Laboratory Test Data – UL 9540A Checklist and Test Result

ORIGINAL TEST DATA

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Master Contract:	302250	Model:	eVault Max	Page number 1 of 38
Project / Network:	80128223	Description:	Li-ion battery rack for stationary applications	

Standard(s): ANSI/CAN/UL 9540A:2019 Fourth Edition, Dated November 12, 2019 - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Testing Laboratory Name:	CCIC-CSA International Certification Co., Ltd. Kunshan Branch
Address:	Building 8, Tsinghua Science Park, No. 1666 Zu chongzhi Rd (S) , Kunshan, Jiangsu (215347)
Testing Program:	**Custom Test:** Cover Letter [ ] Testing Only [X]
	Note: Mark " X " in applicable test program block

If tests were performed at another facility, then described below:

Testing Laboratory Name:	Shanghai Huahui Testing Co.，Ltd
Address:	No. 158, Changbangcun Road, Fengxian District, Shanghai, China
Facility Qualification Number:	260091

	As above / or describe otherwise
Customer:	Fortress Power LLC
Address:	505 Keystone Rd, Southampton, Pennsylvania 18966 United States

Tested By: Nan Wang, Technician(Huahui)
Name, Title

Nan Wang — 2022-05-18
Signature — *Date (YYYY-MM-DD)*

☐ **Reviewed by:**
☒ **Witnessed by:** Austin Chen/Joseph Zhou, Certifier(CSA Group)
Name, Title

Joseph Zhou — 2022-05-18
Signature — *Date (YYYY-MM-DD)*

Version4 : 01/25/2021

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Product Details	
Test Request:	☐ Cell Level Testing ☐ Module Level Testing ☒ Unit Level Testing ☐ Installation Level Testing
Manufacturer	☐ Cell: ☐ Module: ☒ Unit: Fortress Power LLC
Brand name / Trademark	☐ Cell: ☐ Module: ☒ Unit: N/A
Model Number	☐ Cell: ☐ Module: ☒ Unit: eVault Max
Date of receipt of test sample(s)	2022-05-10 (YYYY-MM-DD)
Cell/Battery Type	Li-ion(LFP)
Approximate Dimension (mm)	☐ Cell: ☐ Module: ☒ Unit: W*D*H: 515 ±5 mm * 515 ±5 mm * 1073 ±5 mm
Mass (kg)	☐ Cell: ☐ Module: ☒ Unit: 235
DUT Sample/Serial Number	☐ Cell: ☐ Module: ☒ Unit: DUT1,DUT2
DUT Nominal Voltage Rating (V)	☐ Cell: ☐ Module: ☒ Unit: 51.2V
DUT Nominal Charge Capacity Rating (Ah)	☐ Cell: ☐ Module: ☒ Unit: 360Ah@0.5C
Fire Mitigation Strategies: (For installation level testing)	☐ Water: ☐ Other (Specify): ☒ N/A
Additional Information	N/A

THE TESTING SPECIFIED IN THIS PROCEDURE IS INHERENTLY DANGEROUS

DO NOT ATTEMPT TO PERFORM THIS TEST UNLESS YOU HAVE BEEN PROPERLY TRAINED REGARDING SAFELY WORKING WITH THE HAZARDS INVOLVED

Important Test Consideration:

- As some batteries expose in test described above, it is important that personnel be protected from the flying fragments, explosive force, and sudden release of heat, chemical burns, and noise resulting from such explosions. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases.
- Temperature of the surface of the battery casing shall be monitored during the tests described above. All personnel involved in the testing of batteries are to be instructed never to approach a battery until the surface temperature returns to ambient temperature.
- Test shall be conducted in separate room or equipped with an adequate safety barrier separating the test area from observer.

UL 9540 A – Definition

-“BATTERY ENERGY STORAGE SYSTEM (BESS)” - Stationary equipment that receives electrical energy and then utilizes batteries to store that energy to supply electrical energy at some future time. The BESS, at a minimum consists of one or more modules, a power conditioning system (PCS), battery management system (BMS) and balance of plant components.

NOTE: For flow battery systems the energy is stored within one or more electrolyte storage tanks.

a) INITIATING BATTERY ENERGY STORAGE SYSTEM UNIT (INITIATING BESS) – A BESS unit which has been equipped with resistance heaters in order to create the internal fire condition necessary for the installation level test (Section 9).
b) TARGET BATTERY ENERGY STORAGE SYSTEM UNIT (TARGET BESS) – The enclosure and/or rack hardware that physically supports and/or contains the components that comprise a BESS. The target BESS unit does not contain energy storage components, but serves to enable instrumentation to measure the thermal exposure from the initiating BESS.

-“BATTERY SYSTEM” - Is a component of a BESS and consists of one or more modules typically in a rack configuration, controls such as the BMS and components that make up the system such as cooling systems, disconnects and protection devices.

-“CELL” - The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, separators, container, and terminals. It is a source of electrical energy by direct conversion of chemical energy.

-“DUT” - Device under test.

-“ELECTRICAL RESISTANCE HEATERS” - Devices that convert electrical energy supplied from a laboratory source into thermal energy.

-“END OF DISCHARGE VOLTAGE (EODV)” - The manufacturer's specified minimum voltage level during discharge.

-“ENERGY RESERVOIR” - The solution which stores the active energy in the flow battery energy storage system. This can be in the form of one electrolyte, two electrolytes, or one electrolyte with solid metal particles.

-“FLEXIBLE FILM HEATERS” - Electrical resistance heaters of a film, tape or otherwise thin sheet like construction that easily conform to the surface of cells.

-“FLOW BATTERY” - A battery technology that stores its active materials in the form of one or more electrolytes (with or without solid metal particles) within one or more storage tanks, and when operating, the electrolytes are transferred between the reactor (battery stacks) and the storage tanks

NOTE 1: Three commercially available flow battery technologies are zinc air, zinc bromine and vanadium redox.

NOTE 2: Unlike a fuel cell system, a flow battery is a closed system and has no net consumption of fuel.

-“MAXIMUM SURFACE TEMPERATURE END POINT” - The final hold temperature measured on the cell case after conducting the thermal ramp when using the external heater method to achieve thermal runaway of the cell.

-“MODULE” - A subassembly that is a component of a BESS that consists of a group of cells or electrochemical capacitors connected either in a series and/or parallel configuration (sometimes referred to as a block) with or without protective devices and monitoring circuitry.

-“MONOBLOC” - A battery design with a common case containing one or more internal cells, electrolyte, a vent or pressure relief valve assembly, intercell connections and hardware. A typical example of a common monobloc battery is an SLI lead acid battery.

-“NON-RESIDENTIAL USE” - Intended for use in commercial, industrial or utility owned locations.

-“RESIDENTIAL USE” - In accordance with this standard, intended for use in one or two family homes and townhomes and individual dwelling units of multi-family dwellings.

-“STATE OF CHARGE (SOC)” - The available capacity in a BESS, pack, module or cell expressed as a percentage of rated capacity.

-“THERMAL RUNAWAY” - The incident when an electrochemical cell increases its temperature through self-heating in an uncontrollable fashion. The thermal runaway progresses when the cell's generation of heat is at a higher rate than the heat it can dissipate. This may lead to fire, explosion and gas evolution.

-“UNIT” - A frame, rack or enclosure that consists of a functional BESS which includes components and subassemblies such as cells, modules, battery management systems, ventilation devices and other ancillary equipment.

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ANSI/CAN/UL 9540A:2019 Fourth Edition, Dated November 12, 2019 - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Section	Requirement	Test (T) / Waive (W) / Not App. (N/A)	Comments
5	General		
5.1	Cell	N/A	Cell testing conducted by TÜV SÜD New Energy Testing (Guangdong) Co.,Ltd during report no. 64.280.21.60315.01 issue date 2022-07-22
5.1.1	The cells associated with the BESS were tested.	---	See Attachment Att.1_UL 9540A_Cell Level test report for Cell Level testing data provided by manufacturer
5.1.2	Cells associated with the BESS comply with UL 1973	---	Cell comply with UL 1973, see attachment Att.2_UL 1973 Certificate_LFP48173170E-120Ah
5.1.3	Cell level test report	---	Cell testing conducted by TÜV SÜD New Energy Testing (Guangdong) Co.,Ltd. during report no. 64.280.21.60315.01, issue date 2022-07-22.
5.2	Module	N/A	Module testing not requested by manufacturer
5.2.1	The module associated with the BESS were tested.	--	Module testing not requested by manufacturer
5.2.2	Modules associated with the BESS comply with UL 1973	---	See Attachment 3 for module certificate complying UL 1973 provided by manufacturer
5.2.3	Module level test report	---	Module testing not requested by manufacturer
5.3	Battery energy storage system unit	T	Test Conducted
5.3.1	BESS were tested.	---	Manufacturer Name: Fortress Power LLC Model: eVault Max Nominal Voltage: 51.2V BESS Capacity (Ahr): 360Ah@0.5C BESS Energy (Whr): 18.5
5.3.2	BESS comply with UL 9540	---	See Attachment 2 for BESS certificate complying UL 9540 and UL 1973 provided by manufacturer Number of modules in the BESS: 4 module Electrical configuration of the module: 4S3P Other major components of the BESS: BESS was designed with full cabinet enclosure to safeguard

