) of performance of tests.....: 14 June. 2023 – 15 June. 2023
General remarks:
"(see Attachment #)" refers to additional information appended to the report. "(see appended table)" refers to a table appended to the report. The tests results presented in this report relate only to the object tested. This report shall not be reproduced except in full without the written approval of the testing laboratory. List of test equipment must be kept on file and available for review. Additional test data and/or information provided in the attachments to this report. Throughout this report a ☐ comma / ☒ **point** is used as the decimal separator. Determination of the test results includes consideration of measurement uncertainty from the test equipment and methods. **Remark: Due to the rise temperature of wall exceeding 97°C, this system should be installed in non-combustible construction.**
General product information: This test unit is a non-residential indoor floor mounted battery system. It also can cover non-residential indoor wall mounted, outdoor ground and wall mounted battery systems.

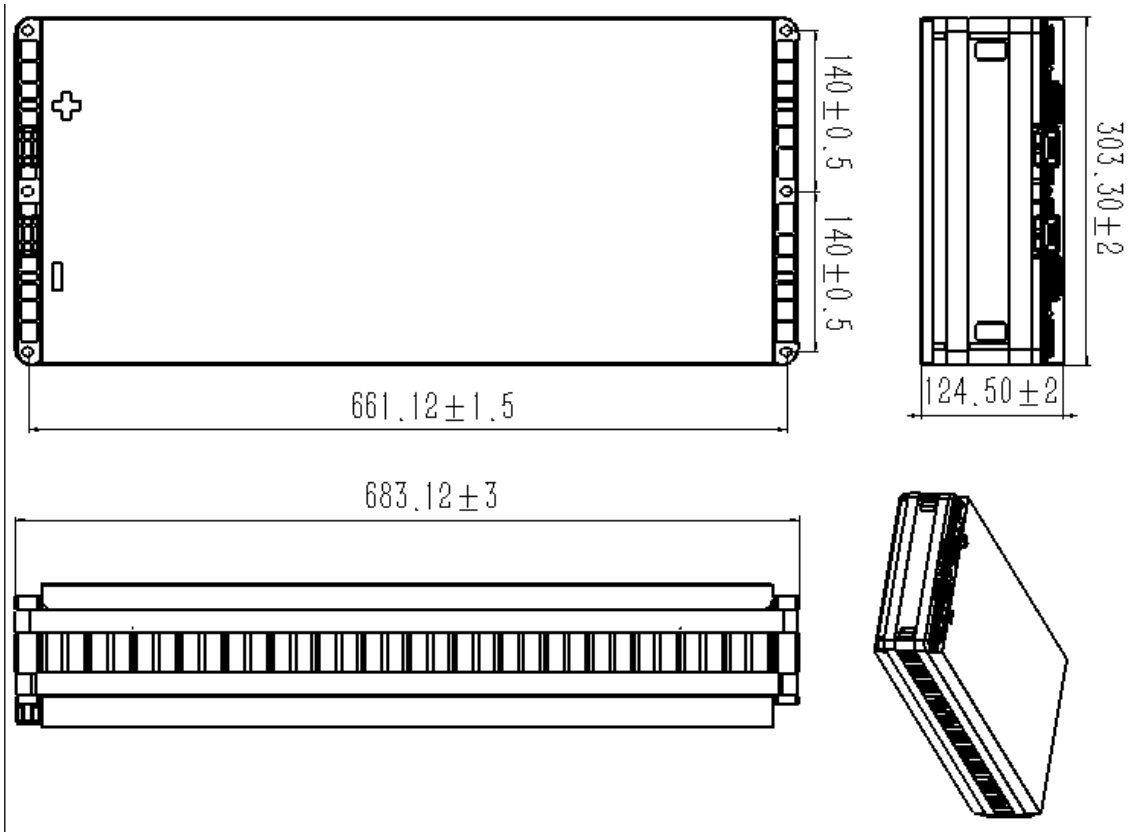
Product information:	
Cell information	
Manufacturer.....:	REPT BATTERO Energy Co., Ltd.
Model name .....:	CB59
Chemistry.....:	LiFePO4
Physical configuration.....:	Prismatic
Dimension (L*W*H) .....:	148.66(±1)mm x 39.72(±1)mm x 110.01(±1)mm
Weight.....:	1380±150g
Nominal voltage .....:	3.2V
Rated capacity .....:	72Ah
If the cell compliance with UL 1973 .....:	Compliance / UL MH64238-20220829
Standard charge method	
Charge current.....:	36A
End of charge voltage.....:	3.65V
Cut off current .....:	3.6A
Standard discharge method	
Discharge current .....:	72A
End of discharge voltage .....:	2.5V
Test result from cell level 9540A test report	
Cell level test report .....:	Issued by UL(Changzhou) Quality Technical Service Co., LTD Guangzhou Branch. Report No. 4790517961
Average cell venting temperature ..... :	154°C
Average cell thermal runaway onset temperature ....:	211°C
Gas composition .....:	See cell level UL9540A test report.
LFL at ambient temperature .....:	7.95% at 25°C
LFL cell venting temperature .....:	6.95% at 154°C
Burning velocity .....:	125.8cm/s
P_{max} .....:	0.654 MPa at 25°C

Diagram of cell with overall dimension

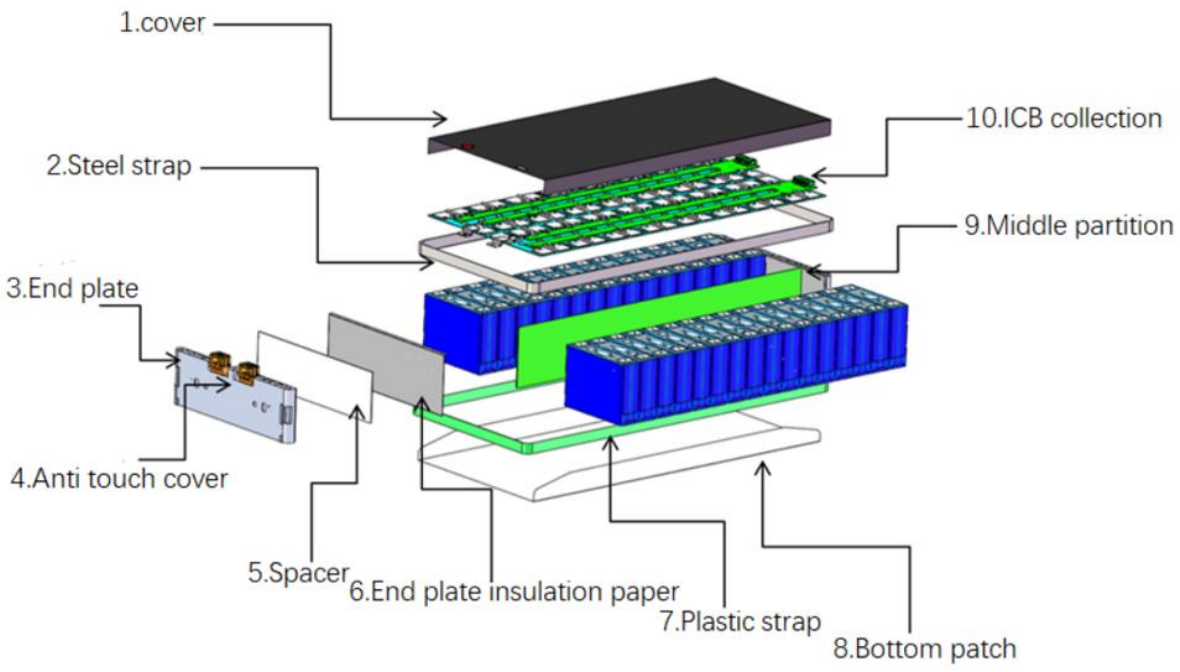


Module information	
Manufacturer ..... :	REPT BATTERO Energy Co., Ltd.
Model name ..... :	H1132B59FA (32S1P)
Physical configuration	
Enclosure material..... :	Metal and plastic
Dimension (L*W*H) ..... :	683.12±3mm*124.50±2mm*303.30±2mm
Weight..... :	47±1.5kg
Cells in series/parallel: ..... :	32S1P
Total number of cells: ..... :	32cells
Cooling method ..... :	Nature cooling
Separation between cells ..... :	2mm by epoxy board
Electrical rating	
Rated energy ..... :	7.37kWh
Nominal voltage..... :	102.4V
Standard charge method	
Charge current..... :	50.4A
End of charge voltage..... :	116.8V (cell end of charge voltage:3.65V)
Standard discharge method	
Discharge current ..... :	50.4A
End of discharge voltage ..... :	80V (cell end of discharge voltage:2.5V)
If the module compliance with UL 1973 ..... :	N/A
Test result from module level 9540A test report	
Module level test report ..... :	N/A
Peak chemical heat release rate HRR (kW) ..... :	N/A
Peak smoke release rate SRR (m2/s) ..... :	N/A
Total smoke release TSR (m2) ..... :	N/A
Total Hydrocarbons (equivalent to C3H8, measured by FID) ..... :	N/A
Module weight loss (kg)..... :	N/A

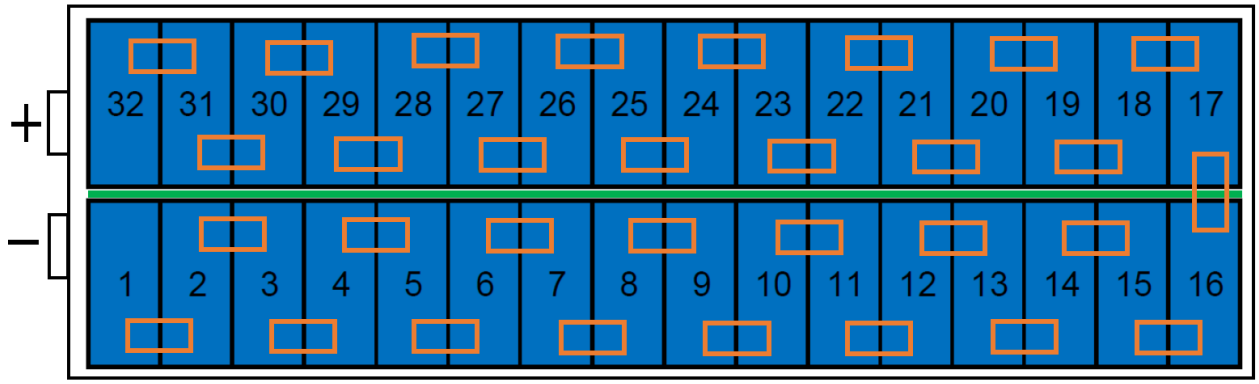
Diagram of module with overall dimension



Contents (main components) of the module



Layout of the module contents



Module structure diagram and cell series and/or parallel configuration (with cell numbered)

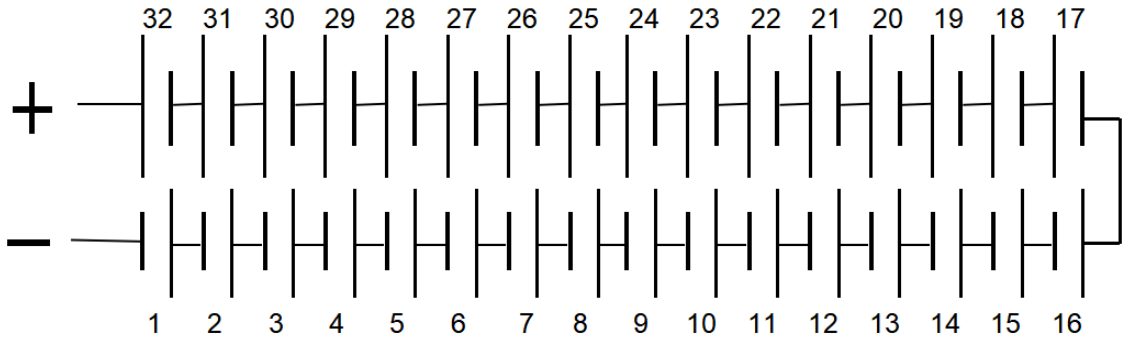
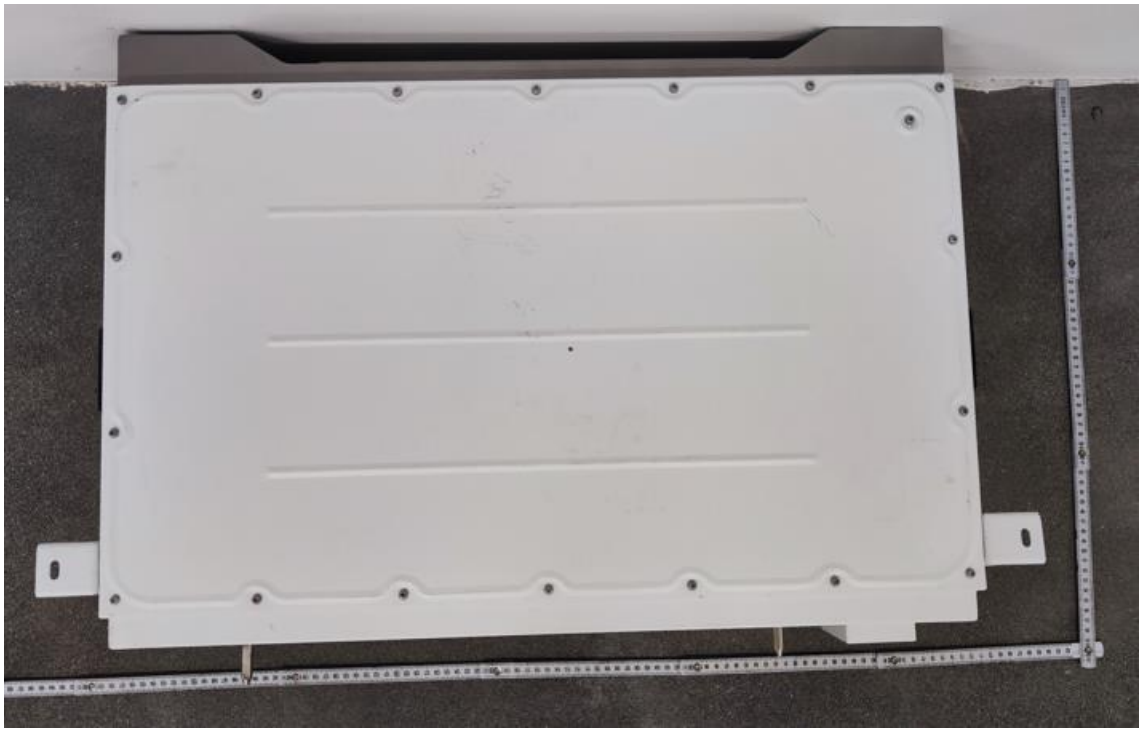


