Letter of Attestation

Document: 80028282 **Master Contract:** N/A

Project: 80051872 **Date Issued:** Sep 30, 2020

Issued to: Contemporary Amperex Technology Co., Limited
No. 2 Xingang Road, Zhangwan Town, Jiaocheng District
Ningde City, Fujian Province 352100, P. R. China
Attention: Ms. Sandy Lv

CSA Group hereby confirms that it has completed an evaluation of: Li-ion Battery Rack, models R852280-P-T-I-1, R852280-E-T-I-1, Rx52280-P-T-U-1, Rx52280-E-T-U-1, FRx52280-P-T-U-0, FRx52280-E-T-U-0, Ox52280-P, Ox52280-E (x means module number 4-8)

CSA Group hereby attests that the products identified above and described in test report 80028282 dated Jan 17, 2020 complies with the following standards/tests, to the extent applicable:

UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 3rd edition, Revision Date Jun 15, 2018, Section 8 Unit Level Testing.

Issued by: *Joseph Zhou*

CSA Group

THIS LETTER OF ATTESTATION DOES NOT AUTHORIZE THE USE OF THE CSA MARK ON THE SUBJECT PRODUCTS.
QUOTATIONS FROM THE TEST REPORT OR THE USE OF THE NAME OF THE CANADIAN STANDARDS ASSOCIATION AND CSA GROUP OR ITS REGISTERED TRADEMARK, IN ANY WAY, IS NOT PERMITTED WITHOUT PRIOR WRITTEN CONSENT OF CSA GROUP.

Descriptive Report and Test Results

MASTER CONTRACT: N/A
REPORT: 80028282
PROJECT: 80051872

Edition 1: Feb 25, 2020; Project 80028282 - Cleveland
Issued by Joseph Zhou, Reviewed by Anuj Amin

Edition 2: Sep 30, 2020; Project 80051872 - Cleveland
Prepared by Joseph Zhou, Authorized by Anuj Amin

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Description and Tests - Pages 1 to 28

PRODUCTS

Li-ion Battery Rack, models R852280-P-T-I-1, R852280-E-T-I-1, Rx52280-P-T-U-1, Rx52280-E-T-U, FRx52280-P-T-U-0, FRx52280-E-T-U-0, Ox52280-P, Ox52280-E (x means module number 4-8)

APPLICABLE REQUIREMENTS

UL 9540A - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 3rd edition

MARKINGS

N/A

ALTERATIONS

N/A

FACTORY TESTS

N/A

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DESCRIPTION

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:** Latter of Attestation [X] Testing Only [ ] Note: Mark "X" in applicable test program block

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

Testing Laboratory Name:	Contemporary Amperex Technology Co., Limited
Address:	No.2 Xingang Road, Zhangwan Town, Jiaocheng District Ningde, Fujian, 150 35200, China
Facility Number: **Qualification**	N/A

	As above / or describe otherwise
Customer:	Contemporary Amperex Technology Co., Limited
Address:	No.2 Xingang Road, Zhangwan Town, Jiaocheng District Ningde, Fujian, 150 35200, China

Tested By: Jianfang Zhu, Test Engineer
Name, Title

Jianfang Zhu, Test Engineer 2019-11-30 to 2019-12-4
Signature *Date (YYYY-MM-DD)*

☐ **Reviewed by:** Joseph Zhou/Giggle Pei, Certifier
☒ **Witnessed by:**
Name, Title