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Section	Requirement	Test (T) / Waive (W) / Not App. (N/A)	Comments
			the battery modules inside, modules were rack mounting with power wire interconnected. BESS enclosure overall dimensions (mm): W*D*H: 515 ±5 mm * 515 ±5 mm * 1073 ±5 mm BESS enclosure material: Metal Enclosure Battery system complies with UL 1973, See Attachment 2 for battery system certificate complying UL 1973 provided by manufacturer
5.3.3	Fire detection and suppression systems	---	BESS do not have fire detection and suppression system
5.3.4	BESS test report	---	See Unit level test section below
5.4	Flow Batteries	N/A	EUT is not flow battery
5.4.1		N/A	EUT is not flow battery
5.4.2	Flow battery comply with UL 1973	N/A	EUT is not flow battery
5.4.3	Flow battery thermal runaway determination level test report	N/A	EUT is not flow battery

Attachments		
No.	**Name**	**Page**
1	Att.1_UL 9540A_Cell Level test report	41
2	Att.2_UL 1973 Certificate_LFP48173170E-120Ah	2
3	Att.3_ eVault Max UL9540_UL 1973 Certificate	1
3	Test Video 1	MP4
4	Test Video 2	MP4
5	Test Video 3	MP4
6	Test Video 4	MP4

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ANSI/CAN/UL 9540A:2019 Fourth Edition, Dated November 12, 2019 - Section 9 Unit Level Testing

Section	Requirement	Comments
9	Unit Level Testing	
9.1	Sample and test configuration	
	The unit level test conducted with BESS units installed as described in the manufacturer's instructions and this section.	Test Configration: Indoor floor mounted residential use BESS;
	Unit level test required one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of installation.	☒ Conformed
	Test conducted for indoor floor mounted installations with fire propagation hazards and separation distances between initiating and target units representative of the installation.	☒ Conformed
	Exception: Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place: ☒ N/A	
	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.	--
	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	☒ Conformed

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Section	Requirement	Comments
	characterization can be done at the battery system level. Note: 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.	
	The initiating BESS unit shall contain components representative of a BESS unit in a complete installation.	☒ Conformed Note: Combustible components that interconnect the initiating and target BESS units shall be included.
	Target BESS units shall include - the outer cabinet (if part of the design), racking, - module enclosures, and - components that retain cells components.	☒ Conformed Outer cabinet was provided for target BESS unit, temperature measured on the cabinet enclosure was used to verify the propagation between units.

	Initiating BESS sample tested within 8 after charging BESS as per manufacturer specification to obtain maximum operating state of charge.	☒ Conformed Manufacturer recommended charge/discharge method: Charging Procedure: CC Charging Voltage (V): 56.8 Charging Current (A): 120 Charging End Condition (A): battery module voltage reached 56.8V. Discharging Procedure: CC Discharging Current (A): 120 End of Discharge Voltage (V): 48
	BESS unit includes an integral fire suppression system.	Integral fire suppression system : ☐ Optional ☐ Part of BESS Evaluation ☐ DUT tested with Integral fire suppression system ☒ DUT tested without Integral fire suppression system
	Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing.	☒ Conformed
9.2	Test method – Indoor floor mounted BESS units	
	During the test, the test room environment shall be controlled to prevent drafts that may affect test results.	Temperature(ºC): 22.8 to 20.9 Humidity (% RH): 61%
	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units	☒ Conformed

Sample Number for battery module inside the unit	Final charge end time (Date and Time)	Test Start time (Date and Time)
2022040010	22/05/18 12:29PM	22/05/18 14:48PM

	closed, latched and locked at the beginning and duration of the test.	
	The initiating BESS unit positioned adjacent to two instrumented wall sections.	☒ Conformed
	Instrumented wall sections extend not less than 1.6 ft. (0.49 m) horizontally beyond the exterior of the target BESS units.	☒ Conformed
	Instrumented wall sections was 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	☒ Conformed
	The surface of the instrumented wall sections were covered with 5/8-in (16-mm) gypsum wall board and painted flat black.	☒ Conformed
	The initiating BESS unit was centred underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter	☒ Conformed
	The light transmission measured in the calorimeter’s exhaust duct of the heat release rate calorimeter.	☒ Conformed
	The smoke release rate calculated.	☒ Conformed
	The chemical and convective heat release rates shall be measured for the duration of the test	☒ Conformed
	The heat release rate measurement system was calibrated using an atomized heptane diffusion burner.	☒ Conformed
	The convective heat release rate shall be measured using 1. Thermopile, 2. Velocity probe, and 3. Type K thermocouple, located in the exhaust system of the exhaust duct	☒ Conformed
	Following test configuration used for testing.	
	- Installation of BESS unit with two or more rows	N/A
	- Installation of BESS units with a single row	Conformed

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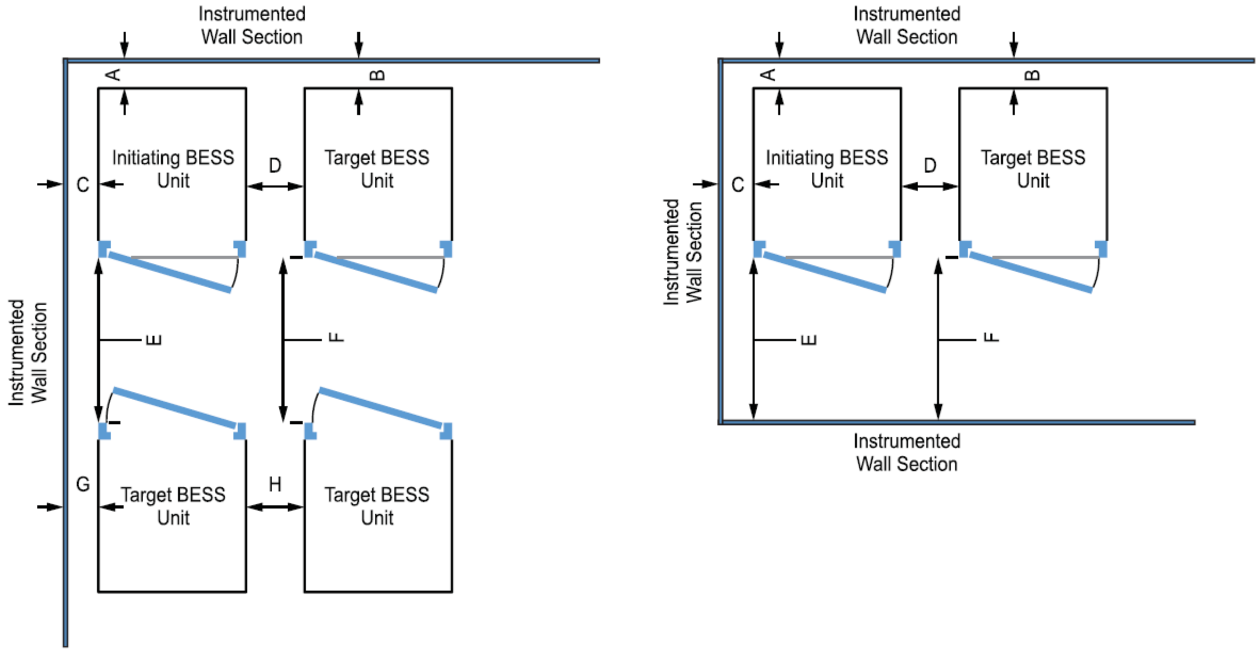
Figure 8.1
Examples of potential SBA test arrangements



ID.	Location	Required Value (mm)	Measured Value (mm)
A	Separation distance between the initiating BESS unit and instrumented wall section behind initiating BESS unit.	1 inch	1 inch
B	Separation distance between the target BESS unit and instrumented wall section behind target BESS unit.	1 inch	1 inch
C	Separation distance between the initiating BESS unit and instrumented wall section to the side of the initiating BESS unit.	1 inch	1 inch
D	Separation distance between initiating BESS unit and target BESS unit.	1 inch	1 inch
E	Separation distance between initiating BESS unit and target BESS unit or instrumented wall section.	--	--
F	Separation distance between target BESS unit and target BESS unit or instrumented wall section.	--	--
G	Separation distance between target BESS unit and instrumented wall section.	--	--
H	Separation distance between target BESS units.	--	--