Photo of the module

Front view

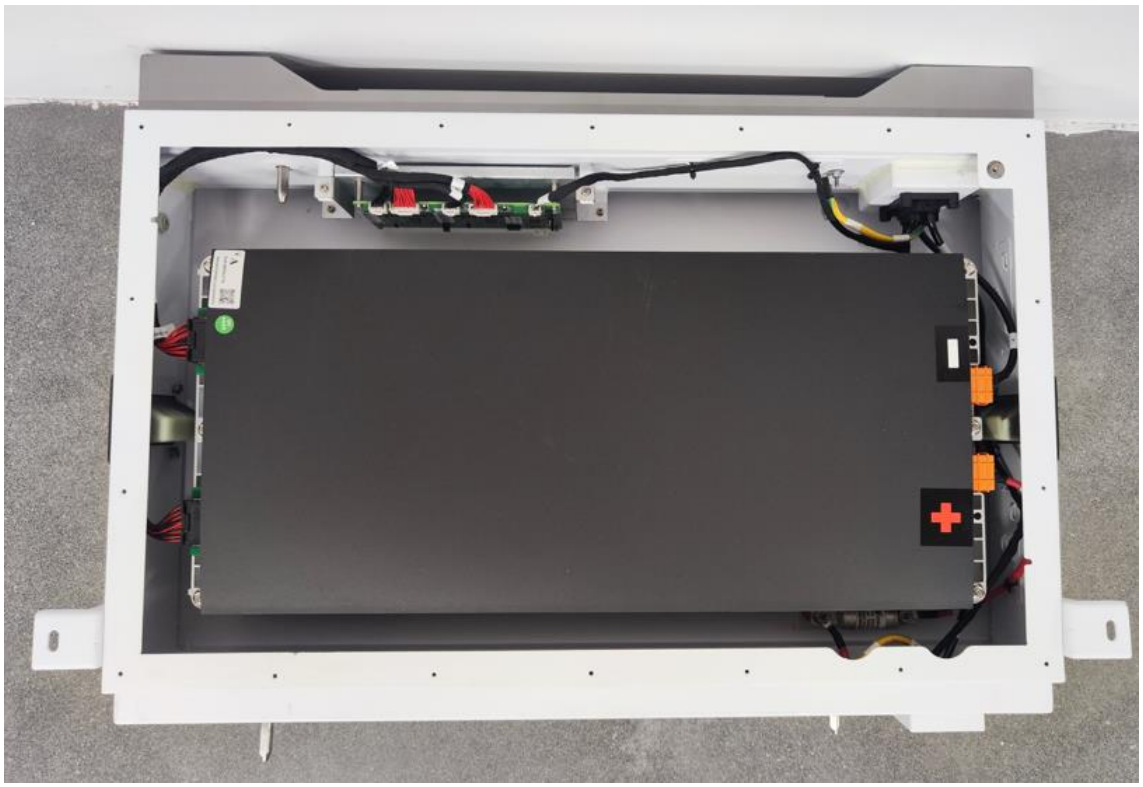


Back view

Connection view

Connection view

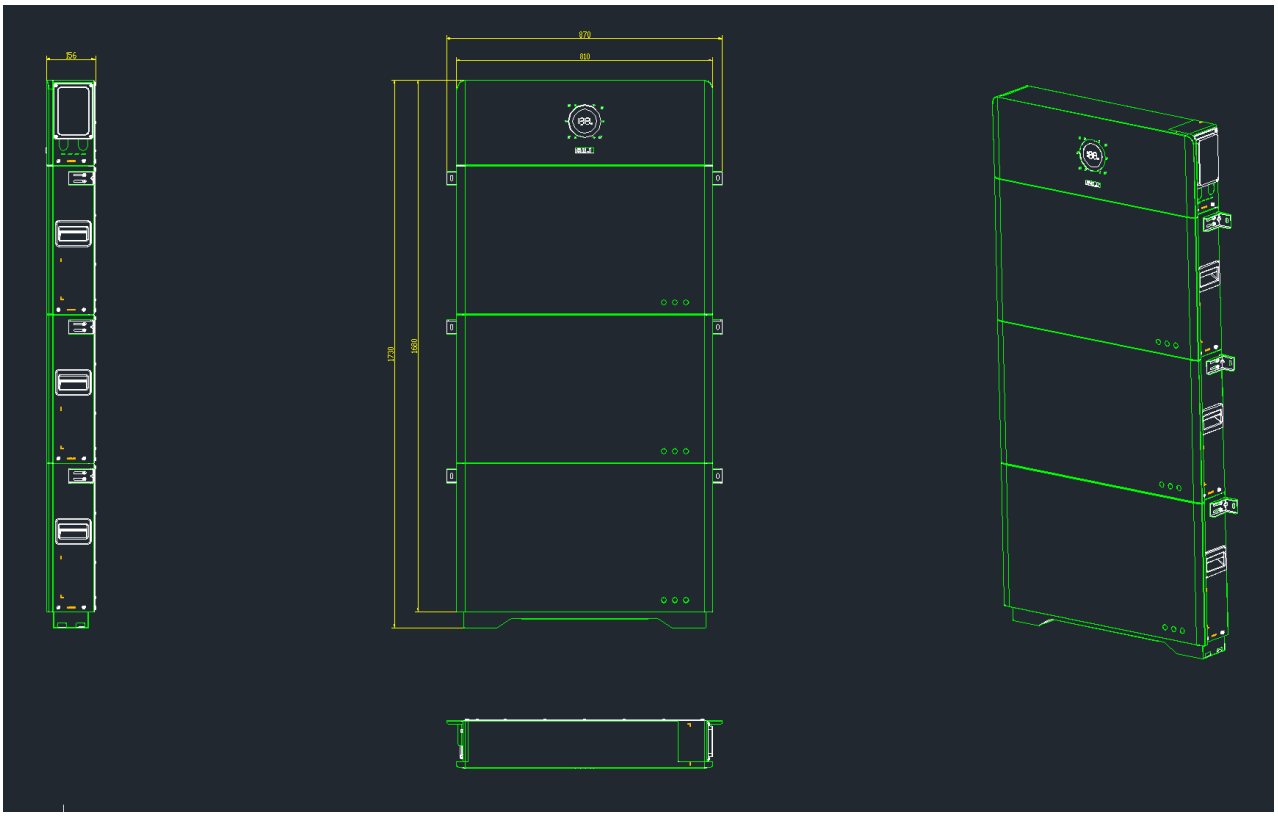
Internal view-1



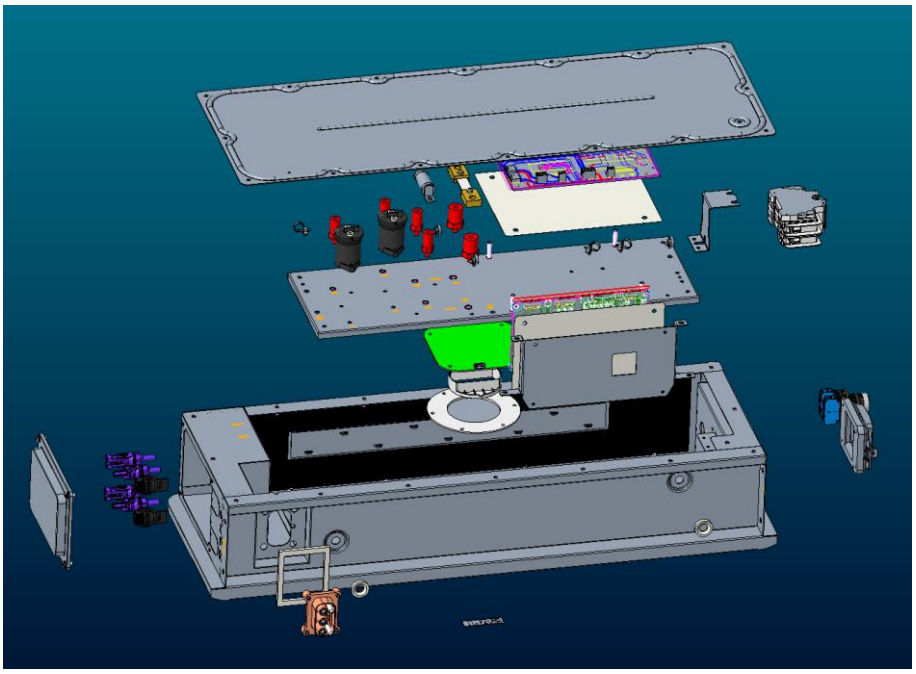
Internal view-2

Unit information			
Manufacturer:	Jiangxi Sanjing Electric C., Ltd.		
Model number:	B2-7.3-HV5, B2-14.6-HV5, B2-21.9-HV5		
Test model	B2-21.9-HV5		
Type of system:	☒ Battery System (BS)	☒ Battery ESS	
Intended use location:	☐ Residential ☐ Non-residential rooftop ☐ Non-residential open garage use	☒ Non-residential	
Type of installation:	☒ Indoor ☒ Wall mounted	☒ Outdoor ☒ Floor/ground mounted	
Enclosure material:	☒ Metal ☐ Open rack	☒ Non-metal	
Spacing between modules:	No spacing		
Integrated fire protection system in the unit	No fire detection and suppression system installed for the unit level test		
If the unit compliance with UL 1973 or UL 9540:	N/A		
Electrical rating:			
model	B2-7.3-HV5	B2-14.6-HV5	B2-21.9-HV5
Rated energy (Wh):	7.3kWh	14.6kWh	21.9kWh
Nominal voltage (V):	102.4Vdc	204.8Vdc	307.2Vdc
Weight(kg):	81kg	144.5kg	208kg
Module series and/or parallel configuration:	1S1P	2S1P	3S1P
Total number of cells:	32*1	32*2	32*3
Standard charge method:			
Charge current (A):	50A		
End of charge voltage (V):	115.2V*		
Standard discharge method:			
Discharge current (A):	50A		
End of discharge voltage (V):	89.6V*		
Rest time between charge and discharge	30min		
(*) represent one module's end of charge/discharge voltage.			

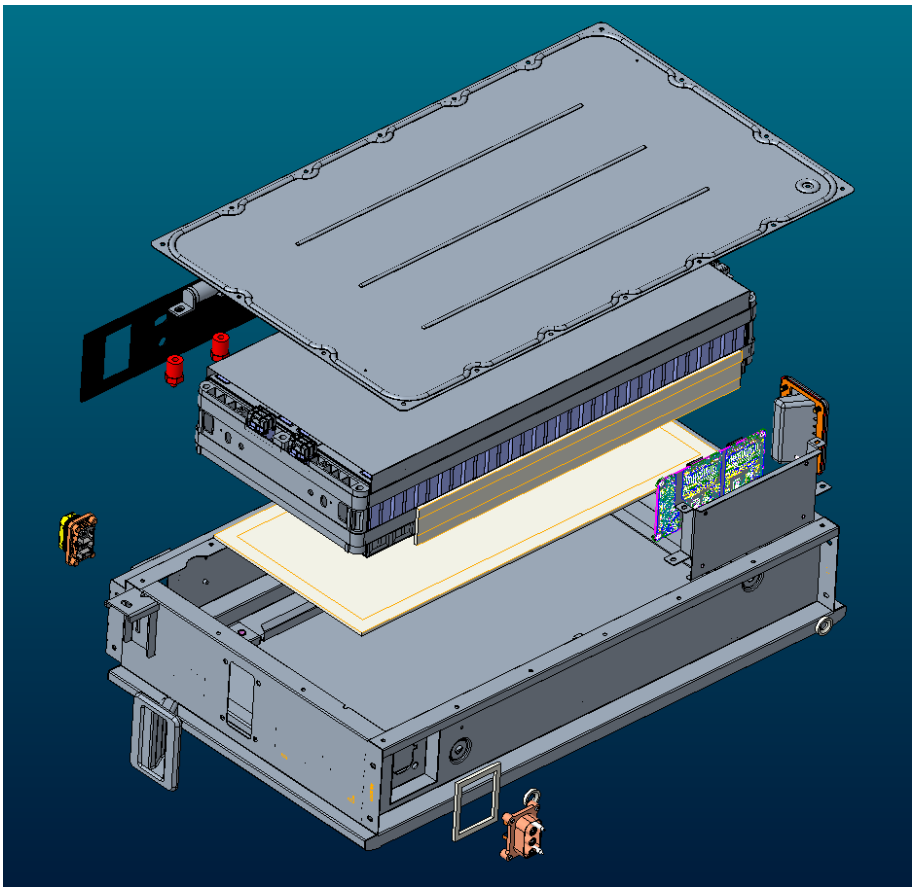
Diagram of unit with overall dimension



Exploded view of the unit contents (show all components inside the unit. Include battery modules, control module(s), bus bars wires etc.)



View 1



View 2

Photo of the unit (without inverter)

Front view

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
5	**Construction – General**		
5.1	**Cell**		--
5.1.1	The cell info associated with the BESS includes:		Pass
	• cell chemistry (e.g. NMC, LFP);	LiFePO4	Pass
	• the physical format of the cell;	Prismatic	Pass
	• the cell electrical rating in capacity and nominal voltage;	72Ah, 3.2V	Pass
	• the overall dimensions of the cell, and weight.	See page 4-5	Pass
5.1.2	The cells associated with the BESS comply with ANSI/CAN/UL 1973 or not.	Certificate provided.	Pass
5.1.3	Further details included in the cell level test report.		Pass
5.2	**Module**		--
5.2.1	The modules info associated with the BESS includes:		Pass
	• the generic enclosure material;	Metal and plastic	Pass
	• the general layout of the module contents;	See page 7-12	Pass
	• the electrical configuration of the cells in the modules and the modules in the BESS.	32S1P	Pass
5.2.2	The modules associated with the BESS comply with UL 1973 or not.	Not provided	Pass
5.2.3	Further details included in the module level test report.	Refer to 8.3	Pass
5.3	**Battery energy storage system unit**		--
5.3.1	The BESS unit info includes:		--
	• the units comply with UL 9540 or not;		Pass
	• the manufacturer and model number;		Pass
	• electrical ratings;		Pass
	• energy capacity of all BESS.		Pass
5.3.2	For BESS units, which UL 9540 compliance cannot be determined, to include:		--
	• the number of modules in the BESS;	3	Pass
	• electrical configuration of the module;	See Unit information (page 12)	Pass
	• physical layout of the modules in the BESS;		Pass
	• battery management system (BMS); and		Pass
	• other major components of the BESS;		Pass
	• the BESS enclosure overall dimensions and generic material;		Pass
	• battery system(s) may be tested as representative of the BESS;		Pass
	• battery system complies with UL 1973 or not.		Pass
5.3.3	Any fire detection and suppression systems that are an integral part of the BESS.	No fire detection and suppression system installed for the test.	N/A
5.3.4	Further details included in the unit level and if applicable, installation level test reports.		Pass
5.4	**Flow Batteries**		--

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
5.4.1	For flow batteries, to include the following info:		N/A
	• the chemistry;		N/A
	• a generic description of the electrolyte (s);		N/A
	• the overall dimensions of the individual stack;		N/A
	• the electrical rating in capacity and nominal voltage of the cell stack.		N/A
	And the Information of the complete flow battery system:		N/A
	• the manufacturer's name and model number of the system;		N/A
	• the electrical rating in volts and rated storage capacity in Ah or Wh;		N/A
	• the number of cells and stacks in the system;		N/A
	• the maximum volume of electrolyte(s) for the system.		N/A
5.4.2	The flow battery system complies with UL 1973 or not.		N/A
5.4.3	Further details included in the flow battery thermal runaway determination level test report.		N/A
6	**Performance – General**		
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices, which may result in various kind of hazards.		Pass
6.2	At the conclusion of testing, samples discharged in accordance with the manufacturer' specifications.		Pass
	All samples disposed of in accordance with local regulations.		Pass
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.	See page 12 for details	Pass
9.1.2	The unit level test requires one initiating BESS unit and target adjacent BESS unit’s representative of an installation.	An internal fire condition as in the module level test is initiated	Pass
	(Modified by UL CRD-2020.10.21) Tests conducted for indoor floor mounted installations for residential BESS may be considered representative of both indoor floors mounted and outdoor ground mounted installations.		N/A
	Exception: Testing can be conducted outdoors for outdoor only installations with controlled environment.		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.		N/A
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.		Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
9.1.5	Target BESS units shall include the outer cabinet, racking, module enclosures, and components that retain cells components. The target BESS unit module enclosures do not need to contain cells.		Pass
9.1.6	The initiating BESS unit shall be at the maximum operating state of charge (MOSOC) for conducting the tests in this standard. After charging and prior to testing, the initiating BESS shall rest for a maximum period of 8h at room ambient.	See attachment 2: sample preparation.	Pass
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 system installed for the test.	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.	BMS function disabled	Pass
	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.	No fire suppression control system	N/A
9.2	**Test method – Indoor floor mounted BESS units**		--
9.2.1	During the test, the test room environment shall be controlled to prevent drafts that may affect test results.	See attachment 5	Pass
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.		N/A
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections.	See attachment 3	Pass
9.2.4	Instrumented wall sections shall extend not less than 0.49m horizontally beyond the exterior of the target BESS units.		Pass
9.2.5	Instrumented wall sections shall be at least 0.61m taller than the BESS unit height, but not less than 3.66m in height above the bottom surface of the unit.		Pass
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.		Pass
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.		Pass
9.2.8	The light transmission in the calorimeter's exhaust duct shall be measured for the duration of the test, and the smoke release rate shall be calculated.		Pass
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, respectively.		Pass
9.2.10	The heat release rate measurement system shall be calibrated using flows of 3.8, 7.6, 11.4 and 15.2 L/min (1, 2, 3 and 4 gpm) of heptane.		Pass
9.2.11	The convective heat release rate shall be measured using a thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct.		Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
9.2.12	The convective heat release rate shall be calculated using the following equation: $HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$	See attachment 9	Pass
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation.	See attachment 3	Pass
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		Pass
	a) The BESS units and the instrumented wall sections; and	See attachment 3	Pass
	b) Adjacent BESS units.	See attachment 3	Pass
9.2.15	Wall surface temperature measurements shall be collected for BESS intended for installation in locations with combustible construction.	See attachment 6	Pass
	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.	Noncombustible construction	N/A
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 #24-gauge, Type-K exposed junction thermocouples; See attachment 6	Pass
	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.		Pass
9.2.17	Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires.		Pass
	The thermocouple tip shall be depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement and held in thermal contact with the surface at that point by the use of pressure-sensitive paper tape.		Pass
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:	Cheesecloth used, refer to 9.2.18.1, heat flux measurement on walls was not measured.	N/A
	a) Both are collinear with the vertical thermocouple array;		N/A
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		N/A
	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.		N/A
9.2.18.1	Heat flux measurements on walls may be waived for residential units that are tested with the cheesecloth indicator of 9.2.22.		N/A