Joseph Zhou 2019-12-04
Signature *Date (YYYY-MM-DD)*

Version: 2019-05-09

Product Details	
Test Request:	☐ Cell Level Testing ☐ Module Level Testing ☒ Unit Level Testing ☐ Installation Level Testing
Manufacturer	☐ Cell: ☐ Module: ☒ Unit: Contemporary Amperex Technology Co., Limited
Brand name / Trademark	☐ Cell: ☐ Module: ☒ Unit: NA
Model Number	☐ Cell: ☐ Module: ☒ Unit: refer to the models indicated on the cover page
Date of receipt of test sample(s)	2019-11-30 (YYYY-MM-DD)
Cell/Battery Type	Li-ion, LFP
Approximate Dimension (mm)	☐ Cell: ☐ Module: ☒ Unit: 924*1185*2329 (W*D*H) [mm]
Mass (g)	☐ Cell: ☐ Module: ☒ Unit: 3100kg
DUT Sample/Serial Number	☐ Cell: ☐ Module: ☒ Unit: TD19-0237
DUT Nominal Voltage Rating (V)	☐ Cell: ☐ Module: ☒ Unit: 1331.2
DUT Nominal Charge Capacity Rating (Ah)	☐ Cell: ☐ Module: ☒ Unit: 280
Fire Mitigation Strategies: (For installation level testing)	☒ Water: ☐ Other (Specify): ☐ N/A
Additional Information	N/A

Model Difference: refer to table below for the model differences:

Model No.	Suffix 1	Rated Current, A	Suffix 2	
R852280-P-T-U-1	P	280	U	UL approved
R852280-P-T-I-1	P	280	I	IEC approved
R852280-E-T-U-1	E	140	U	UL approved
R852280-E-T-I-1	E	140	I	IEC approved

Per client confirmed, models subjected for US certification are the same as models approved IEC standard certification, herein, test performed on models R852280-P-T-U-1 was considered representative of models R852280-P-T-I-1, R852280-E-T-U-1, R852280-E-T-I-1.

Description of changes from models R852280-P-T-I-1, R852280-E-T-I-1, R852280-P-T-U-1, R852280-E-T-U-1 to Rx52280-P-T-U-1, Rx52280-E-T-U-1 (x means module number 4-8).

Compared to models R852280-P-T-I-1, R852280-E-T-I-1, R852280-P-T-U-1, R852280-E-T-U-1, the following changes were included to add models Rx52280-P-T-U-1 and Rx52280-E-T-U-1 (x means module number 4-8)

1. Change the rating label for weight, voltage ranges and capacities;
2. Change the name of component cell from 001CB310 to CB310 and CB2W0.
3. Add new critical components, like Service Plug-Alternate (MSD) and HV connector (B+, B-, HV+, HV-).
4. Update the liquid cooling tube adapter on the top.

Description of changes from Rx52280-P-T-U-1, Rx52280-E-T-U-1 to FRx52280-P-T-U-0, FRx52280-E-T-U-0 (x means module number 4-8):

Compared to models Rx52280-P-T-U-1, Rx52280-E-T-U-1, the following changes were included to add models FRx52280-P-T-U-0, FRx52280-E-T-U-0 (x means module number 4-8):

1. Cancel the rack door, rack feet and baseboard.
2. Change the grounding position to left bottom of rack frame; cancel grounding position on the top.
3. Cancel the water protection cover on the top of rack.
4. Change the shape of cabling outlet on the top of rack.
5. Change the nameplate position: two pieces on the left and right side of rack frame.
6. Size change: 914mm*1185mm*2327mm changed to 919mm*1250mm*2248mm

Model series Ox52280-P, Ox52280-E are same as model series Rx52280-P-T-U-1, Rx52280-E-T-U-1 except for the location of control box and addition of liquid chiller.

Based on the model difference indicated, no additional test deemed necessary for the above alternation.

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 personal be protected from the flying fragments, explosive force, and sudden release of heat, chemical burns, and noise result from such explosions. The test area is to be well ventilated to protect personal from possible harmful fumes or gases.
- Temperature of the surface of the battery casing shall be monitored during the tests described above. All personal involve in the testing of batteries are to be instructed never to approach a battery until the surface temperature return 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 for later use in order to supply electrical energy when needed. The BESS consists of one or more modules, a power conditioning system (PCS) and balance of plant components.

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 8).
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.

- "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.

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

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

- "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 a cells, modules, battery management systems, ventilation devices and other ancillary equipment.