	Note: The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation. For example, the left side of Figure 9.1 shows a layout of BESS units of two or more rows. The right side of Figure 9.1 shows a layout of BESS units of a single row, with an instrumented wall taking place of the target BESS units as the nearest potential item exposed to thermal energy from the initiating BESS unit in thermal runaway	
	Wall surface temperature measurements collected for BESS intended for installation in locations with combustible construction.	☒ Conformed
	Wall surface temperatures 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.	☒ Conformed
	Thermocouples shall be secured to gypsum surfaces by the .	☒ Conformed
	Heat flux measured with at least two water-cooled Schmidt- Boelter gauges at the surface of each instrumented wall:	☒ Conformed Heat flux gauge were used for reference, as the cheese cloth was used following the CRD issued on Mar 21, 2021 and Oct 21, 2021

	a) Both are collinear with the vertical thermocouple array;	See above
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and	See above
	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.	See above
	Heat flux measured with at least two water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit:	☒ Conformed See above
	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	See above
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.	See above
	For non-residential use BESS, heat flux measured with 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.	☒ Conformed Heat flux gauge positioned at the mid heigh of the initiating unit for reference.
	No. 24-gauge or smaller, Type-K exposed junction thermocouples 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 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 placed to account for convoluted enclosure interior geometries.	☒ Conformed

	For residential use BESS, the DUT covered with a single layer of cheese cloth ignition indicator.	☒ Conformed
	An internal fire condition in accordance with the module level test created within a single module in the initiating BESS unit:	☒ Conformed
	a) The position of the module 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	2nd module located from the bottom was used as initiating module.
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module is same as that used to initiate and propagate thermal runaway within the module level test (Section 8).	Module level test was not requested by the client
	The composition, velocity and temperature of the initiating BESS unit vent gases measured within the calorimeter's exhaust duct.	☒ Conformed
	Gas composition 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.	☒ Conformed FTIR was used additionally for THC measurement
	The hydrocarbon content of the vent gas shall be measured using flame ionization detection.	☒ Conformed
	Hydrogen gas measured with a palladium-nickel thin-film solid state sensor.	☒ Conformed
	The test shall be terminated if:	
	a) Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;	☒ Conformed
	b) The fire propagates to adjacent units or to adjacent walls; or	☐ Conformed
	c) A condition hazardous to test staff or the test facility requires mitigation.	☐ Conformed

	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.	☒ Conformed Client declared minimum 24.793m3 room with the following parameters: 1 in from the side of the BESS cabinet; 1 in from the back of the BESS cabinet; 1 in from the front of the BESS cabinet
9.3	Test method – Outdoor ground mounted units	
	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.	☐ Conformed Indoor floor mounted
9.4	Test Method – Indoor wall mounted units	
	Indoor wall mounted BESS tested in accordance with Section 9.2, except as modified in this section.	☐ Conformed Indoor floor mounted
9.5	Test Method – Outdoor wall mounted units	
	Outdoor wall mounted BESS tested in accordance with Section 9.2, except as modifiedin this section.	☐ Conformed Indoor floor mounted
9.6	Rooftop and open garage installations	
	Non-residential use rooftop or open garage installations BESS tested be in accordance with 9.2.	☐ Conformed Indoor floor mounted

Section 9	**TABLE: Unit Level Test**
Sample No	2022040010
Type of Installation:	Indoor floor mounted residential use
Representative of Other Type of Installation:	Residential: Indoor floor mounted , Outdoor ground mounted Non-residential: Outdoor ground mounted, indoor floor mounted; rooftop, open garage
Open Circuit Voltage of Initiating BESS Before Test(Vdc):	53.4Vdc
Thermal runaway initiation Method:	Film heaters
Location of Initiating module within BESS:	2^{nd} module located from the bottom of the rack was used as initiating.

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	Refer to Fig. 7 for detailed heater and TC wire placement inside the initiating module.

Heat Release Rate

Calibration to the calorimeter was conducted using heptane before battery system unit subjected to the unit level testing. Chemical heat release rate over the duration of the test was calculated using the gas concentration and exhaust flow rate measurements.

Convective heat release rate was measured over the duration of the test. Ambient temperature in the test enclosure, exhaust gas temperature was measured with temperature thermopile constructed from type-K thermocouples, the velocity probe measurements were applied to the calculation of the heat release rate in accordance with the requirement specified in UL 9540A: 2019.

Since no fire ignited during the whole unit level testing, almost no chemical heat release rate was captured. Results for heat release rate are shown in Plot 1, and the peak heat release rate(Peak HRR) was 7.37 kw at 16:15 from the beginning of the test, and the total heat release(THR) was 13.209MJ. No convective heat release was captured during the test.

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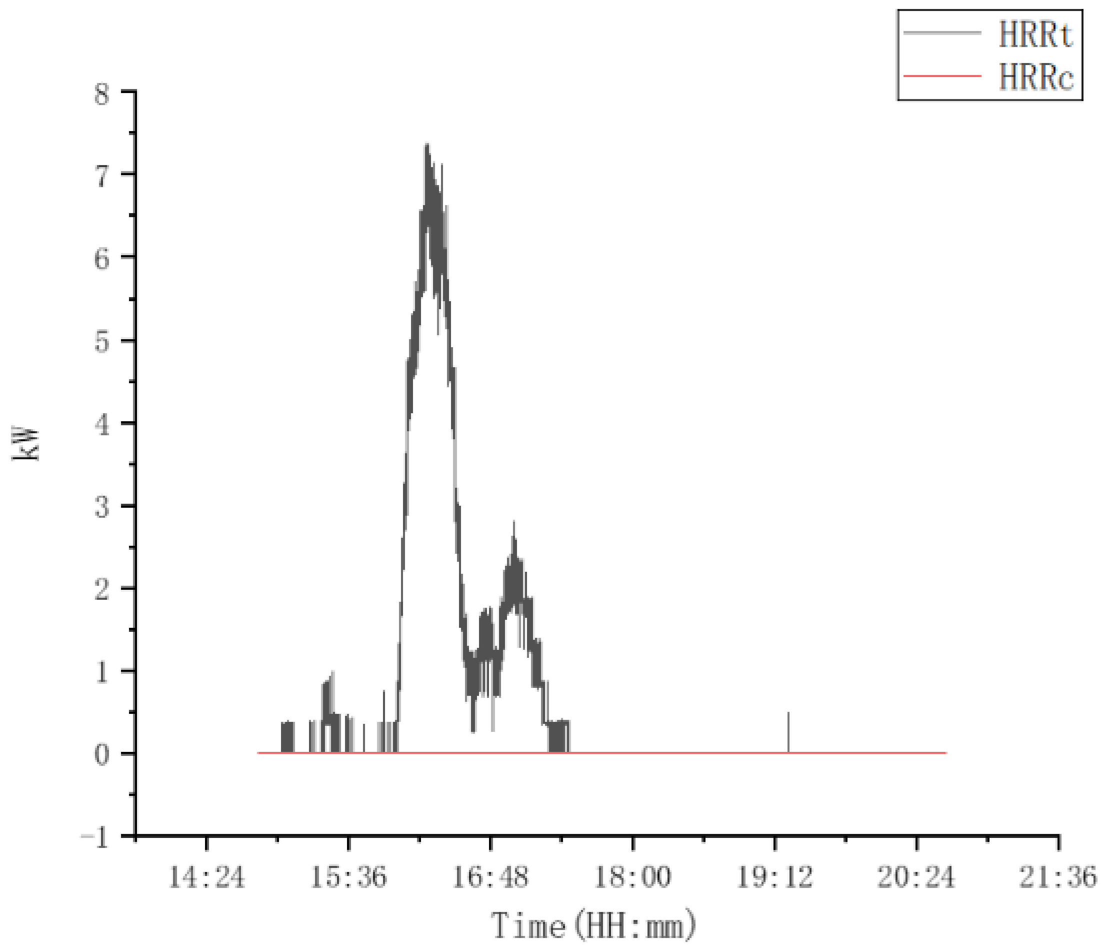

Plot 1. Chemical and convective heat release rate versus time

Observation of Flying Debris or Explosive Discharge of Gases

No flying debris or explosive discharge of gases was observed during the whole testing, refer to the test vedio for detailed infomrations.

Video Time (H:MM:SS)	Event Type	Description
14:48/05-18	Heating started	Heating initiated on cell 10# with heating rate of 5 ºC/minute
15:51:48	Audible	Cell vented with pop sounds
16:02:40	Visible	1st TR initiated with smoke release was observed from the front and the rear of the initiating unit, and lasted for about 5min.
16:04:37	Audible	Cell vented with pop sounds
16:05:11	Audible	Cell vented with pop sounds
16:09:24	Visible	2nd TR initiated. Heavy smoke release was observed from he front and the rear of the initiating unit, and lasted for about 7min

16:12:28	Audible	Cell vented with pop sounds
16:17:40	Audible	Cell vented with pop sounds; 3rd TR initiated. Heavy smoke release was observed from he front and the rear of the initiating unit, and lasted for about 9min
16:22:18	Visible	4th TR initiated. Heavy smoke release was observed from he front and the rear of the initiating unit, and lasted for about 5min
16:24:43	Visible/ Visible/Audible	5th TR initiated. Heavy smoke release was observed from he front and the rear of the initiating unit, and lasted for about 5min Cell vented with pop sounds
16:28:43	Visible/Audible	Cell vented with pop sounds 6th TR initiated and Heavy smoke release was observed from he front and the rear of the initiating unit, and lasted for about 5min
9:01:59/05-19	Test Termination	Video monitor stopped

Flammable Gas Generation and Composition Data

Gas mixture pulled from the exhaust duct throughout the testing was measured for the concentrations including Oxygen, Carbon Monoxide, Carbon Dioxide, total hydrocarbon(THC) and hydrogen. The concentration of gases indicated was scaled based on the exhaust flow characteristics, and the production for the gases was calculated over the testing duration.