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
9.2.18.2	(added by UL CRD-2021.03.26) With reference to 9.2.18, if b) and c) are deemed to be at the same location, only one gauge may be installed on the wall for the measurement.		N/A
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:		N/A
	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		N/A
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		N/A
9.2.19.1	(added by UL CRD-2021.03.26) Heat flux measurements on target units may be waived for residential units that are tested with the cheesecloth indicator of 9.2.22.		N/A
9.2.19.2	(added by UL CRD-2021.03.26) With reference to 9.2.19, if a) and b) are deemed to be at the same location, only one gauge may be installed on the target unit for the measurement.		N/A
9.2.20	(added by UL CRD-2021.03.26) For non-residential use BESS and outdoor ground mounted residential use BESS, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter or Gardon gauge positioned at the mid height of the initiating unit or the point where the majority of off-gas venting is expected from the initiating unit in the center of the accessible means of egress.		Pass
9.2.21	Measure the temperature of:		Pass
	the surface proximate to the cells and between the cells and exposed face of the initiating module;		Pass
	Each non-initiating module enclosure within the initiating BESS unit;		Pass
	Convoluted enclosure interior geometries.		Pass
9.2.22	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.		Pass
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:		Pass
	a) The position of the module shall be selected to present the greatest thermal exposure to adjacent modules, based on the results from the module level test; and		Pass
	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).		Pass
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct.	Via the testing system which has the sensors in the exhaust duct	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
	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.		Pass
	Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.		Pass
9.2.25	The hydrocarbon components of the vent gas composition shall be measured using flame ionization detection.	Integrated FID in the testing system used	Pass
9.2.26	The test shall be terminated if:		Pass
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;		Pass
	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 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	N/A
9.3	**Test method – Outdoor ground mounted units**		Pass
9.3.1	Outdoor ground mounted non-residential use BESS being evaluated for installation in close proximity to buildings and structures.	(The test method described in section 9.2)	Pass
	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.	(The test method described in section 9.2)	N/A
	Heat flux measurements for the accessible means of egress.	(Measured in accordance with 9.2.20)	Pass
	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.	(Instrumented wall size and construction, see equipment list)	Pass
	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.	(See photo documentation for sample installation set up)	Pass
	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.	Noncombustible construction	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
9.3.4	Target BESS shall be installed on each side of the initiating BESS and keep the min. separation distances specified by the manufacturer.	Min. 50cm	Pass
9.4	**Test Method – Indoor wall mounted units**		Pass
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)	Pass
9.4.2	Conduct testing in a standard NFPA 286 fire test room (12 x 8 x 8-ft) high, with a 2-1/2 x 7-ft high opening.		N/A
9.4.2.1	(Added by UL CRD-2020.10.21) BESS intended for residential installations only may be tested using instrumented wall sections not less than 2.44m (8-ft) in height & width instead of the test room.		N/A
9.4.3	The initiating BESS unit shall be positioned on the wall opposite of the door opening, with the center located 4-ft above the floor, and halfway between adjacent walls.		N/A
9.4.3.1	(added by UL CRD-2020.10.21) When residential BESS are tested in accordance with 9.4.2.1, the initiating BESS unit shall be positioned with the center located 1.22m (4-ft) above the floor, and halfway between adjacent walls.		N/A
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.	(Keep the min. physical spacing between BESS units specified by the manufacturer)	Pass
9.4.5	The wall on which the initiating and target BESS units are mounted shall be instrumented.		Pass
9.4.6	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.	(Gas collection methods per clause 9.2)	N/A
9.4.7	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.	(See equipment list)	N/A
9.4.8	(added by UL CRD-2020.10.21) When testing BESS for residential only installations, the criteria in 9.2.9. 9.2.18 and 9.2.19 may be waived.		N/A
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)	Pass
	If intended for outdoor use only wall mount installations, the smoke release rate, the convective and chemical heat release rate; and the content, velocity and temperature of the released vent gases need not be measured.		N/A
9.5.2	Test samples shall be mounted on an instrumented wall (undersurface of the eave shown in Figure 9.4).		Pass
9.5.3	The initiating BESS unit shall be positioned on the instrumented wall, with its center located 4-ft above the floor, and halfway between wall edges.		Pass
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 and keep the min. separation distances specified by the manufacturer.		Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
9.5.5	The wall on which the initiating and target BESS units are mounted shall be instrumented.	(See clause 9.2)	Pass
9.5.6	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.	(See testing equipment list)	N/A
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:		Pass
	a) Indoor floor mounted non-residential use BESS;		Pass
	b) Indoor floor mounted residential use BESS;		N/A
	c) Outdoor ground mounted non-residential use BESS;		Pass
	d) Outdoor ground mounted residential use BESS;		N/A
	e) Indoor wall mounted non-residential use BESS;		Pass
	f) Indoor wall mounted residential use BESS;		N/A
	g) Outdoor wall mounted non-residential use BESS;		Pass
	h) Outdoor wall mounted residential use BESS;		N/A
	i) Rooftop installed non-residential use BESS; or		N/A
	j) Open garage installed non-residential use BESS.		N/A
9.7.2	If testing is intended to represent more than one installation type, this shall be noted in the report.	See page 12 for details	Pass
9.7.3	The report shall include the following, as applicable:		Pass
	a) Unit manufacturer name and model number (and whether UL 9540 compliant);	See unit information (page 12)	Pass
	b) Number of modules in the initiating BESS unit;	See Attachment 3	Pass
	c) The construction of the initiating BESS unit per 5.3;	See unit information (page 12)	Pass
	d) Fire protection features/detection/suppression systems within unit;	No fire detection and suppression system installed for the test.	N/A
	e) Module voltage(s) corresponding to the tested SOC;	See Attachment 2	Pass
	f) The thermal runaway initiation method used;	See Attachment 4	Pass
	g) Location of the initiating module within the BESS unit;	See Attachment 3	Pass
	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 3	Pass
	i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	See Attachment 5	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
	j) Chemical and convective heat release rate versus time data;	See Attachment 8 and attachment 9	Pass
	k) Separation distances from the initiating BESS unit to target walls (A and C in Figure 9.1);	See Attachment 3	Pass
	l) Separation distances from the initiating BESS unit to target BESS units (D and H in Figure 9.1);	See Attachment 3	Pass
	m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	See Attachment 6	Pass
	n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;	See Attachment 6	Pass
	o) The maximum incident heat flux on target wall surfaces and target BESS units;		N/A
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;		N/A
	q) Gas generation and composition data	See Attachment 10	Pass
	r) Peak smoke release rate and total smoke release data;	See Attachment 11	Pass
	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 system installed for the test.	N/A
	t) Observation of flying debris or explosive discharge of gases;	See Attachment 5	Pass
	u) Observation of re-ignition(s) from thermal runaway events;	See Attachment 5	Pass
	v) Observation(s) of sparks, electrical arcs, or other electrical events;	See Attachment 5	Pass
	w) Observations of the damage to:	See Attachment 1	Pass
	1) The initiating BESS unit;	See Attachment 1	Pass
	2) Target BESS units;	See Attachment 1	Pass
	3) Adjacent walls, ceilings, or soffits; and	See Attachment 1	Pass
	x) Photos and video of the test.	See Attachment 1 and 20230510-1.mp4 and 20230510-2.mp4	Pass
9.8	**Performance at unit level testing**		--
9.8.1	Installation level testing in Section 10 is not required if the performance conditions outlined in Table 9.1 are met during the unit level test.		Pass
	Non-Residential Installations		--
Indoor Floor Mounted	a) Flaming outside the initiating BESS unit is not observed;		Pass
	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;		Pass
	c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15;	Exceed 97°C. The system should be installed in non-combustible construction.	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	Additional engineering consideration for flammable gas removal, or something to that effect need further evaluation.	Pass
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.		Pass
Outdoor Ground Mounted	a) If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.	Not observed	Pass
	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;		Pass
	c) For BESS units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15;	Exceed 97°C. The system should be installed in non-combustible construction.	Pass
	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	Additional engineering consideration for flammable gas removal, or something to that effect need further evaluation.	Pass
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.		Pass
Indoor Wall Mounted	a) Flaming outside the initiating BESS unit is not observed;		Pass
	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;		Pass
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15;	Exceed 97°C. The system should be installed in non-combustible construction.	Pass
	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	Additional engineering consideration for flammable gas removal, or something to that effect need further evaluation.	Pass
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.		Pass
Outdoor Wall Mounted	a) Flaming outside the initiating BESS unit is not observed;		Pass
	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;		Pass
	c) For BESS units intended for installation on walls with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15;	Exceed 97°C. The system should be installed in non-combustible construction.	Pass

ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and	Additional engineering consideration for flammable gas removal, or something to that effect need further evaluation.	Pass
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.		Pass
Rooftop and Open Garages	a) If flaming outside the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test;		N/A
	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;		N/A
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15;		N/A
	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		N/A
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.		N/A
	Residential Installations		**N/A**
Indoor Floor Mounted	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;		N/A
	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;		N/A
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15;		N/A
	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		N/A
	e) The concentration of flammable gas does not exceed 25% LFL in air for the smallest specified room installation size.		N/A
Outdoor Ground Mounted	a) If flaming outside of the unit is observed, separation distances to exposures shall be determined by greatest flame extension observed during test.		N/A
	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;		N/A

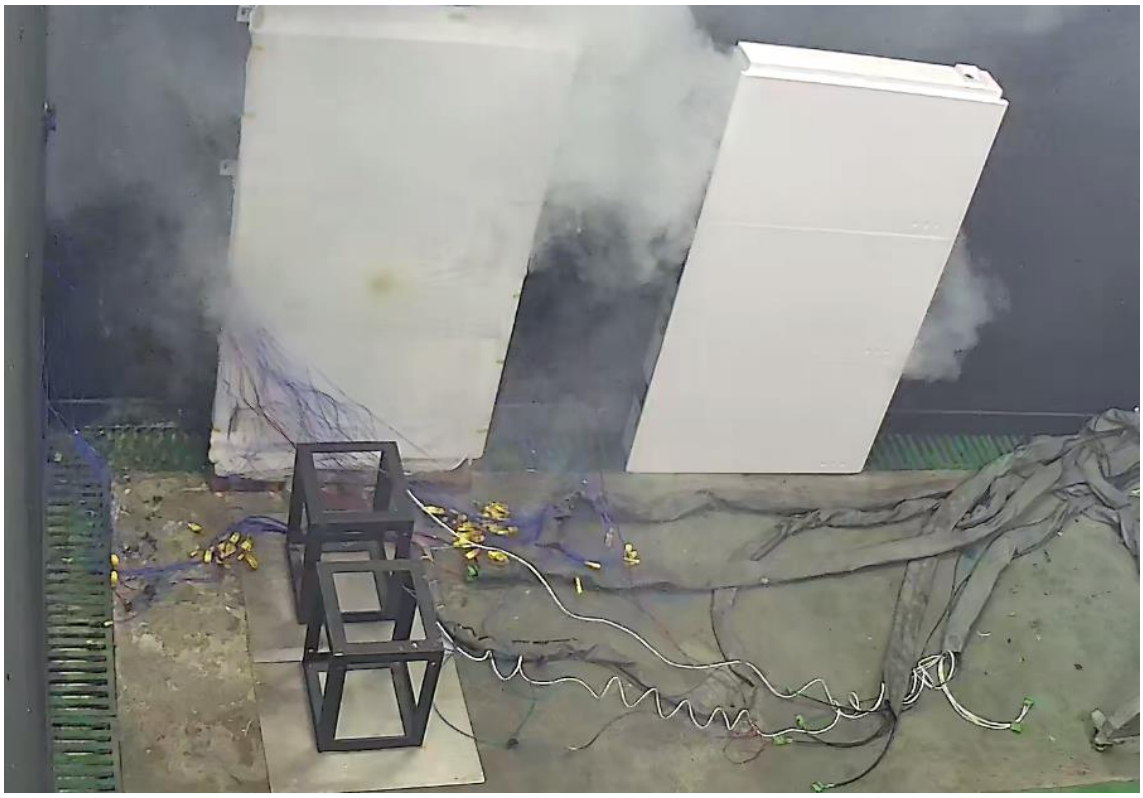
ANSI/CAN/UL 9540A			
Clause	Requirement – Test	Result - Remark	Verdict
	c) For BESS units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15;		N/A
	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases; and		N/A
	e) Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m2.		N/A
Indoor Wall Mounted	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;		N/A
	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;		N/A
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15;		N/A
	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		N/A
	e) The concentration of flammable gas does not exceed 25% LFL for the smallest intended room installation size.		N/A
Outdoor Wall Mounted	a) Flaming outside the initiating BESS unit is not observed as demonstrated by no flaming or charring of the cheesecloth indicator;		N/A
	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;		N/A
	c) For BESS units intended for installation in locations with combustible construction, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient per 9.2.15; and		N/A
	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.		N/A

Attachment 1 Photos

The battery system before test

Front side

During test



Smoke release from initiating unit

The battery system after test

Front side

Internal view of initiating module, after test

Attachment 2 Sample preparation

The battery system consists of 3 modules and 3 BMS, 3 modules was considered as a unit, total 3 complete modules and 3 empty modules (target unit) were provided for the test.

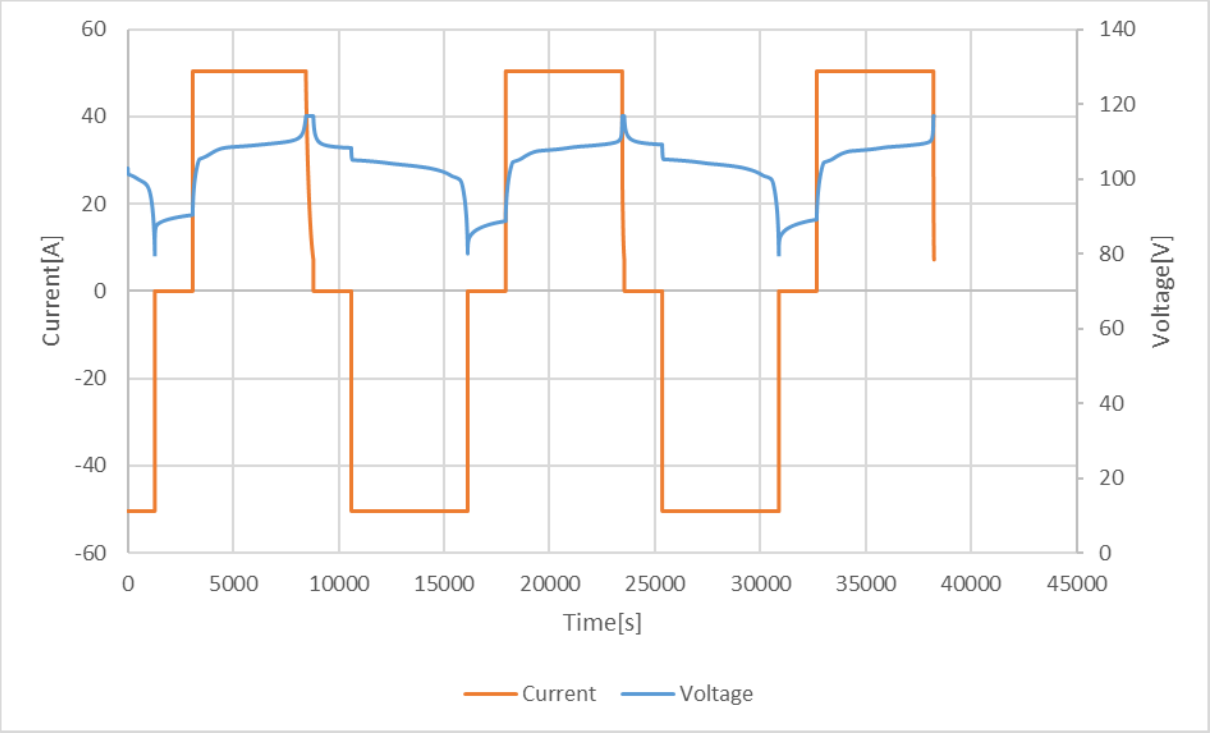
The unit were conditioned, prior to testing, through charge and discharge cycles for 2 cycles per the manufacturer's instructions to verify that the unit was functional.

As manufacturer specified, the unit was charged with 50A* current to unit end charge voltage 115.2V, then keep the unit stabilized for 30 minutes (not shown). After being stabilized, the unit was discharged, the unit was discharged with 50A* current to unit end discharge voltage 89.6V, then keep the unit stabilized for 30 minutes (not shown). (* represent one module's charge/discharge current, total four modules. Three modules Parallel use, inside with cells and a module only with an empty enclosure)

After repeating the cycle above twice and then unit was fully charged with 50A* current to unit end charge voltage 115.2V, and before testing, the unit was stabilized for about 4 hours. (* represent one module's charge/discharge current)

During conditioning the ambient temperature was maintained at 25 ±5°C and 50 ±15% RH.

The cycling curve of the initiating unit is shown below.