UL 9540A Third Edition, Dated June 15, 2018 - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Section	Requirement	Test (T) / Waive (W) / Not App. (N/A)	Comments
1	**Scope:** The test methodology in this document evaluates the fire characteristics of a battery energy storage system that undergoes thermal runaway. Fire protection requirements not related to battery energy storage system equipment are covered by appropriate installation codes.		
	Section 6: Cell Level Test	W	1. Cell testing not requested by manufacturer Cell Thermal runaway methodology: External heating method with ceramic heater 1 PCS, rated 220/230V, 500W Cell Surface temperature at gas venting (ºC): 143.3 Cell Surface temperature at thermal runaway(ºC): 209.8 Gas Composition and LFL: C2H4, C2H6, C3H6, C3H8, H2, CH4, CO, CO2 Lower Flammability Limit(LFL) = 6.14%@12~18 ºC,101.3~101.5kPa Pmax:109.36PSI(0.754MPa) Pmax Rise Rate: 23153.83(159.64MPa/Sec) PSI/Sec Lower Flammability Limit(LFL）at venting temperature = 5.4%@143±1°C, 101±2kPa Gas Burning Velocity: 0.584m/s @ ambient temperature (22~30°C), atmospheric pressure See project 80040846 for Cell Level testing data provided by manufacturer
	Section 7: Module Level Test	W	Module testing not requested by manufacturer Cell Thermal Runaway Methodology: External heating method with ceramic heater 1 PCS, rated 220/230V, 500W Cell Surface Temperature at Gas Venting (ºC): 92.3 Cell Surface temperature at thermal runaway(ºC): 123.9 Module Heat Release Rate (kW/m^2): 0 Cell/Module Gas Generation and Composition: C2H2, C2H4, C2H6, C3H6, C3H8, H2, CH4, CO, CO2

Section	Requirement	Test (T) / Waive (W) / Not App. (N/A)	Comments
			Module External Flaming and Flying Debris Hazard: N/A, no fire or explosion, no flying debris during test Module Location of Flame Venting: Not applied no fire occurred during the whole testing See project 80025390 for Module Level testing data provided by manufacturer
	Section 8: Unit Level Test	T	Manufacturer Name: Contemporary Amperex Technology Co., Limited Model: R852280-P-T-U-1 Electrical Rating: nominal voltage 1331.2V BESS Energy (Whr): 332736 BESS Capacity (Ahr): 280 Number of Module: 8 Module Configuration: 52S-1P Approximate Dimension (mm): 924*1185*2329 (W*D*H) Weight (kg): 3100 BMS Model no: N/A Fire Detection System: N/A Fire Suppression System: N/A Fire Detection/Suppression System (Optional/Part of system): N/A Manufacturer request to perform test with Fire Detection/suppression System (Yes/No): No, no fire detection/suppression test designed on the battery system. BESS Enclosure Material: Metallic BESS Comply with UL 1973 Requirement (Yes/No): Yes, refer to Certification No. CU 50272100 001 from TUV Rheinland, and report No. 64.280.20.60131.01 from TUV SUD
	Section 9: Installation Level Test (With fire mitigation strategies)	N/A	1. BESS Meet Unit level performance requirement and No Installation Level test required.