Palladium-nickel thin-film solid state sensor was used for hydrogen measurement, while thermal conductive sensor was used for reference only. Refer to below table for each gas presented.

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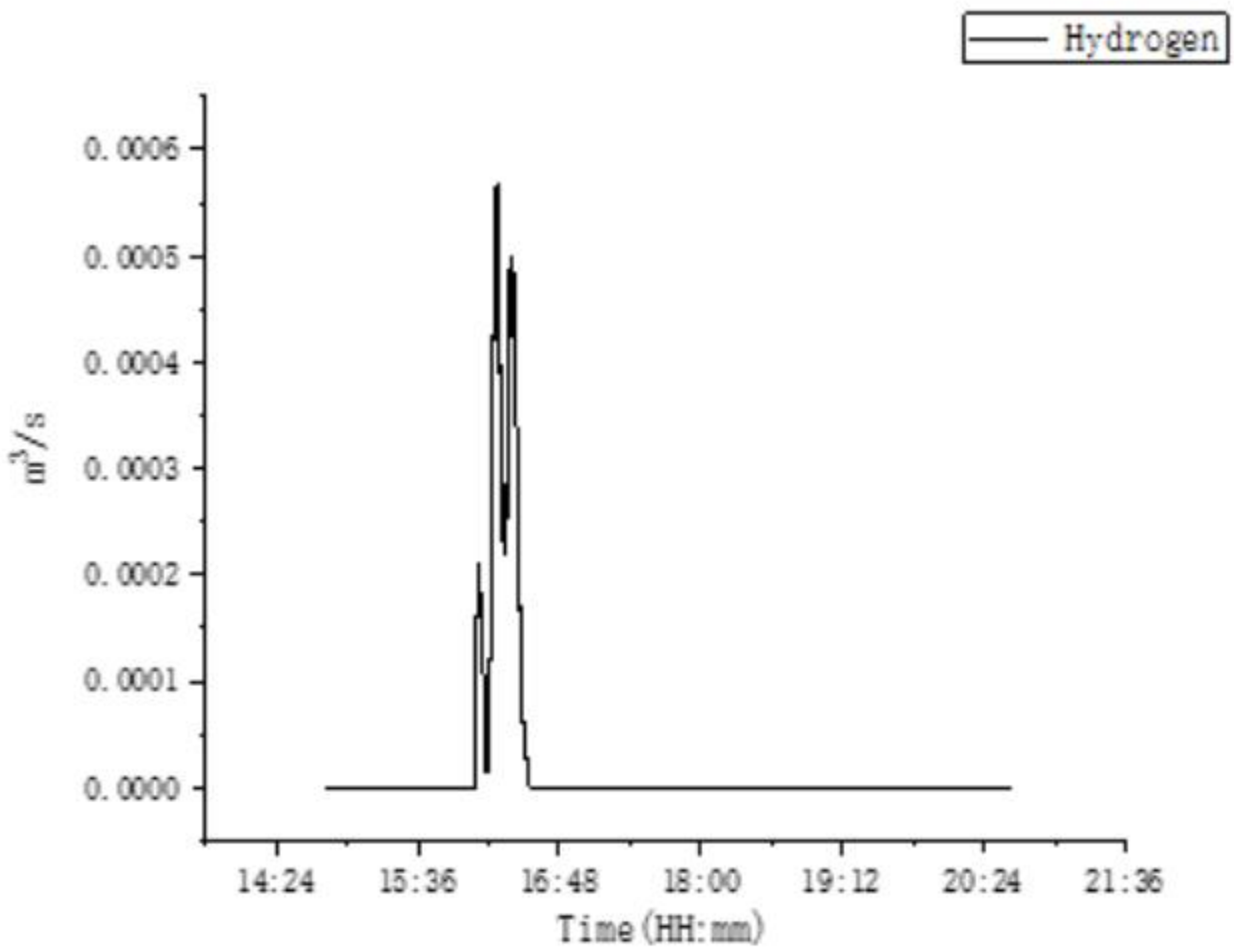

Plot 2. Hydrogen measurement from thermal conductive sensor

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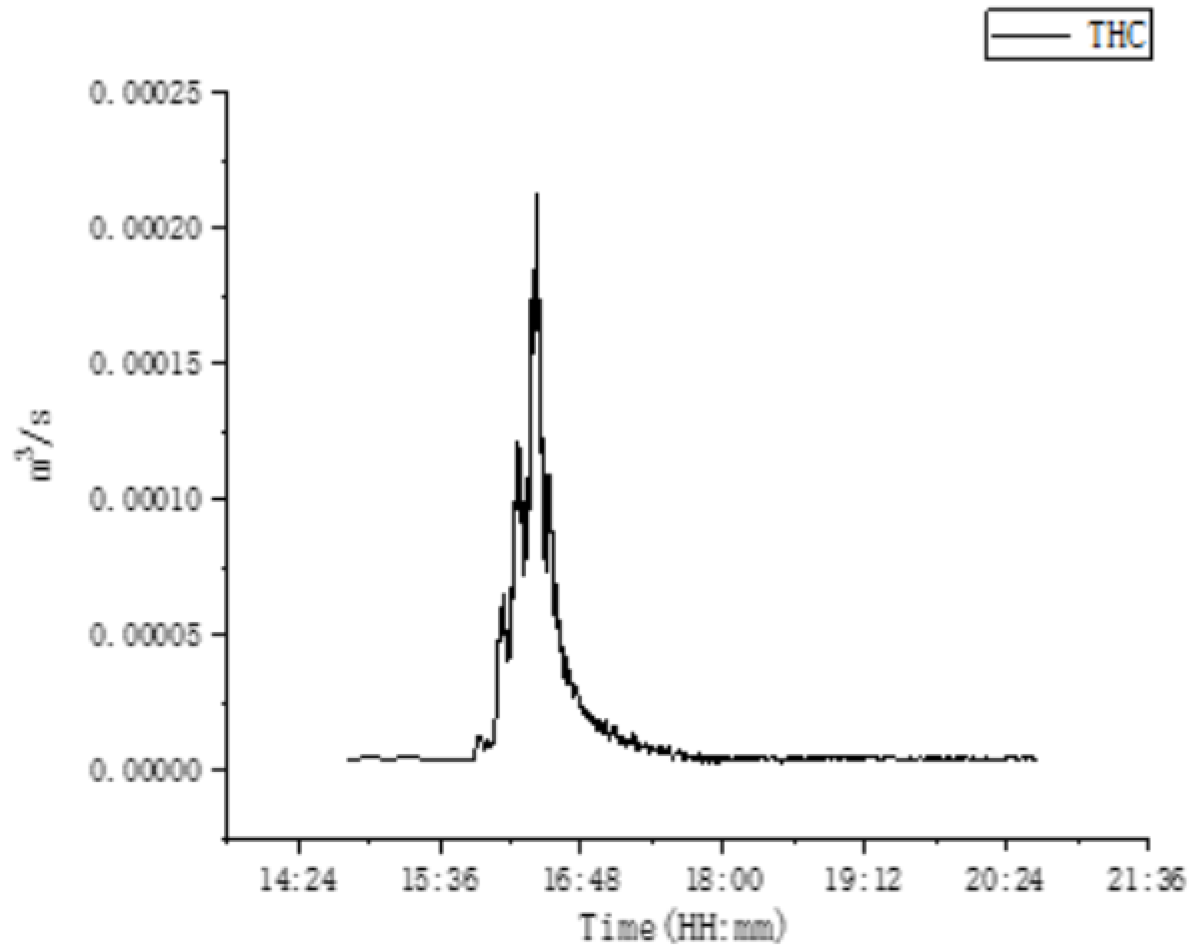