Initiating unit charge and discharge voltage/current profiles

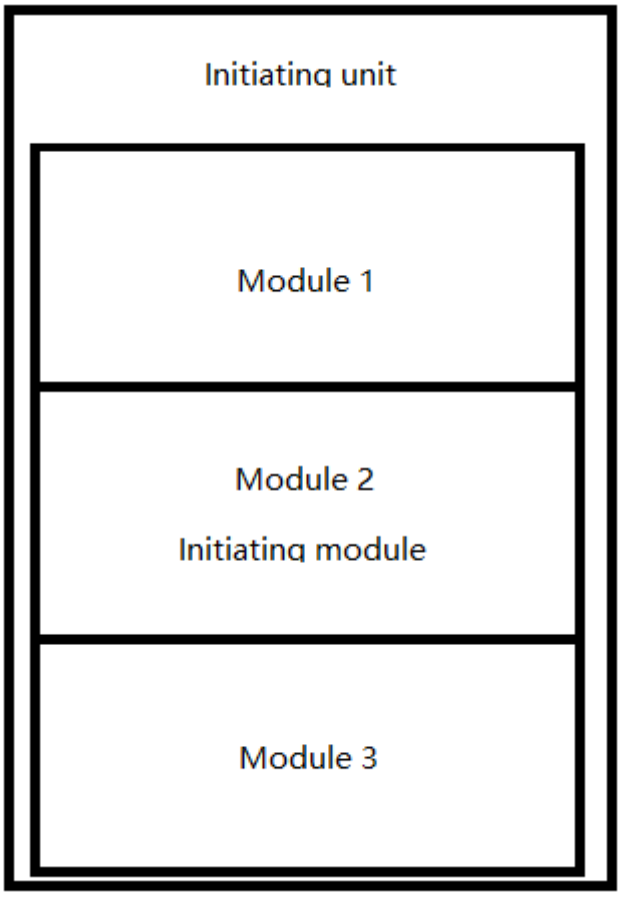
Attachment 3 Arrangement of the unit

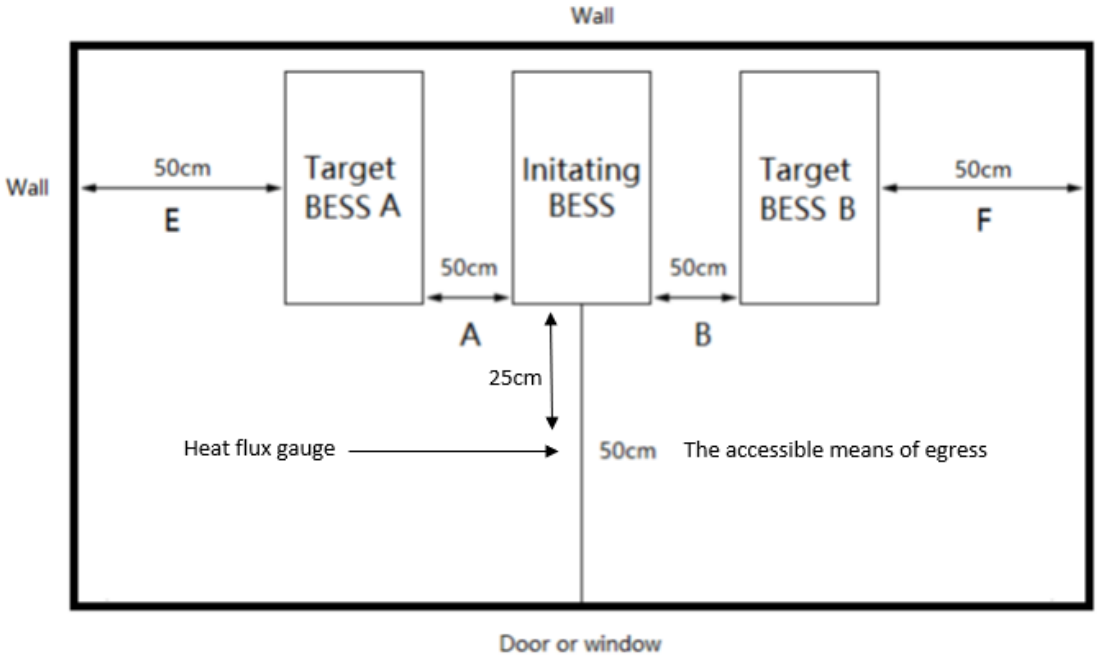
The installation information was provided by the client as below.

Intended use location .....:	☐ Residential	☒ Non-residential
	☐ Non-residential rooftop	
	☐ Non-residential open garage use	
Type of installation .....:	☒ Indoor	☒ Outdoor
	☒ Floor/ground mounted	☒ Wall mounted
Row(s) of installation	☒ Single	☐ Multiple

Three instrumented walls (wall A, wall B, wall C) were used for the test. Walls were constructed of 16 mm (5/8-inch) gypsum painted flat black.

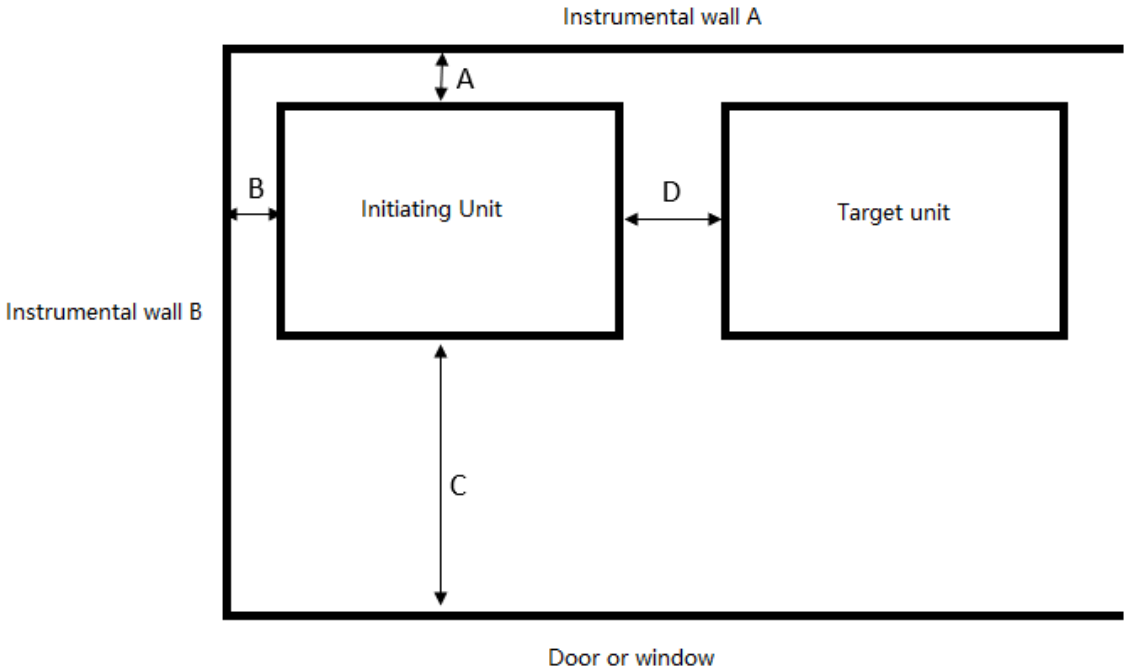
One unit was used for the purpose of the test. To identify the modules in each unit, the modules in each unit were numbered as the figure below.





Top view of the unit arrangement

Minimum separation distance from the units to instrumental walls were shown in below figure. Top view of the unit arrangement and separation distance from units to instrumental walls are shown in below figure. Due the weight and size of the unit, the accuracy of the distance may have a 0.5 cm tolerance.



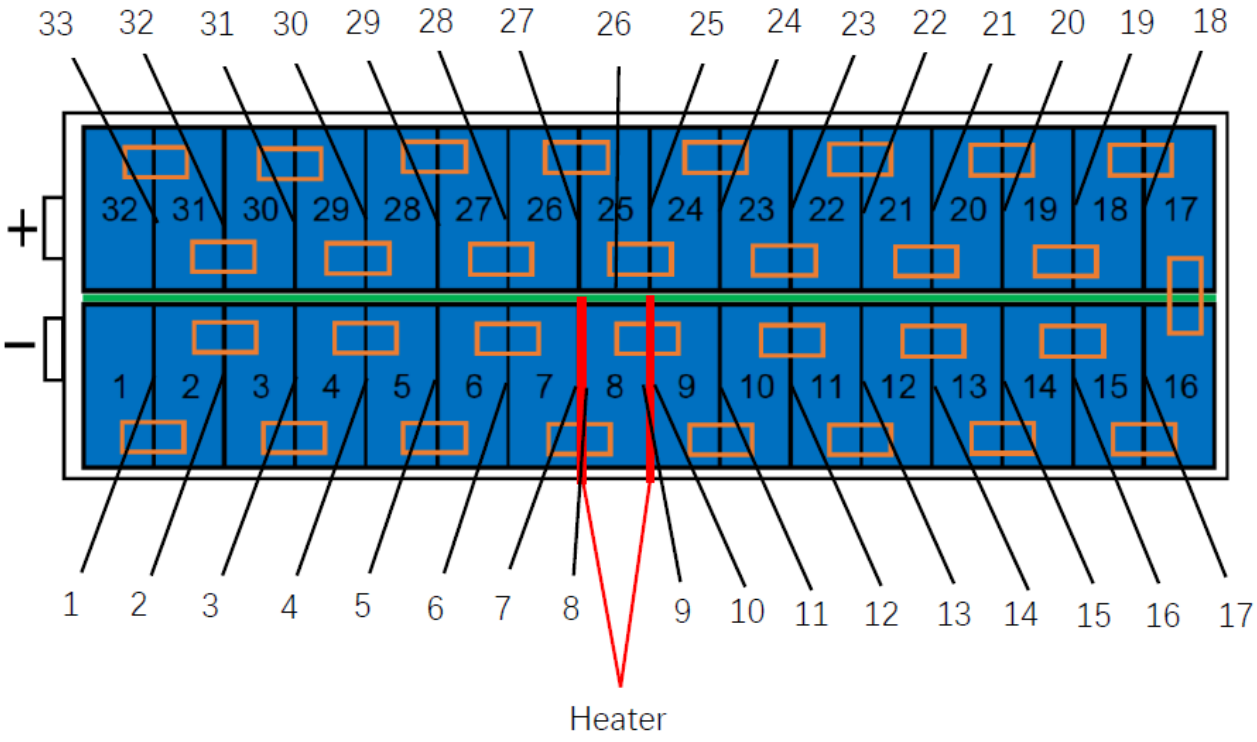
A= min.4cm	B= min.50cm	C= min. 50cm	D= min. 50cm

Attachment 4 Thermal runaway preparation

Module 2 in initiating unit was selected as the initiating module.

The initiating module was charged to 100% SOC and allowed to stabilize for a minimum of 1 h and a maximum of 8 h before the start of the test.

External heating method was used to initiate thermal runaway in the module. 2 flexible film heaters, rated 220VAC/300W each, sized 127X101.6mm, were pasted on two big sides of Cell 8.



Cell 8 was heated as the target cell at a rate of 4°C-7°C per minute until thermal runaway was occurred When thermal runaway occurred, the heater will de-energized immediately.

Attachment 5 Observations and records

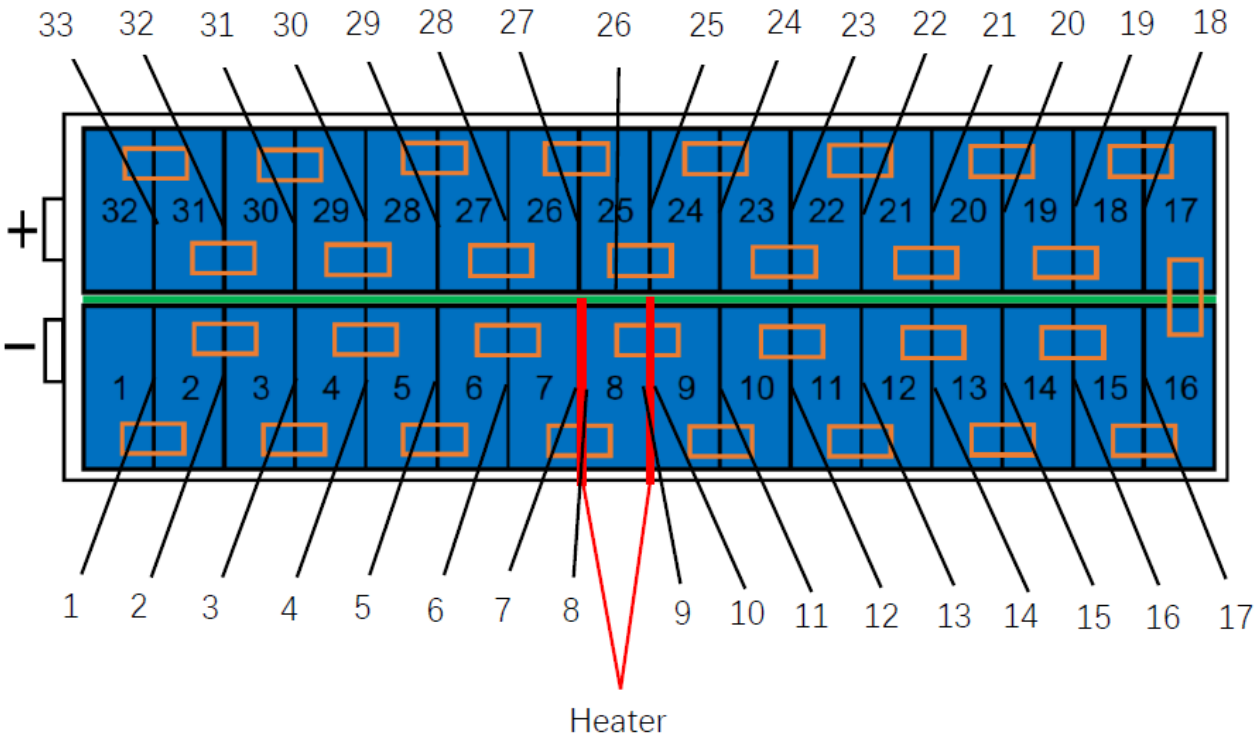
Before the test, the initiating module was charged to 100% SOC and stabilized for about 4 h before the start of the test.

Below table summarizes the details:

Ambient conditions at the initiation of the test:	26°C 53%RH			
Electronics and software controls within the module?	☒ Yes, but not relied upon for this testing ☐ No such controls			
Time when test was initiated:	15 June 2023, 10:00 AM			
Observations during test:	1st vented	11:46	1st thermal runaway	11:47
	2nd vented	11:50	2nd thermal runaway	11:51
	3rd vented	11:58	3rd thermal runaway	11:59
	4th vented	12:00	4th thermal runaway	12:01
	5th vented	12:04	5th thermal runaway	12:05
	6th vented	12:12	6th thermal runaway	12:15
	7th vented	12:16	7th thermal runaway	12:16
	8th vented	12:17	8th thermal runaway	12:17
	9th vented	12:18	9th thermal runaway	12:18
	10th vented	12:19	10th thermal runaway	12:19
	11th vented	12:22	10th thermal runaway	12:22
	12th vented	12:23	10th thermal runaway	12:23
	12th vented	12:27	10th thermal runaway	12:28
	12th vented	12:29	10th thermal runaway	12:29
	12th vented	12:31	10th thermal runaway	12:31
	No flying debris or explosive discharge of gases. No sparks, electrical arcs, or other electrical events. No external flaming was observed			
Post-test evaluation:	In initiating unit, no thermal runaway propagation from initiating module to rest modules in initiating unit. In initiating module, Cell 8 went to thermal runaway, due to external heating. all cells vented and went to thermal runaway. The rise temperature on the wall exceeds the limit temperature. This system should be installed in non-combustible construction. No damage on target units.			

Attachment 6 Temperature measurements

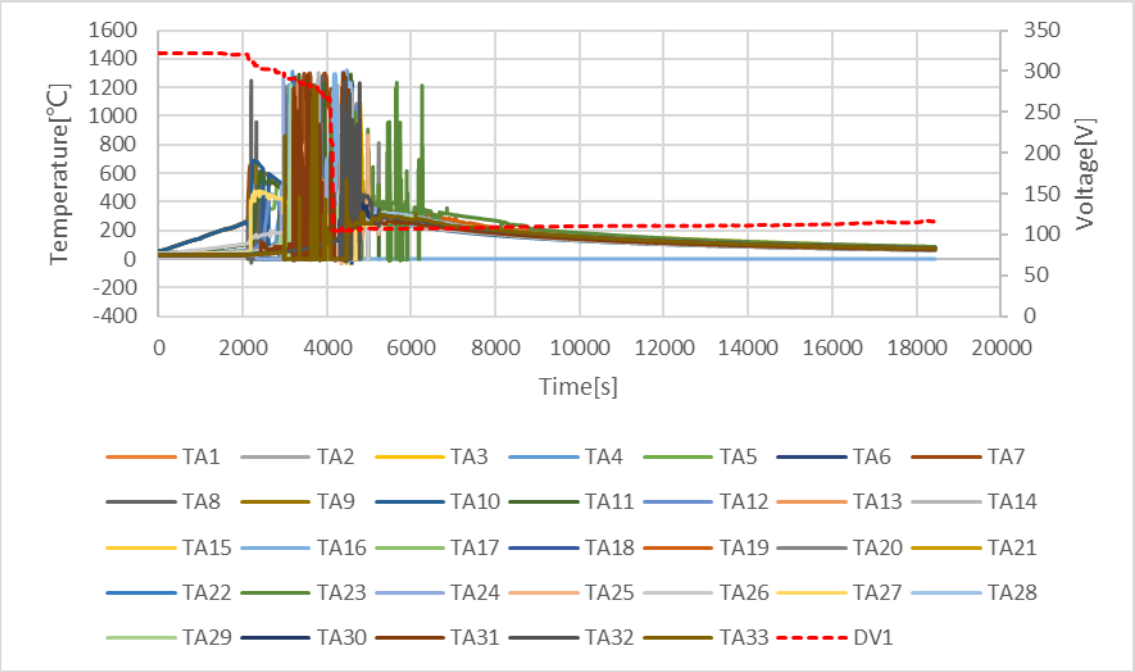
To monitor the cells temperature inside the module, 33 thermocouples, Type K, were used. See below figure and table for detail location of the film heaters and thermocouples.