Plot 3 Hydrocarbon measurement in equivalent methane volume

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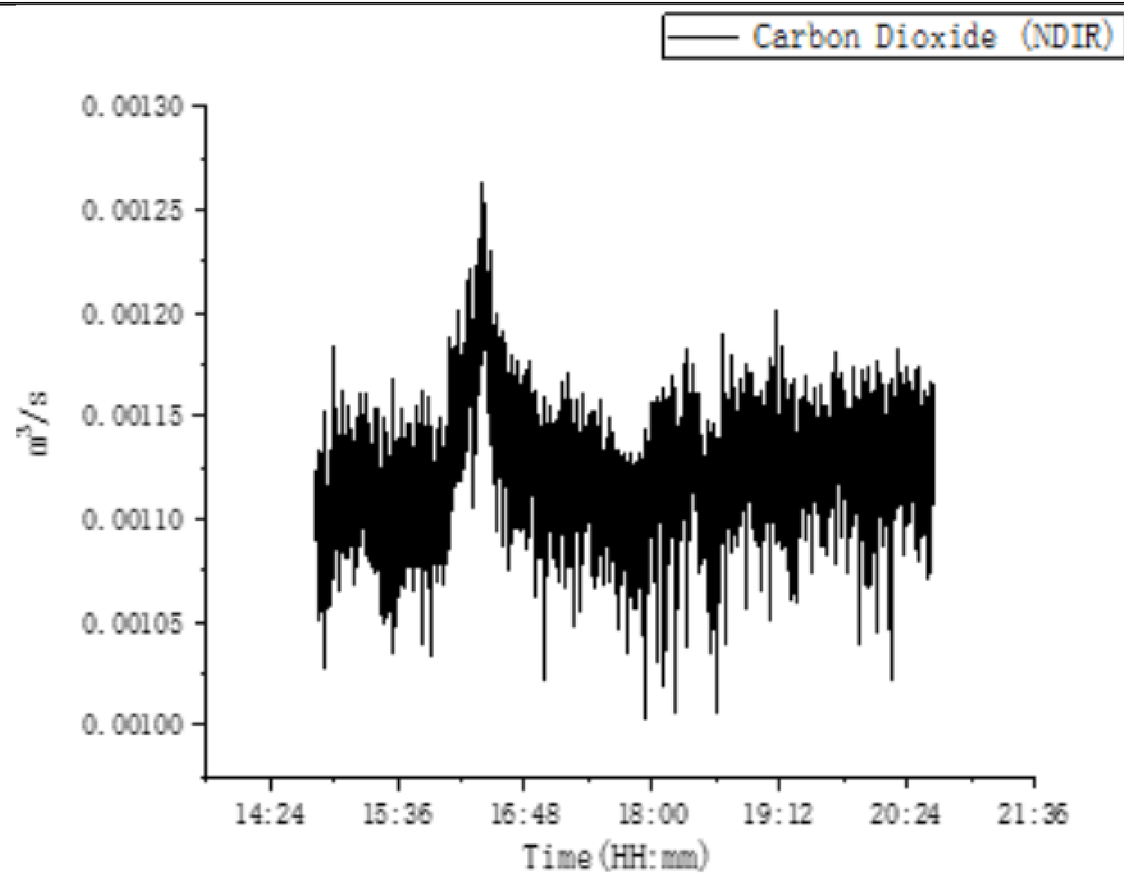

Plot 4 Carbon dioxide measurement

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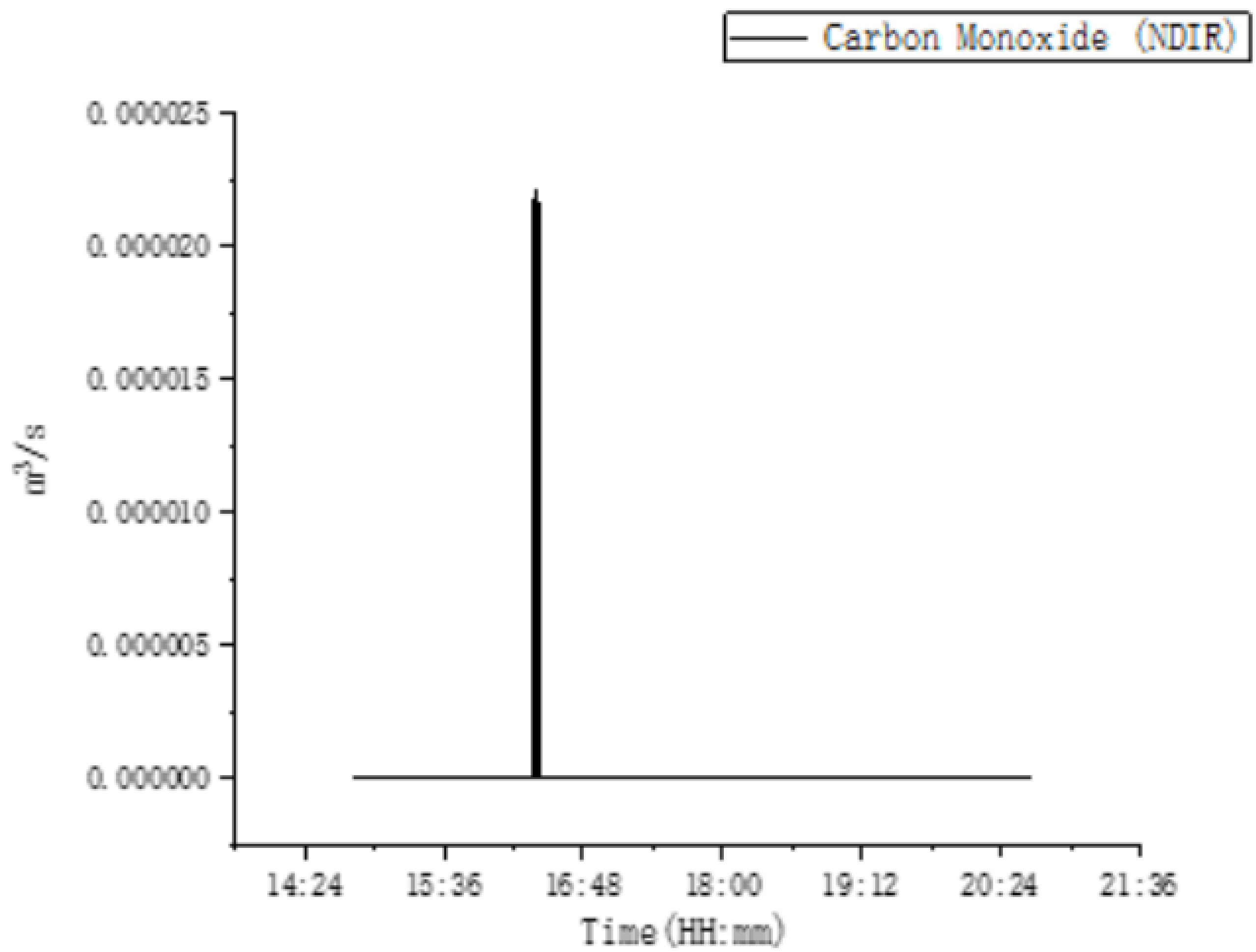

Plot 5 Carbon monoxide measurement

Gas Component	Detection method	Measurement Range	Volume Released (After thermal runaway) (Liters)
Total Hydrogen Carbons	Flame Ionization Detection (FID)	0~5000PPM	222.4
Carbon Monixide	NDIR(CO) Analyzer	0~0.8%	3.0
Carbon Dioxide	NDIR(CO2) Analyzer	0~8%	154.7
Oxygen	Paramagnetic oxygen analyzer	0~21%	-
Hydrogen	Palladium-nickel thin-film	0~100%	Below detectable limits

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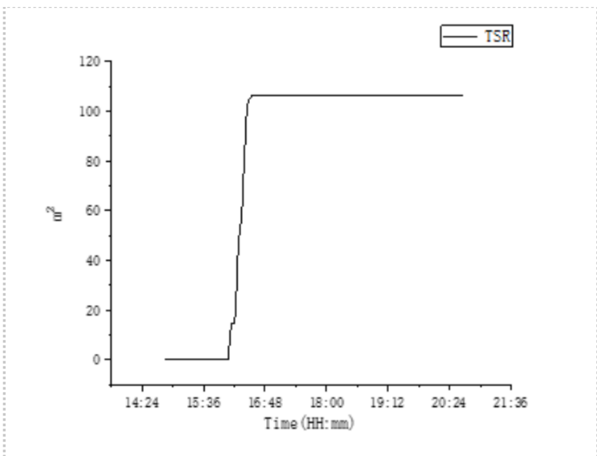
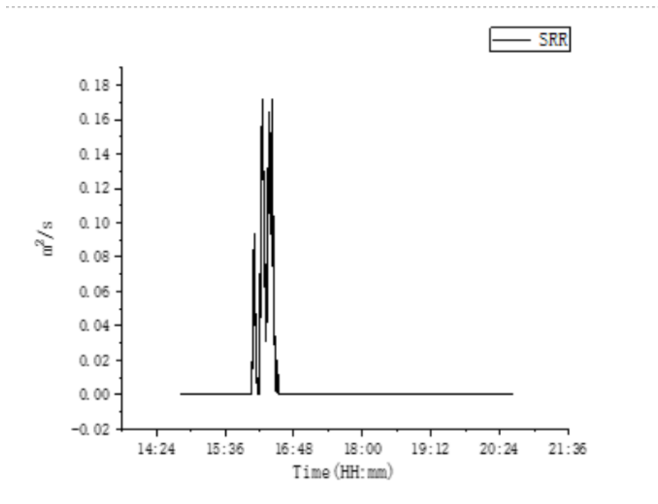
	solid state sensor		

Activation of Integral Fire Protection System.
No fire detection and suppression system was integrated within the BESS units. Test was conducted without fire suppression system.
Smoke release rate
Smoke release rate was measured using a white light source and a photo detector over the test duration. Total smoke release over the duration time was measured 106.16m^2 , and peak smoke release 0.1722m^2/s 16:25 PM from the beginning of the test.