Flexible film heaters and thermocouples location inside the module

Thermocouple No.	Thermocouple location on initiating module 2
1	Centre of big side of cell 1 facing cell 2
2	Centre of big side of cell 2 facing cell 3
3	Centre of big side of cell 3 facing cell 4
4	Centre of big side of cell 4 facing cell 5
5	Centre of big side of cell 5 facing cell 6
6	Centre of big side of cell 6 facing cell 7
7	Centre of big side of cell 7 facing cell 8
8	Centre of big side of cell 8 facing the heater
9	Centre of big side of cell 8 facing the heater
10	Centre of big side of cell 9 facing cell 8
11	Centre of big side of cell 10 facing cell 9
12	Centre of big side of cell 11 facing cell 10
13	Centre of big side of cell 12 facing cell 11
14	Centre of big side of cell 13 facing cell 12
15	Centre of big side of cell 14 facing cell 13
16	Centre of big side of cell 15 facing cell 14
17	Centre of big side of cell 16 facing cell 15
18	Centre of big side of cell 17 facing cell 18
19	Centre of big side of cell 18 facing cell 19
20	Centre of big side of cell 19 facing cell 20
21	Centre of big side of cell 20 facing cell 21
22	Centre of big side of cell 21 facing cell 20
23	Centre of big side of cell 22 facing cell 23
24	Centre of big side of cell 23 facing cell 24
25	Centre of big side of cell 24 facing cell 25
26	Centre of big side of cell 25 facing cell 8
27	Centre of big side of cell 26 facing cell 25
28	Centre of big side of cell 27 facing cell 26
29	Centre of big side of cell 28 facing cell 27
30	Centre of big side of cell 29 facing cell 28
31	Centre of big side of cell 30 facing cell 29
32	Centre of big side of cell 31 facing cell 30
33	Centre of big side of cell 32 facing cell 31

Temperature describing cell to cell propagation in initiating module and initiating unit voltage are show in below figure.

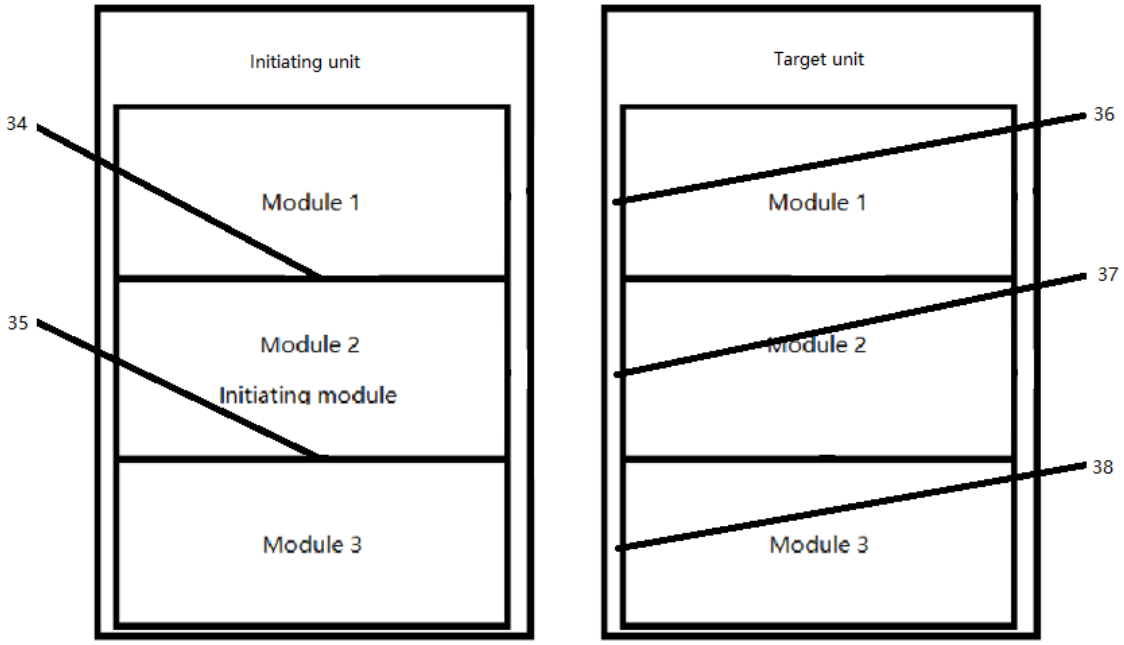


The maximum measured temperature of each location is shown in below table.

Thermocouple No.	Thermocouple location on initiating module 2	Maximum temperature (°C)
TA1	Centre of big side of cell 1 facing cell 2	504.9
TA2	Centre of big side of cell 2 facing cell 3	305.5
TA3	Centre of big side of cell 3 facing cell 4	488.5
TA4	Centre of big side of cell 4 facing cell 5	547.7
TA5	Centre of big side of cell 5 facing cell 6	517.2
TA6	Centre of big side of cell 6 facing cell 7	391.2
TA7	Centre of big side of cell 7 facing cell 8	580.2
TA8	Centre of big side of cell 8 facing the heater	411.3
TA9	Centre of big side of cell 8 facing the heater	648.6
TA10	Centre of big side of cell 9 facing cell 8	685.8
TA11	Centre of big side of cell 10 facing cell 9	608.7
TA12	Centre of big side of cell 11 facing cell 10	536.8
TA13	Centre of big side of cell 12 facing cell 11	583.6
TA14	Centre of big side of cell 13 facing cell 12	408.4
TA15	Centre of big side of cell 14 facing cell 13	439.5
TA16	Centre of big side of cell 15 facing cell 14	458.2
TA17	Centre of big side of cell 16 facing cell 15	506.4
TA18	Centre of big side of cell 17 facing cell 18	312.2
TA19	Centre of big side of cell 18 facing cell 19	337.8
TA20	Centre of big side of cell 19 facing cell 20	377.8
TA21	Centre of big side of cell 20 facing cell 21	357.3
TA22	Centre of big side of cell 21 facing cell 20	425.2
TA23	Centre of big side of cell 22 facing cell 23	387.2
TA24	Centre of big side of cell 23 facing cell 24	324.4

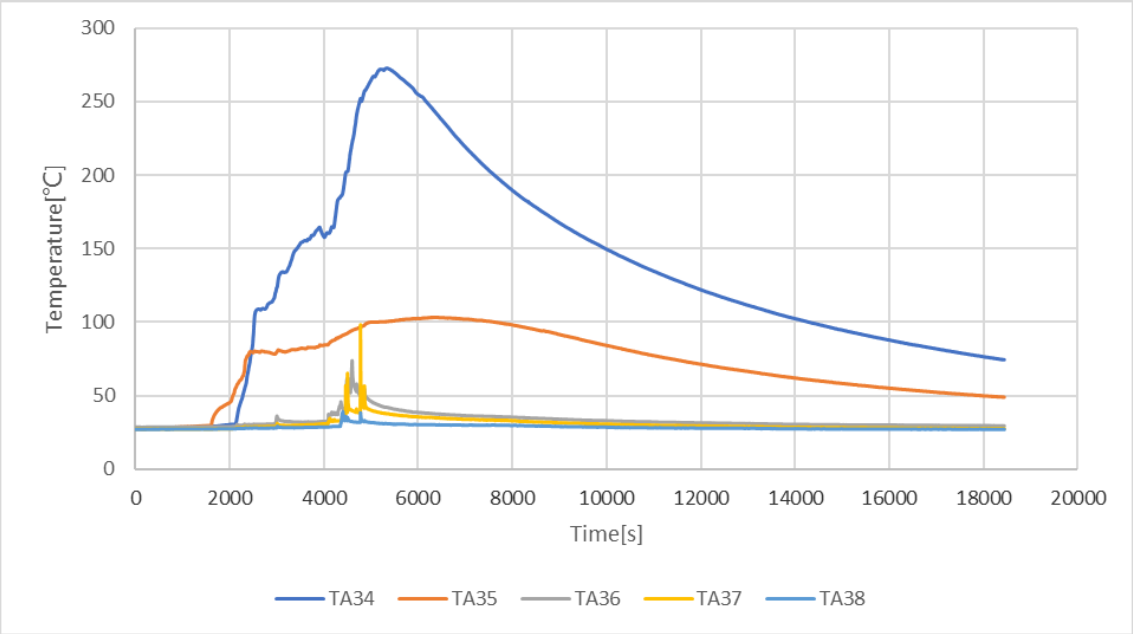
TA25	Centre of big side of cell 24 facing cell 25	306.6
TA26	Centre of big side of cell 25 facing cell 8	301.9
TA27	Centre of big side of cell 26 facing cell 25	474.9
TA28	Centre of big side of cell 27 facing cell 26	329.7
TA29	Centre of big side of cell 28 facing cell 27	370.8
TA30	Centre of big side of cell 29 facing cell 28	502.5
TA31	Centre of big side of cell 30 facing cell 29	287.7
TA32	Centre of big side of cell 31 facing cell 30	418.3
TA33	Centre of big side of cell 32 facing cell 31	306.5
Max. system voltage, after test		
DV1	115.9V	

To monitor the surface temperature of modules in the initiating unit, 2 thermocouples (numbered 34 and 35) and the modules in the target unit 3 thermocouples (numbered 36 - 38) were used, detailed location was shown in below figure and table.



Thermocouple's location in initiating unit and target unit (Front View)

The measured surface temperature of modules in initiating unit and target unit during test is shown in below figure.

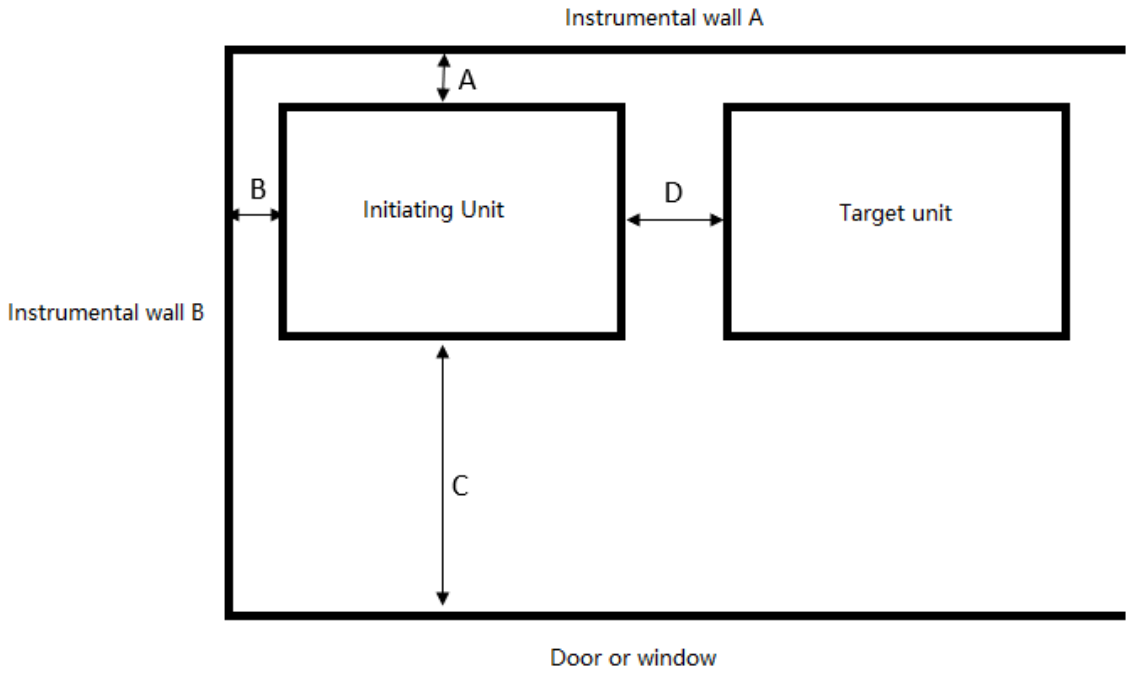


The maximum measured temperature of each location is shown in below table.

Thermocouple No.	Location	Maximum measured temperature (°C)
TA34	Metal enclosure, between module 1 and module 2	272.8
TA35	Metal enclosure, between module 2 and module 3	103.3
Metal enclosure of target unit		
TA36	Target module 1, side	73.8
TA37	Target module 2, side	97.5
TA38	Target module 3, side	39.0

To monitor the surface temperature of instrumental walls, vertical array at 152 mm intervals for the full height of the instrumented wall sections using Type K, 30 AWG thermocouples were used.

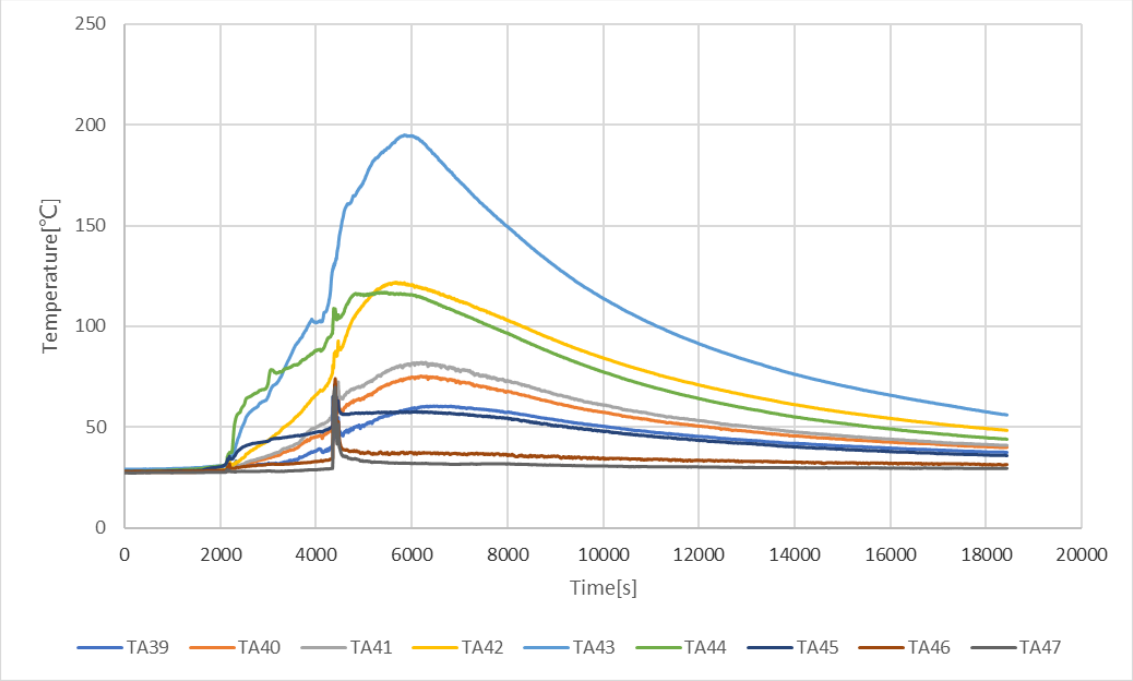
The thermocouple array A was on instrumental wall A, collinear with vertical central line of initiating unit front surface.
The thermocouple array B was on instrumental wall B, collinear with vertical central line of initiating unit left surface.
The detailed locations of the thermocouple arrays are shown in the below figure.



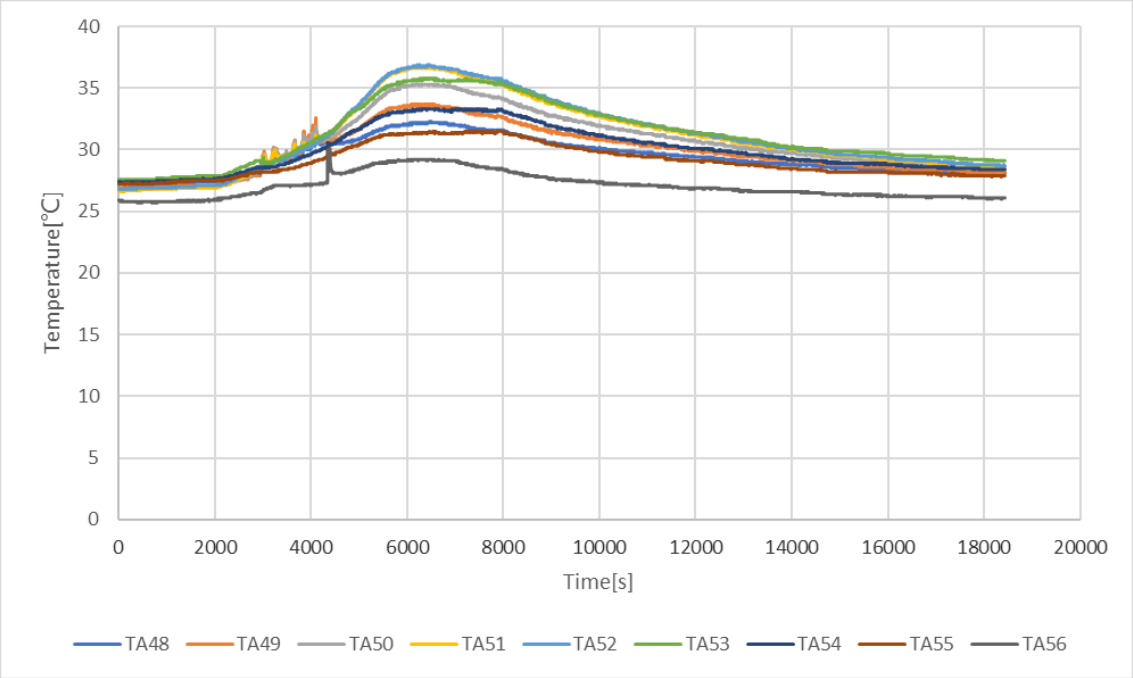
Thermocouple array location (view side: top view)

The first thermocouple starts from 152 mm from the ground. A total of 18 thermocouples were used for array A and array B. The thermocouples were numbered from low to high as TA1 to TA9 for thermocouple array A, TA10 to TA18 for thermocouple array B.

The measured surface temperature of instrumental wall A during test is shown in the below figure.



The measured surface temperature of instrumental wall B during test is shown in the below figure.

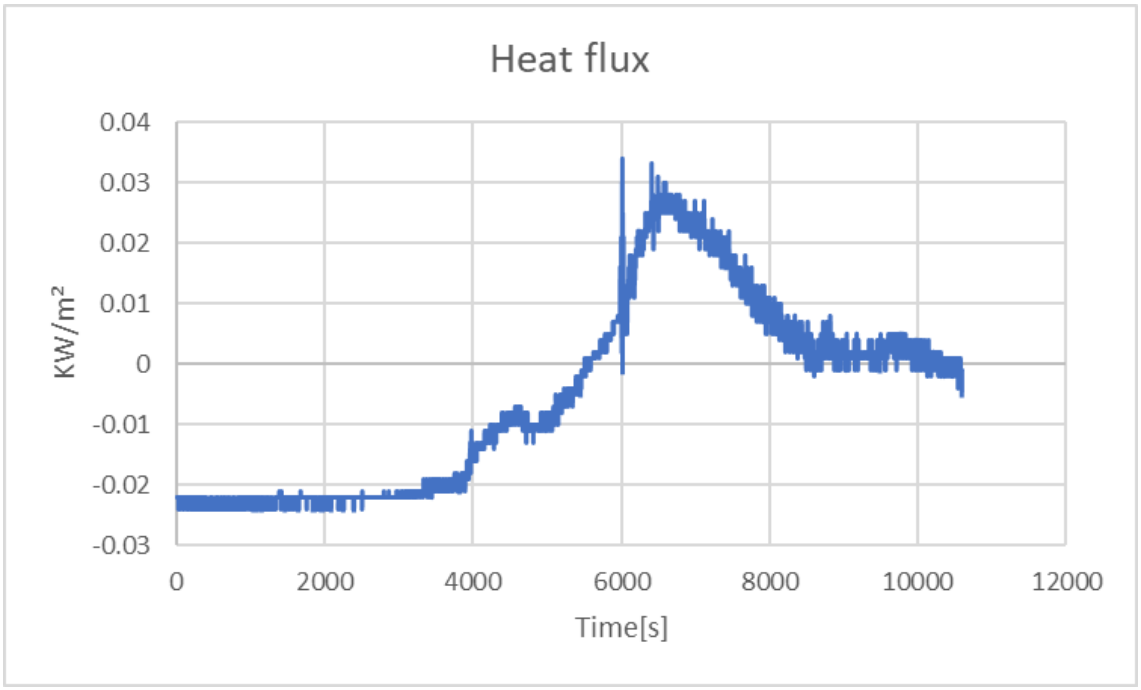


The maximum measured surface temperature of each location on instrumental wall A and Wall B is shown in the below table.

Thermocouple No.	Maximum temperature (°C)
Surface temperature on wall A (Back side of the unit)	
TA39	60.5
TA40	75.4
TA41	82.2
TA42	121.9
TA43	195.0*
TA44	117.0
TA45	71.5
TA46	74.1
TA47	69.9
Surface temperature on wall B (Left side of the unit)	
TA48	32.3
TA49	33.7
TA50	35.3
TA51	36.7
TA52	36.9
TA53	35.8
TA54	33.3
TA55	31.5
TA56	30.1
Remark: Ambient temperature is 28°C, limit temperature rise is 97°C, so the max. temperature is 125°C. ***: Due to the temperature of wall exceed 125°C, this system should be installed in non-combustible construction.**	

Attachment 7 Heat flux measurements

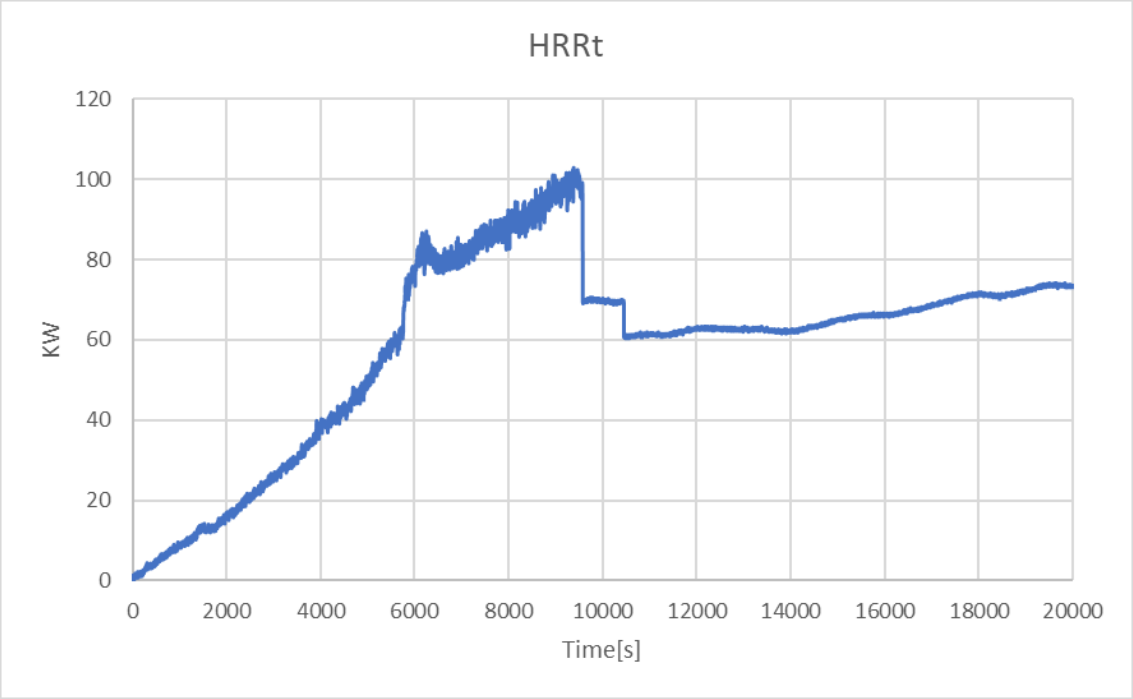
Measure Heat flux in the center of the accessible means of egress: max. 0.034KW/m²



Attachment 8 Chemical heat release rate measurement

The chemical heat release rate was measured by a measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple. The instrumentation was located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influence of bends or exhaust devices.

Measured peak chemical heat release rate HRRt: 102.93 kW.



Chemical heat release rate (HRRt) versus time data curve

Attachment 9 Convective heat release rate measurement

The convective heat release rate was measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct.

The convective heat release rate was calculated at each of the flows as follows:

$$HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$$

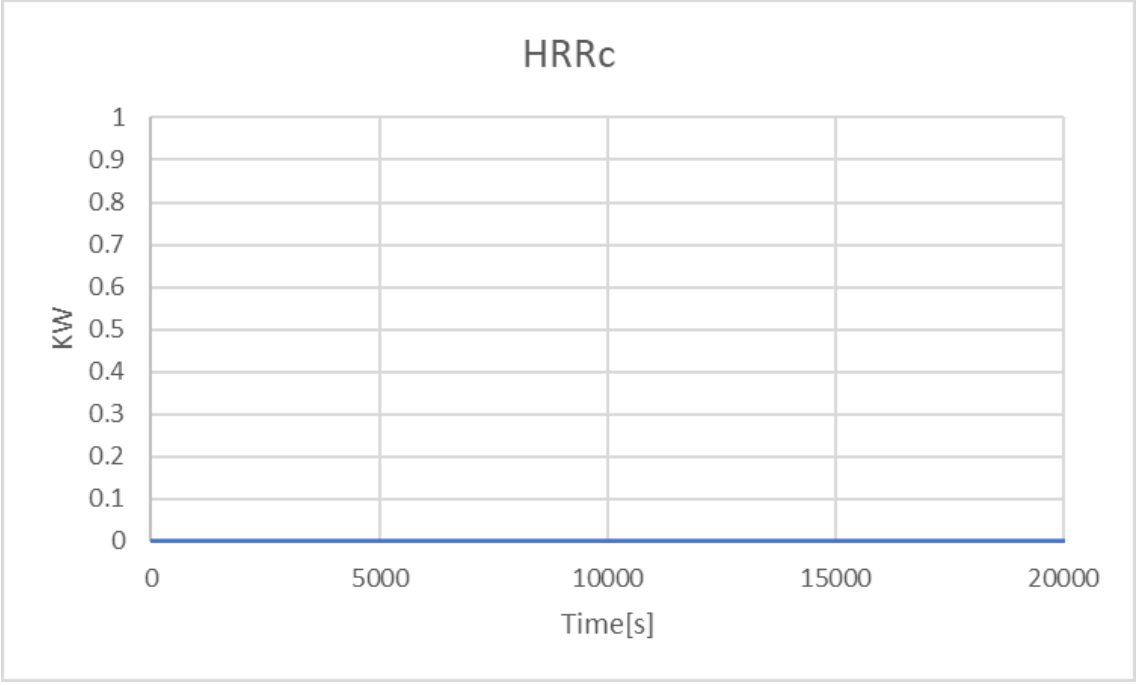
Where:

HRR_c = The convective heat release rate (kW)
V_e = The exhaust velocity (m/s)
A = The exhaust duct cross sectional area (m^2)
T_e = The temperature at the location where exhaust velocity is measured (K)
$353.22/T_e$ = The density of air at the velocity measurement location (kg/m^3)
T_o = The ambient temperature (K) in the test room
T= The thermopile temperature (K)

$$\int_{T_o}^{T} C_p dT = A_0(T - T_o) + A_1/2(T^2 - T_o^2) + A_2/3(T^3 - T_o^3) + A_3/4(T^4 - T_o^4)$$

Cp = Specific heat of air (kJ/kg-K), given as *Cp = A0 + A1T + A2T2 + A3T3*, where:
A0 = 0.9950
A1 = -5.29933E-05
A2 = 3.21022E-07
A3 = -1.22004E-10

The measured peak convective heat release rate HRRc was 0 kW.



Convective heat release rate (HRRc) versus time data curve

Attachment 10 Gas generation measurement

Vent gas composition were measured using a Fourier-Transform Infrared Spectrometer with a resolution of 0.5 cm^{-1} and a path length of 5.11 m within the calorimeter's exhaust duct. And the composition, velocity and temperature of the vent gases were measured within the calorimeter's exhaust duct.

The hydrocarbon content of the vent gas was measured using flame ionization detection.
The Hydrogen content was measured with a palladium-nickel thin-film solid state sensor, a heat conduction sensor and an electrochemistry sensor.

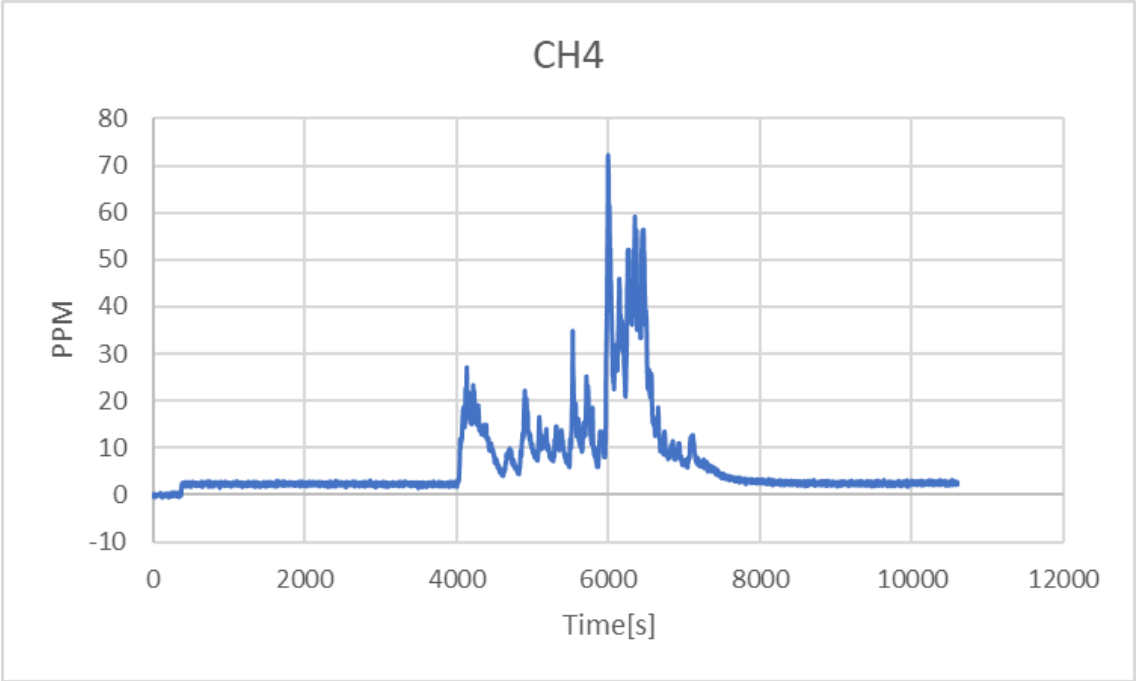
The Hydrogen was not detected by the palladium-nickel thin-film solid state sensor and heat conduction sensor. The Hydrogen content value in the below table was measured by electrochemistry sensor.

The gas composition and volume are shown in the below table.

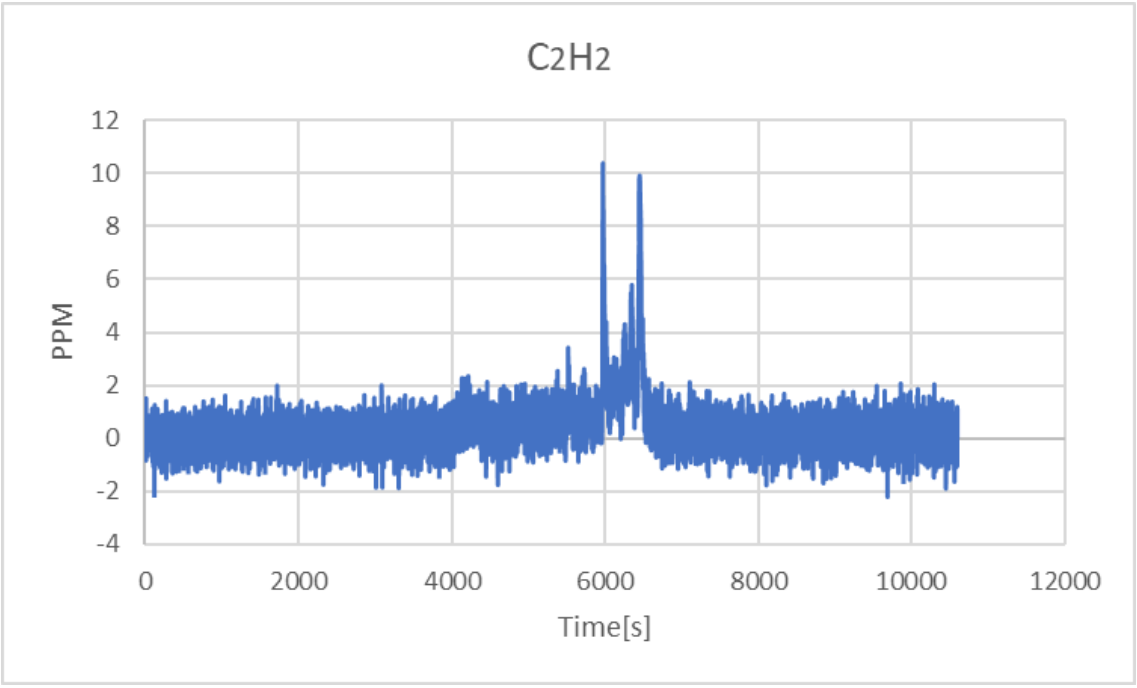
Gas type	Gas components		Total volume of gas (L)
Hydrocarbon species	Methane	CH_4	125.38
	Acetylene	C_2H_2	6.60
	Ethylene	C_2H_4	101.03
	Ethane	C_2H_6	23.95
	Propylene	C_3H_6	198.51
	Propane	C_3H_8	71.80
Hydrogen halide species	Hydrogen Fluoride	HF	122.13
Other species	Carbon Monoxide	CO	130.06
	Carbon Dioxide	CO_2	8520.73
	Ethylmethyl carbonate	C_4H_8O	639.50
	Oil as octane	--	56.86
	Hydrogen	H_2	0
Total Hydrocarbons (equivalent to C_3H_8, measured by FID)			1570.30

Concentration of different gas components according to gas species classification was displayed as following graphs.