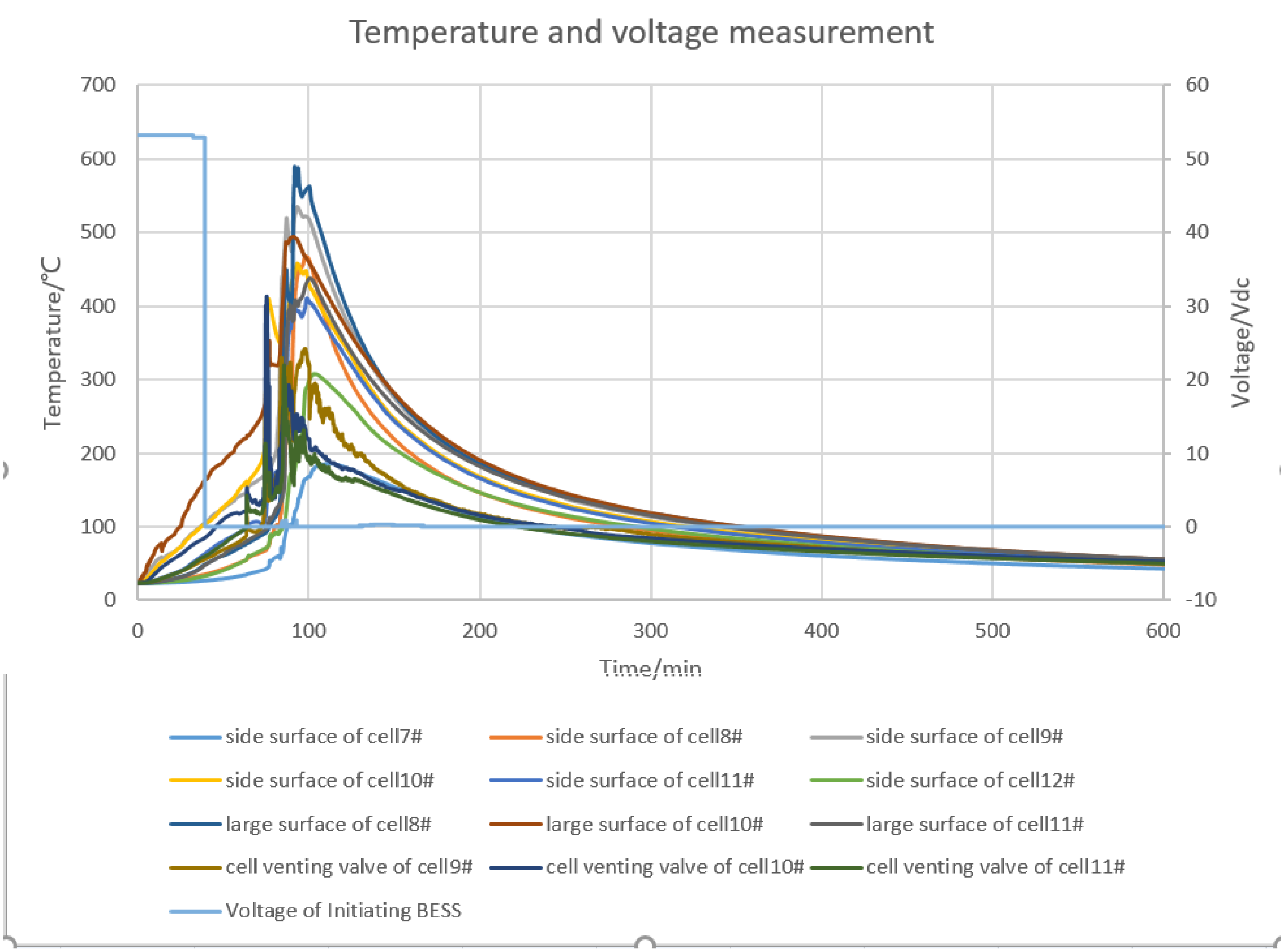


Plot 6 Total smoke release virsus time curve



Plot 7 Smoke release virsus time curve

Temperature Measurement
Temperature on initiating module, adjacent modules' enclosure and cabinet enclosure of both initiating unit target units were measured, see plot 9~16 for details. During the test, thermocouples were installed with vertical array at 6 in intervals for the full height on both section wall. See Plot 17~18 for details.



Plot 8 Temperature and voltage measurement in initiating module

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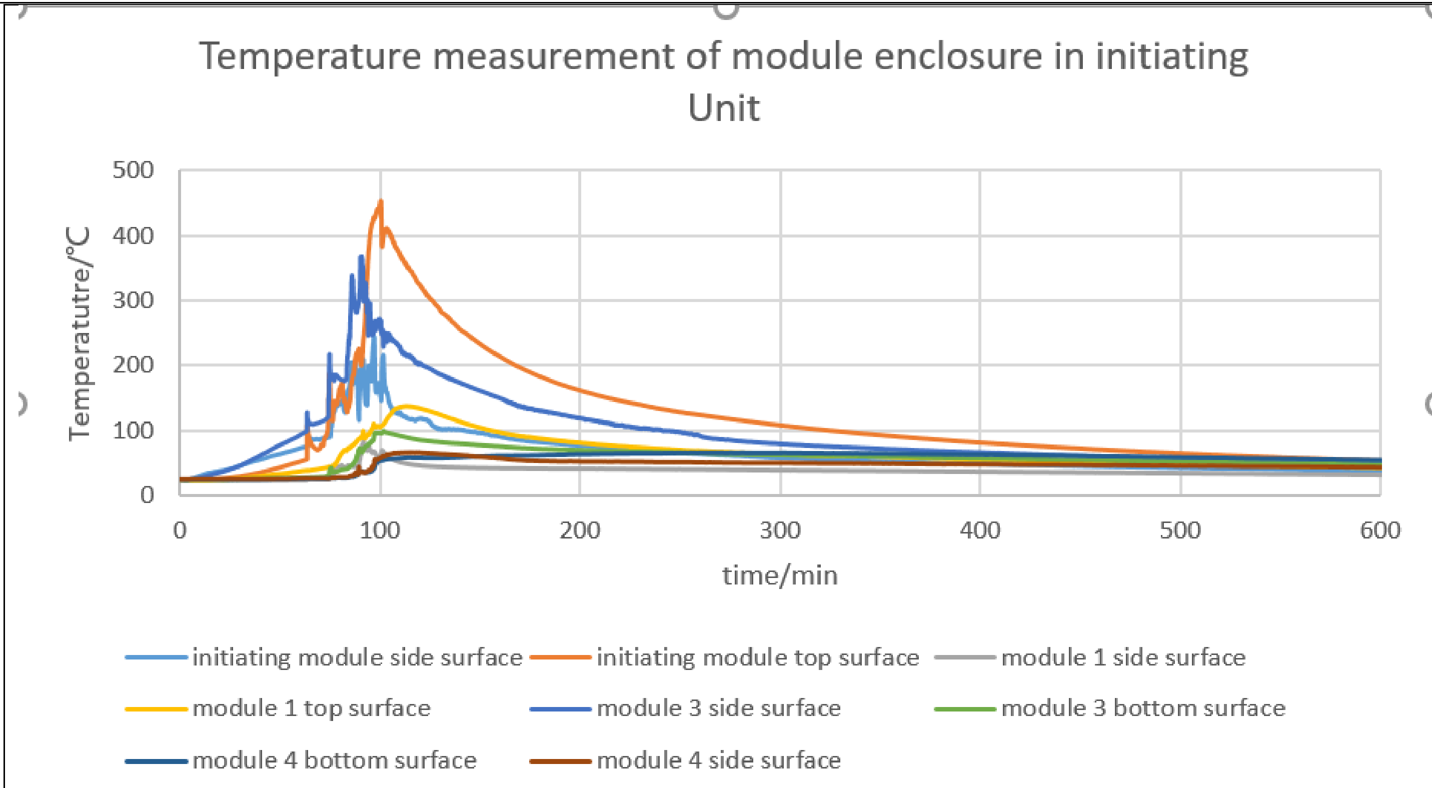