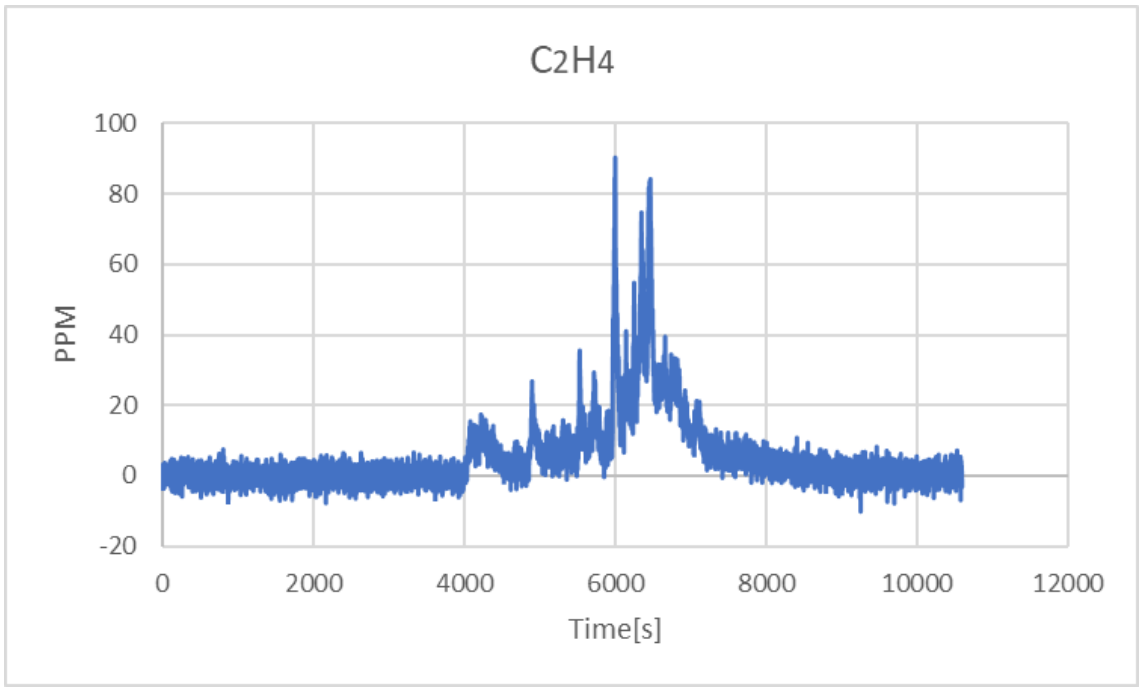
Hydrocarbon species



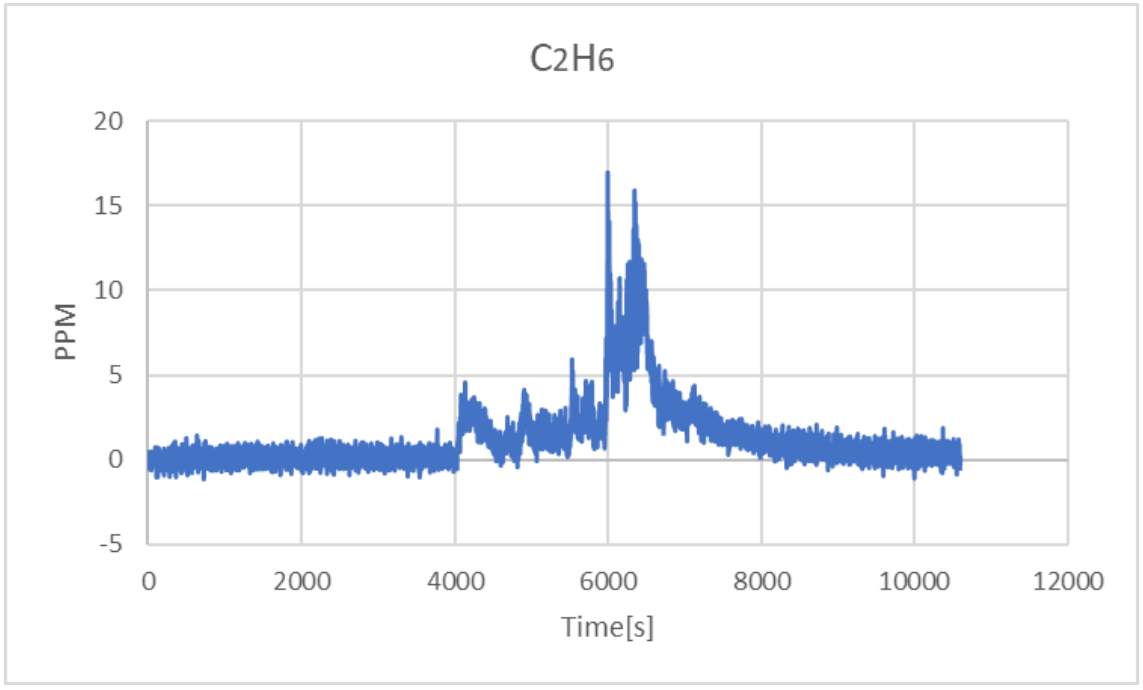
Concentration of Methane (CH_4)



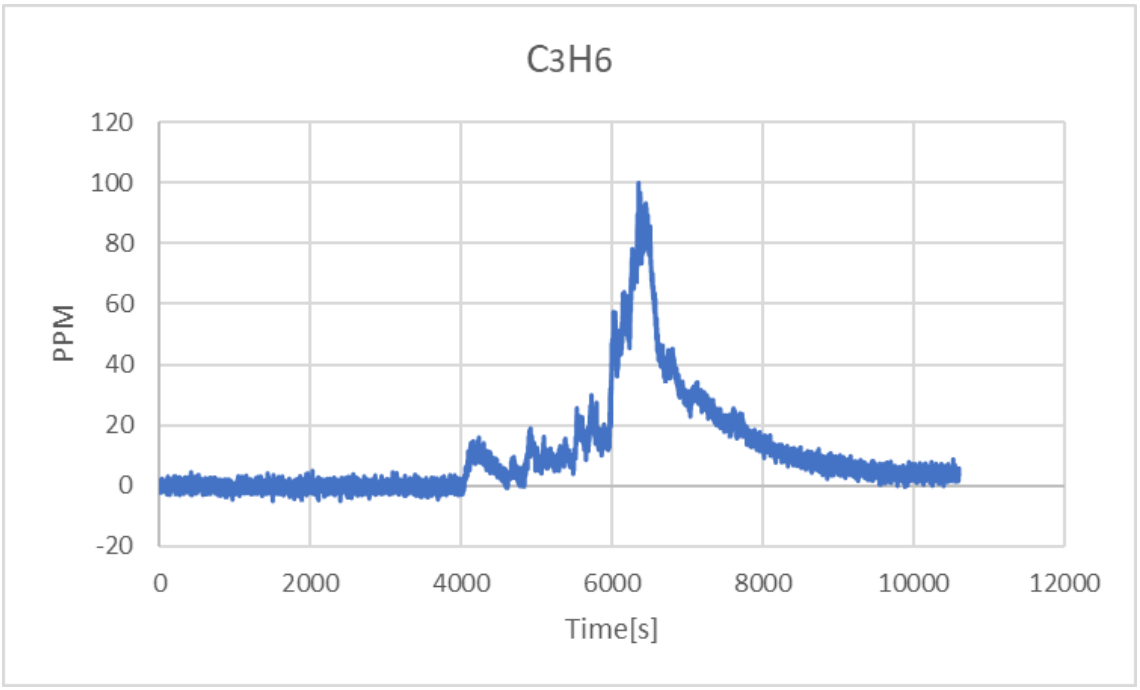
Concentration of Acetylene (C_2H_2)



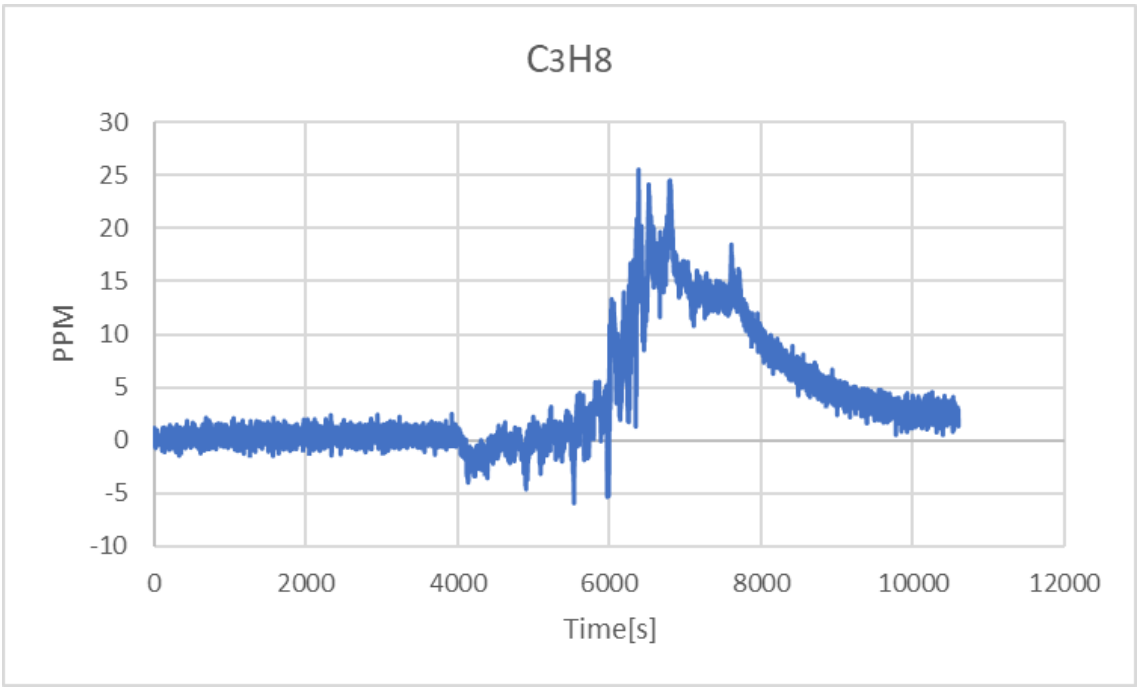
Concentration of Ethylene (C_2H_4)



Concentration of Ethane (C_2H_6)

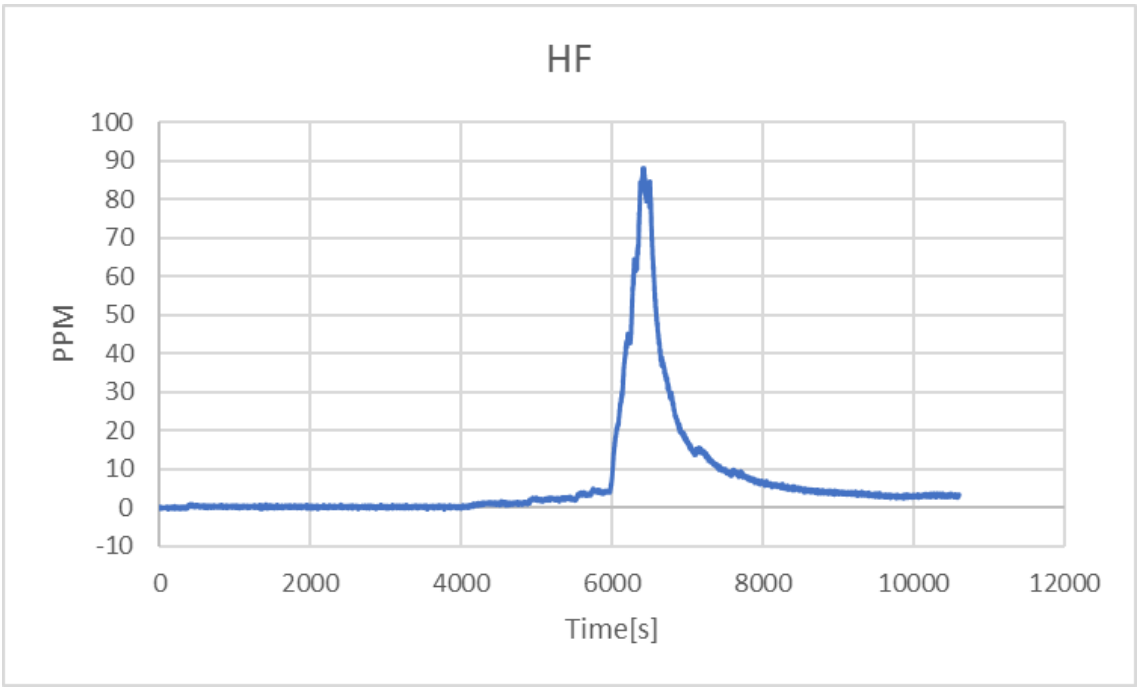


Concentration of Propylene (C_3H_6)



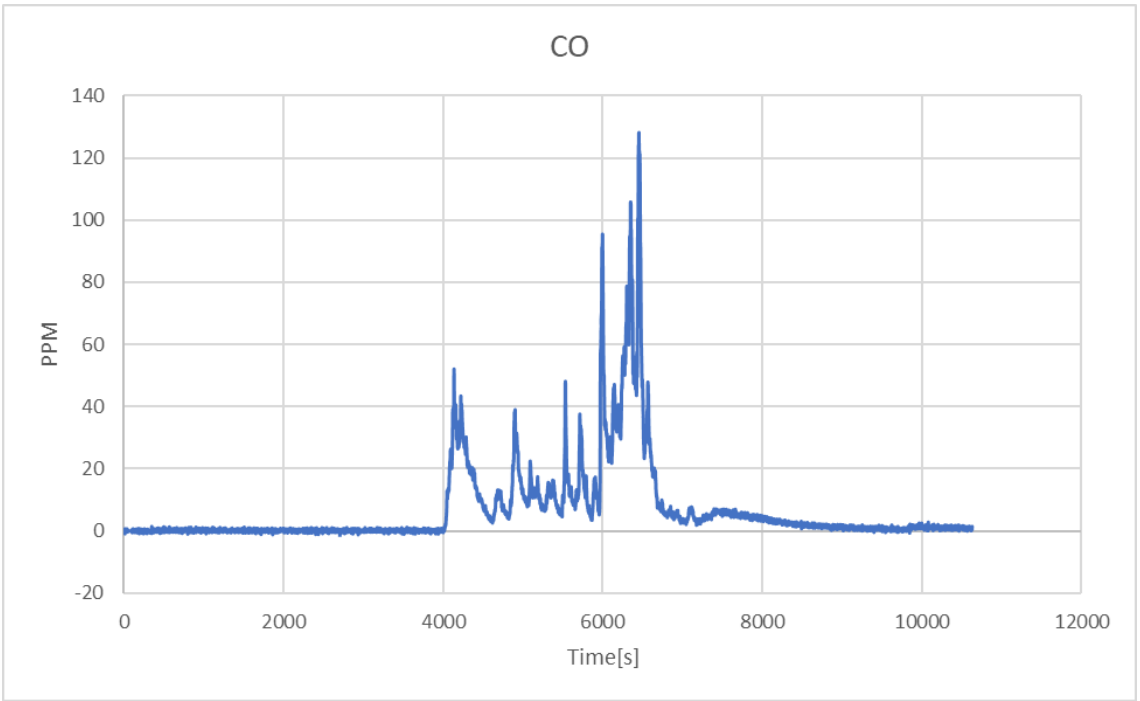
Concentration of Propane (C_3H_8)

Hydrogen halide species

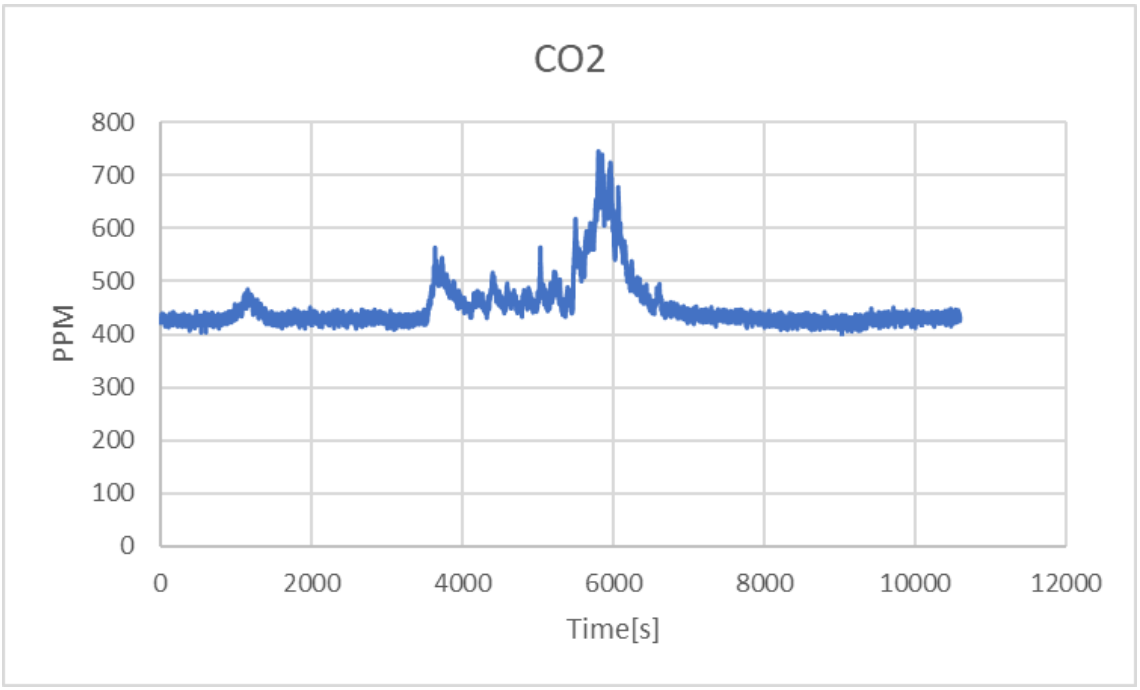


Concentration of Hydrogen Fluoride (HF)