Plot 9 Temperature measurement on module enclosure in initiating Unit

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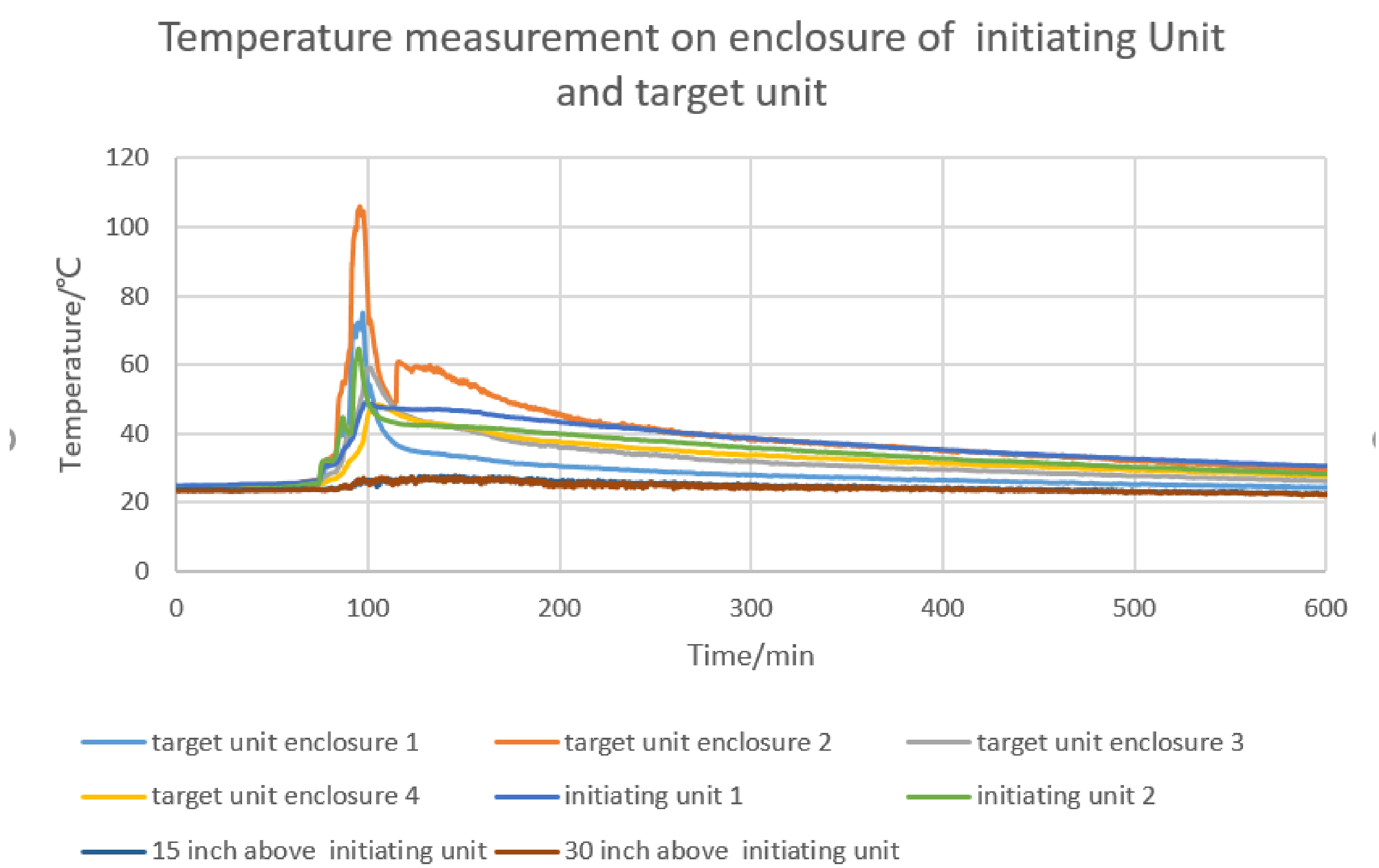

Plot 10 Temperature measurement on enclosure of initiating Unit and target unit

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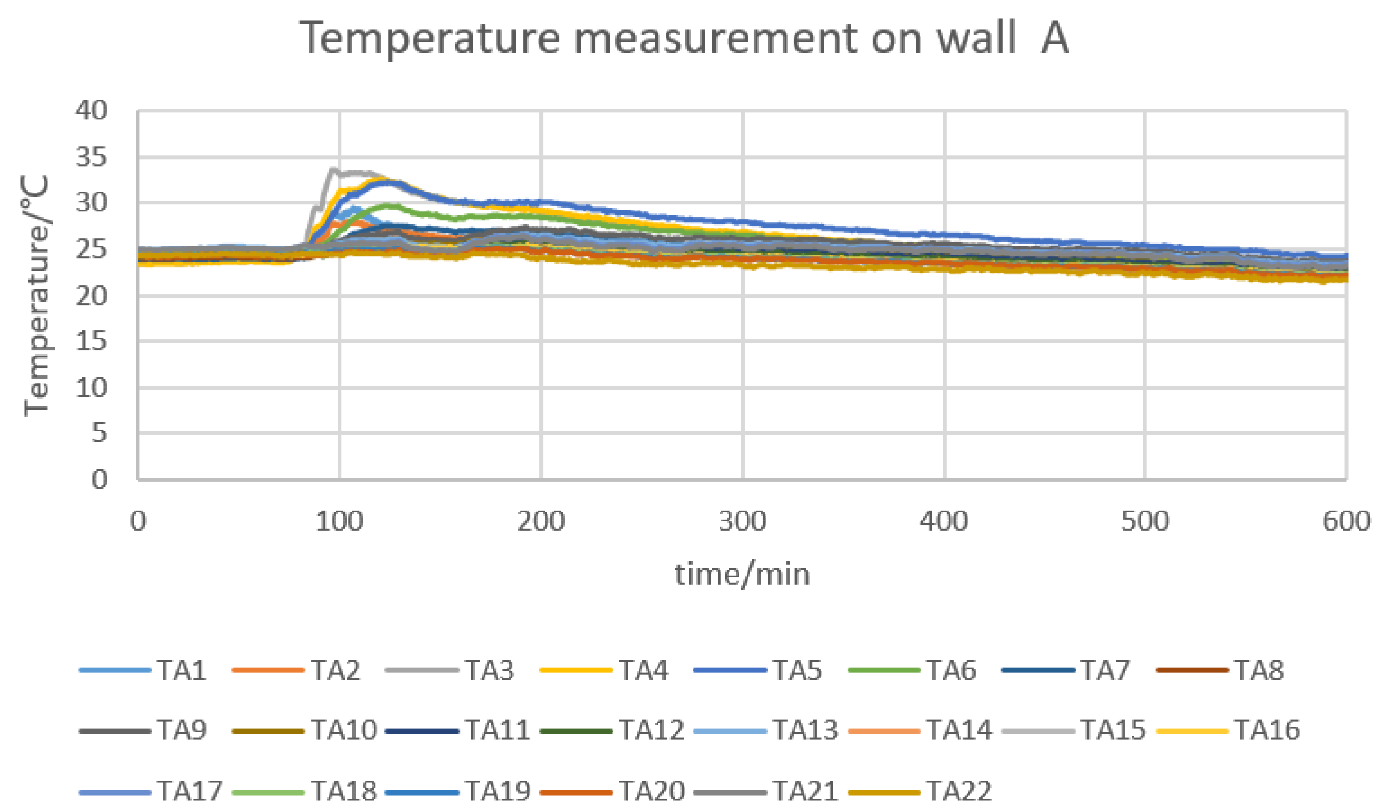

Plot 11 Temperature measurement on wall A

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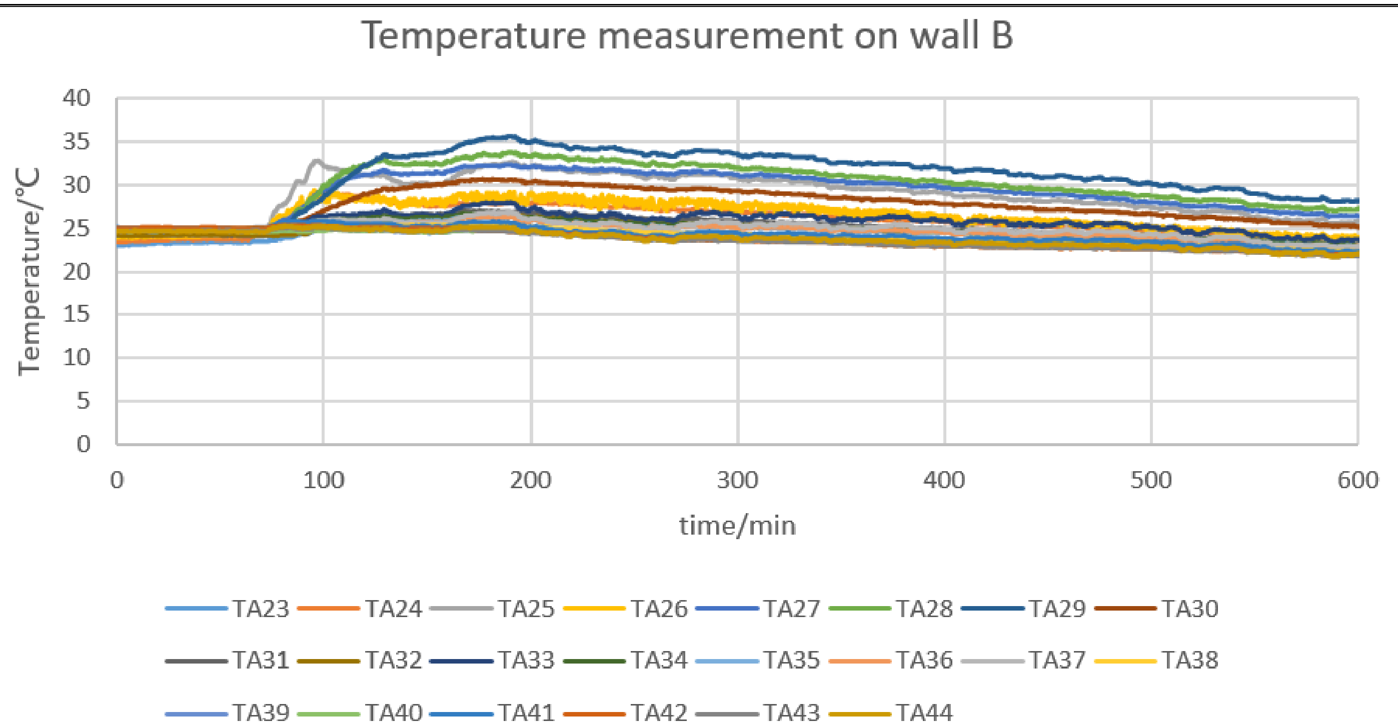

Plot 12 Temperature measurement on wall B

Thermocouple Location	Temperature Limit (ºC)	Measured Maximum Temperature (ºC)
Ambient Temperature Before Test	25± 5	23.0
Max Wall Surface Temperature (wall B TA 29)	122.5	35.6

Heat Flux Measurement

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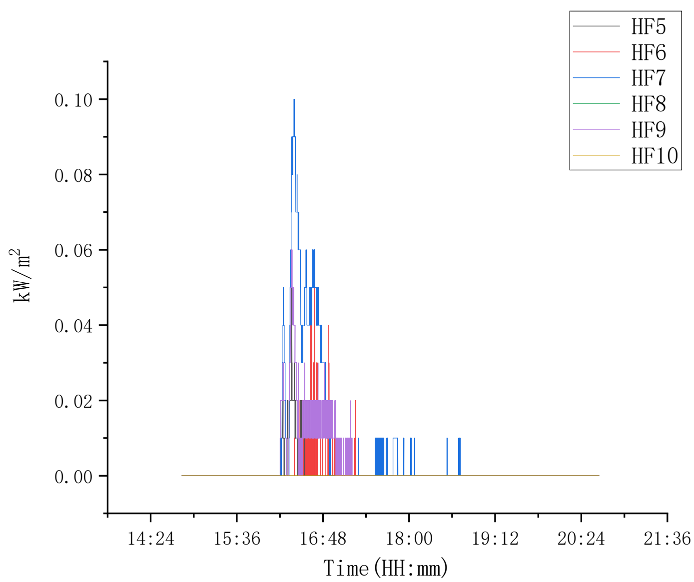

Plot 13 Heat Flux Measurement

HFG No.	Heat flux Location	Measured Maximum Heat Flux (kW/m²)
HF5kW	At the elevation of top module between initiating and target unit	0.05
HF6kW	At the elevation of initiating module between initiating and target unit	0.12
HF7kW	Posterior wall at the elevation of initiating module	0.21
HF8kW	Posterior wall at the elevation of the top module	0
HF9kW	Back Wall at the elevation of initiating module	0.16
HF10kW	Back wall at the elevation of the top module	0

Supplementary information:

Photos of BESS Unit：

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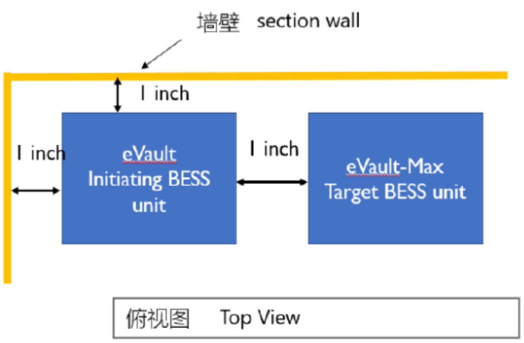

Fig 1 Orientation of units level testing

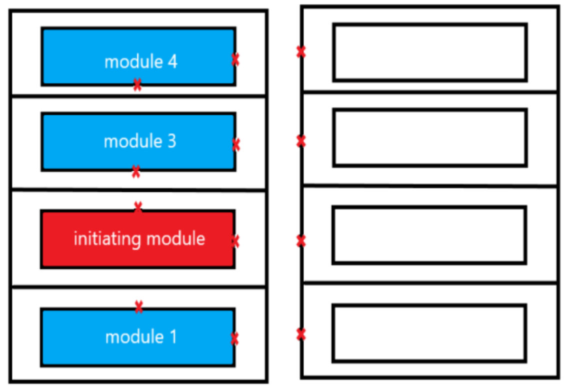

Fig 2 Location of Initiating module

Fig 3 BESS Test Setup

Fig 4 TC and HFG on Section Wall

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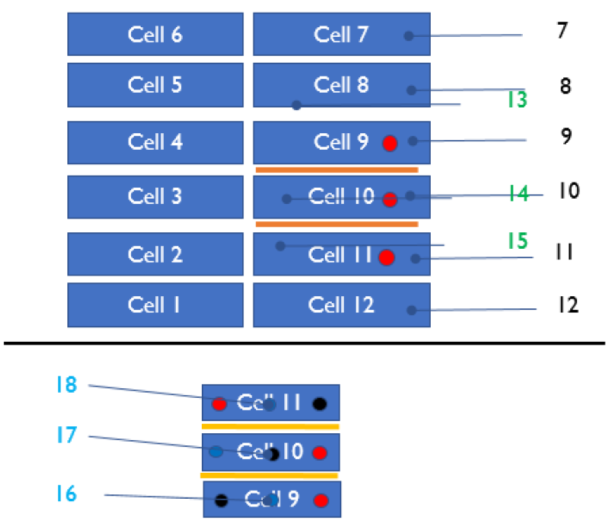
Fig 5 Internal View of Initiating BESS Unit

Fig 6 External View of Initiating BESS Unit



TC wire No. 7~12: cell side surface
TC wire No. 13~15: cell large surface
TC wire No. 16~18: cell venting valve
V9, V10, V11: voltage for cell 9, 10, 11

Thin film heaters rated 700W, wrapped the 2 larger surface and one of the side surface for thermal runaway initiating.
TC Wire: K type TC wire used for testing.

Fig 7 Heater Map of the Iniating Module

BESS Units after Testing

Fig 8 DUT after Testing

Fig 9 Initiating Unit after Testing

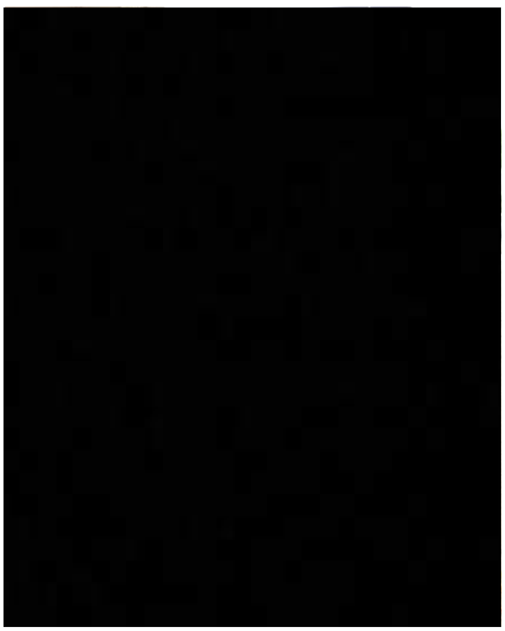


Fig 10 Initiating Unit after Testing

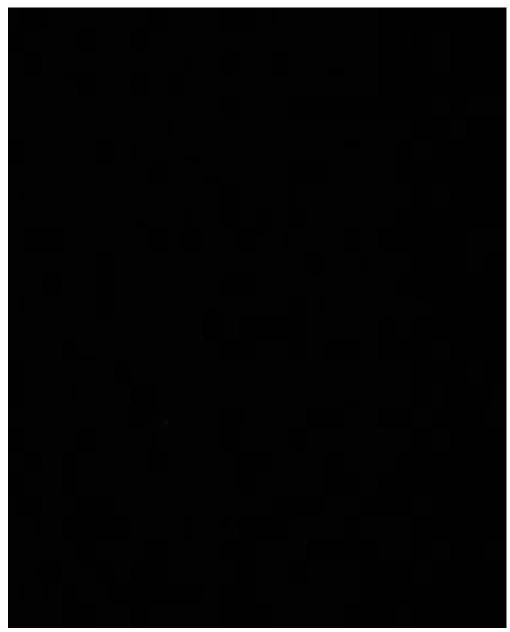


Fig 11 Initiating Module after Testing

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Fig 12 Adjacent Module in Initiating Unit

Fig 13 Adjacent Module in Initiating Unit

Post Photos for Testing Events[Video Time]

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Fig 14a Test Start [14:48]

Fig 14b Fist Venting[15:51]

Fig 14c. 1st TR on Initiating Cell[16:02:40]

Fig 14d TR Propagation[16:09:24]

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Fig 14e. TR Propagation[16:17:40]

Fig 14f. TR Propagation[16:22 :18]

Fig 14g Propagation Event [16:24:43]

Fig 14h Propagation Event [16:28:43]

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Date Start: 22/05/18 (YY/MM/DD)
Date End: 22/05/19 (YY/MM/DD)

End of Report….