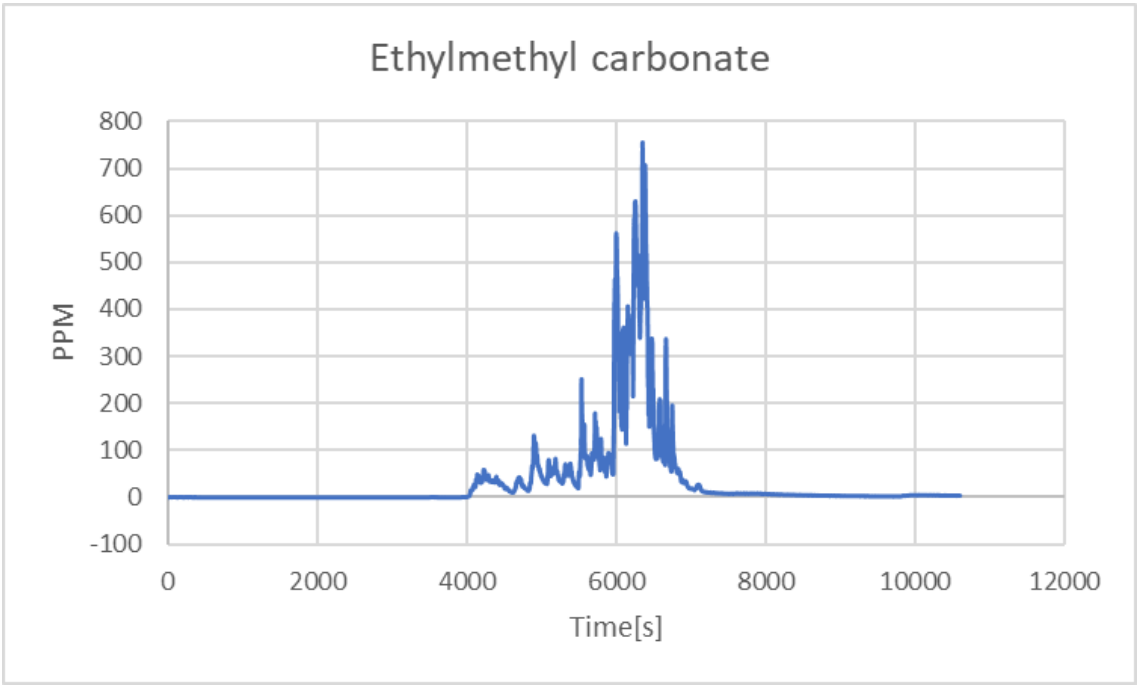
Other species



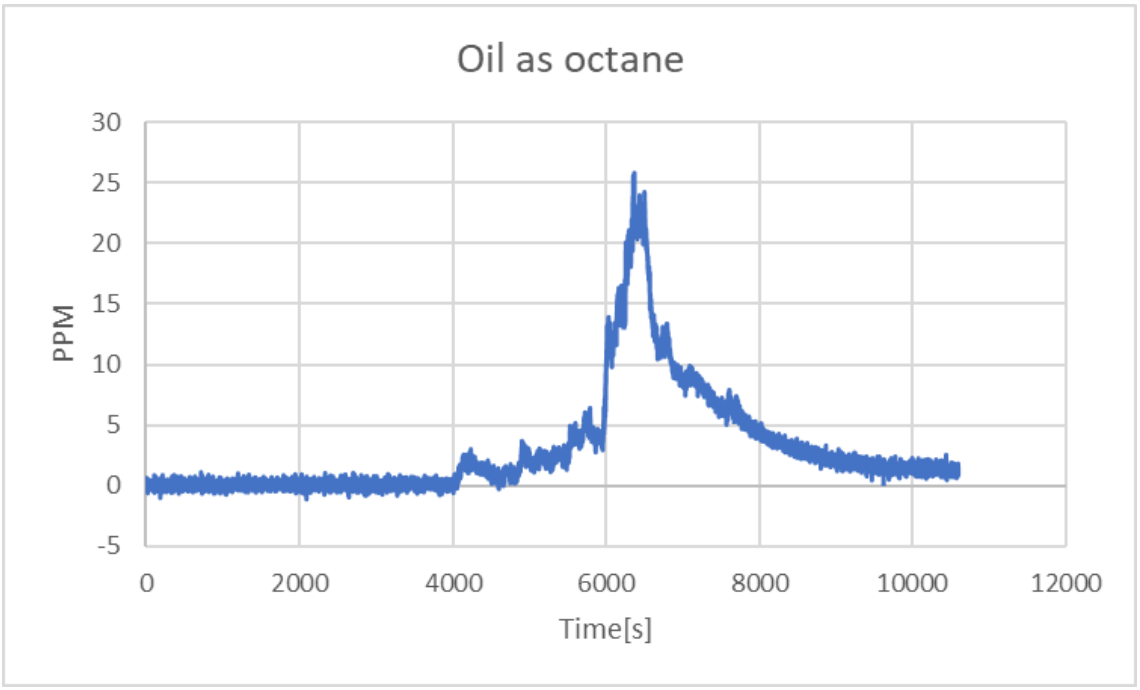
Concentration of Carbon Monoxide (CO)



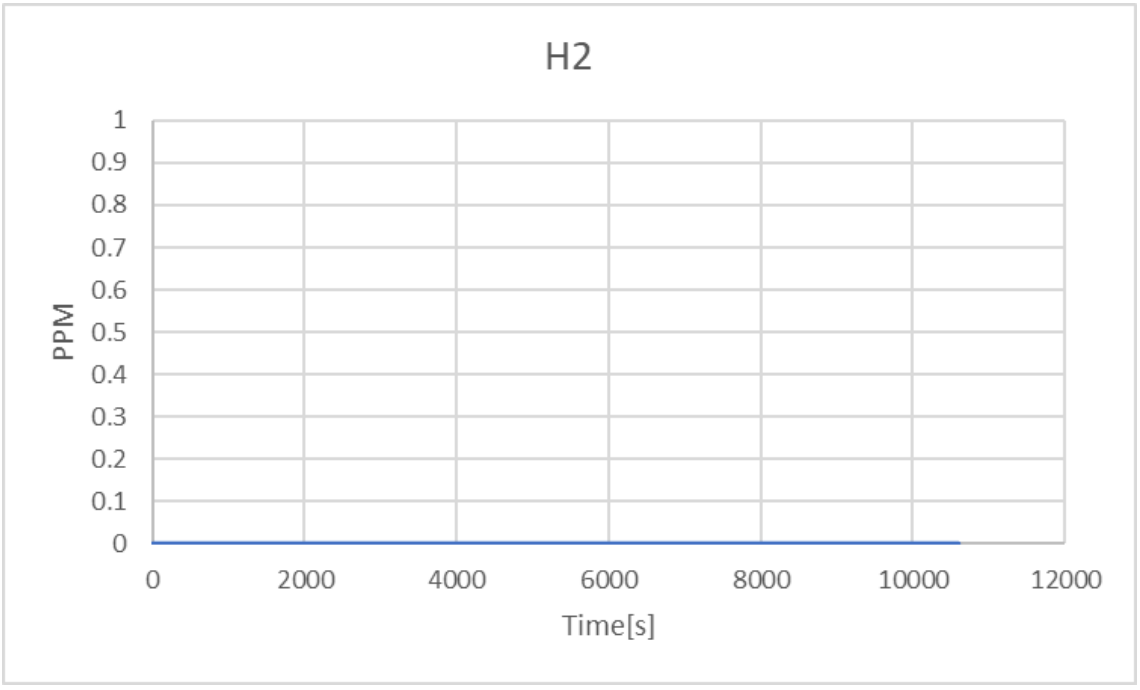
Concentration of Carbon Dioxide (CO_2)



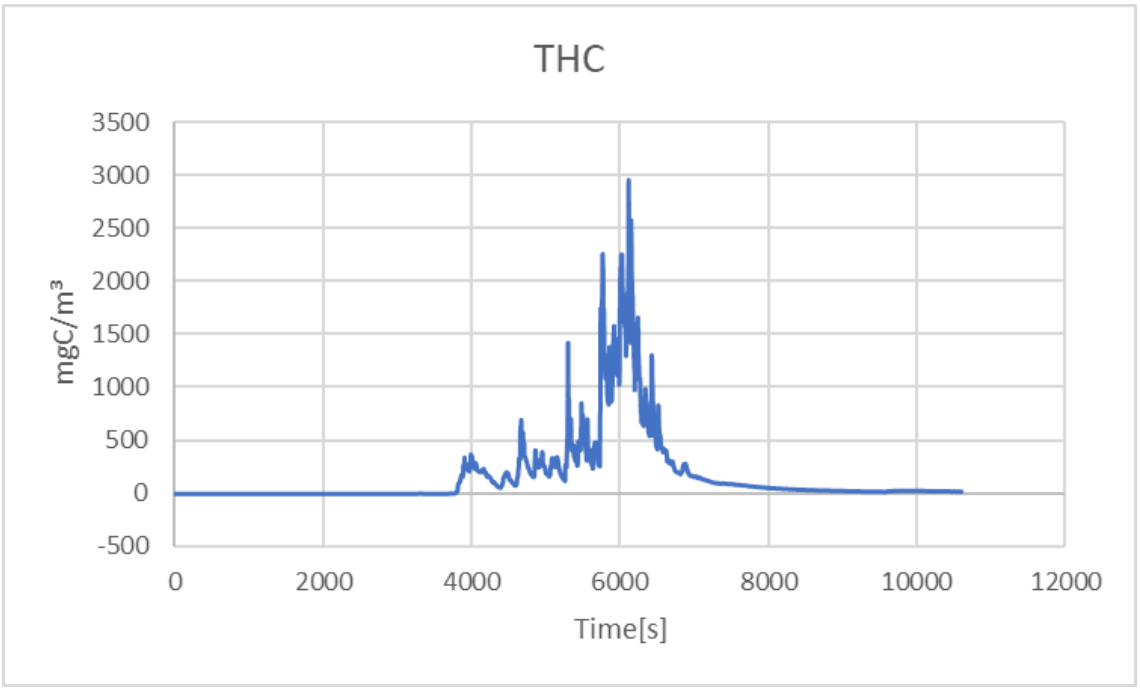
Concentration of Ethylmethyl carbonate



Concentration of Oil as octane



Concentration of Hydrogen (H2)
Electrochemical sensor



Concentration of total hydrocarbons (measured by FID)

Attachment 11 Smoke release rate measurement

Smoke release rate shall be calculated as follows:

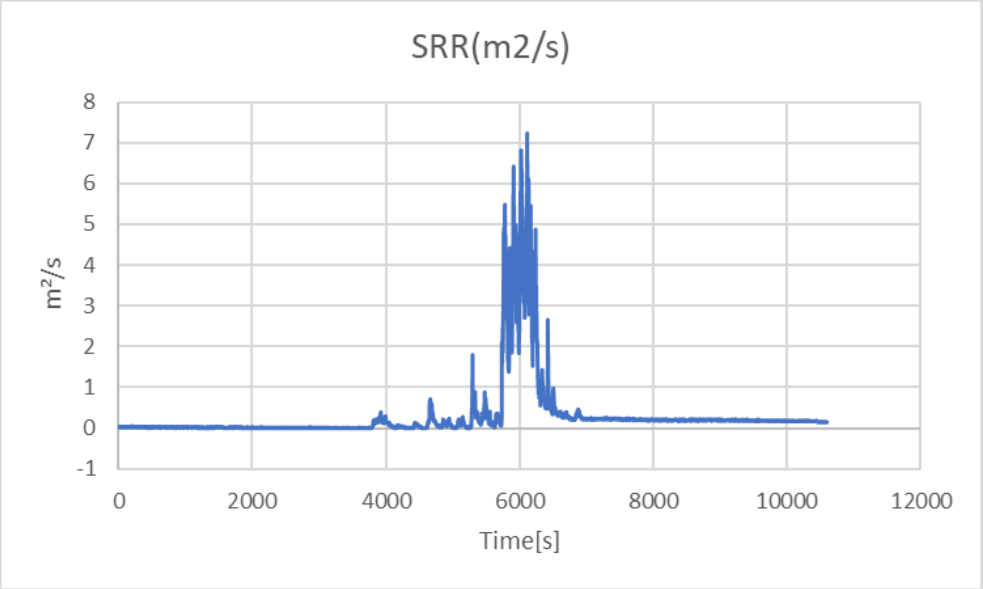
$$SRR = 2.303\left(\frac{V}{D}\right) Log_{10}\left(\frac{I_o}{I}\right)$$

Where:
SRR = Smoke release rate (m^2/s)
V = Volumetric exhaust duct flow rate (m^3/s)
D = duct diameter (m)
Io = Light transmission signal of clear (pre-test) beam (V)
I = Light transmission signal during test (V)

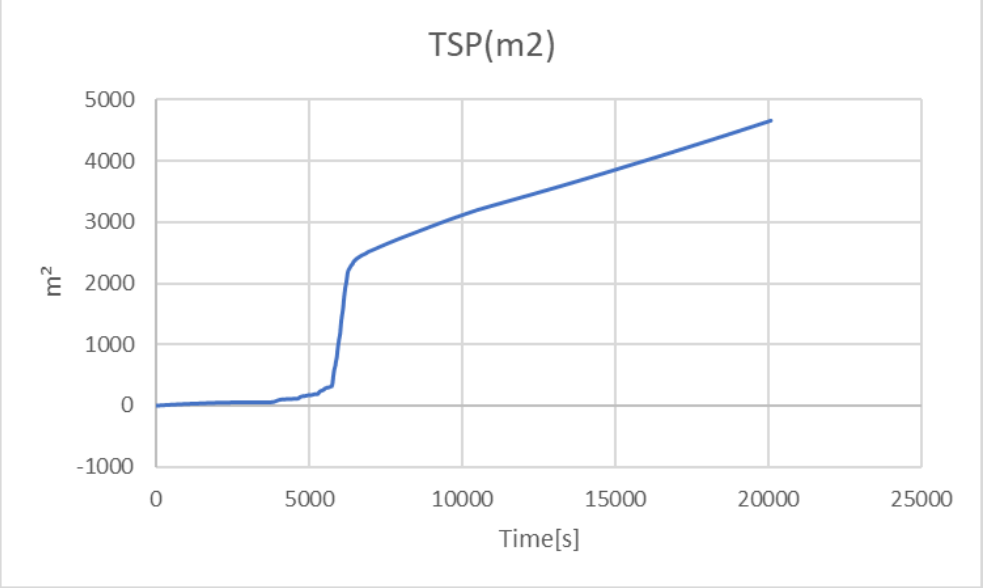
The smoke release rate measurement system was self-checked using calibrated light filter before test.

Measured peak smoke release rate SRR: 7.216m^2/s
Measured total smoke release TSR: 4659.74m^2

Smoke release rate (SRR) versus time data curve



Total smoke release (TSR) versus time data curve



Attachment 12 Equipment list

No.	Equipment	Model	Rating	Inventory no.	Last Cal. date
1	Ambient monitor	RS210	0%RH to 100%RH/ +/- 3%RH, -20°C to 70°C /±0.5°C	SA047-177	2022-10-24
2	Digital multi-meter	175	ac/dc mV: (0.1~600) mV ac/dc V: (0.001~1) kV	SA012-179	2023-01-04
3	Electronic Balance	TC150KA	0-150kg	SA028-24	2022-10-08
4	Charge /discharge equipment	BAT-NE-250-V001	Max 900V, 400A	SA064-40	2022-08-06
5	3MW lithium battery heat release calorimeter	RHR	(0-1100) °C	SA200-69	2022-09-01
6	Gas analyzer	ABB AO2020	O_2: 0-25% CO_2: 0-10% CO: 0-1%	SA200-69-01	2022-09-09
7	The total hydrocarbon gas analyzer	ABB EL3020	TCH: 0-10000ppm CH_4: 0-10000ppm, C_3H_8: 0-3300ppm	SA200-70	2022-09-09
8	Palladium-nickel hydrogen analyzer	H2SCAN 710B	0.1%-10%	SA200-71	2022-09-09
9	On-line Fourier infrared analyzer	MKS 6030	$500cm^{-1}$-$4200cm^{-1}$ 0.01ppm-100%	SA200-72	2022-09-09
10	Temperature and voltage acquisition device	60 channels	(0-1100)°C	SA200-73	2022-09-01
11	Electrochemical hydrogen analyzer	JKBS-J001-H2-Y05	0-1000ppm	SA200-74	2022-09-09

End of test report