UL 9540A Third Edition, Dated June 15, 2018 - Section 8 Unit Level Testing

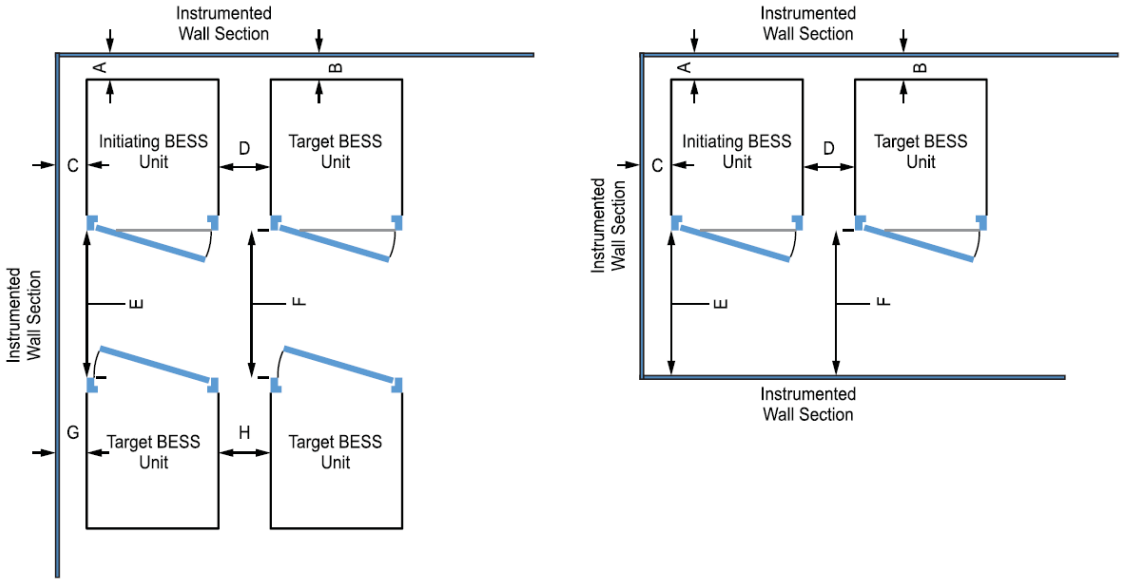
Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
8	Unit Level Testing		P
8.1	BESS Sample tested within 8 after charging BESS as per manufacturer specification to obtain maximum operating state of charge.	Manufacture recommended charge/discharge method: Charging Procedure: CP-CV Charging Voltage (V): 1497.6 Charging Current (A): see below： 1. charge the unit with 0.25P(93184W) to cell voltage 3.65V 2. charge the unit with 0.1P(37273.6W) to cell voltage 3.65V 3. charge the unit with 0.05P(18636.8W) to cell voltage 3.65V Charging End Condition (A): 14A Discharging Procedure: CP Discharging Current (A): 140 0.25P(93184W) End of Discharge Voltage (V): 2.5V/Cell Rest Duration after charging (HH:MM): 8h	P
	Following test configuration used for testing.	See below	P
	- Installation of BESS unit with two or more rows	confirmed	P
	- Installation of BESS units with a single row	See above	N/A

Section	Requirement	Comments	Verdict

Possible test case verdicts:

Test case does not apply to the test object: N/A (Not Applicable)
Test object does meet the requirement: P (Pass)
Test object does not meet the requirement: F (Fail)

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.	160	150
B	Separation distance between the target BESS unit and instrumented wall section to the side of target BESS unit.	160	150
C	Separation distance between the initiating BESS unit and instrumented wall section to the side of the initiating BESS unit.	260	250
D	Separation distance between initiating BESS unit and target BESS unit.	10	10
E	Separation distance between initiating BESS unit and target BESS unit or instrumented wall section.	10	10
F	Separation distance between target BESS unit and target BESS unit or instrumented wall section.	10	10
G	Separation distance between target BESS unit and instrumented wall section.	260	250
H	Separation distance between target BESS units.	10	10

Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: N/A (Not Applicable) Test object does meet the requirement: P (Pass) Test object does not meet the requirement: F (Fail)			
	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 8.1 shows a layout of BESS units of two or more rows. The right side of Figure 8.1 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		
	The initiating BESS unit contained components representative of a BESS unit in a complete installation.	☒ Conformed	P
	Combustible components that interconnect the initiating and target BESS units included during testing.	☒ Conformed	P
	Target BESS units have the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components.	☒ Conformed Shelf included in the target BESS, also the module enclosure included to retain the cells.	P
	BESS unit included an integral fire suppression system	No integral fire suppression system designed in the BESS unit	N/A
	BESS unit provided with optional fire suppression system	No optional fire suppression system provided for the BESS unit.	N/A
	Ambient temperature during BESS charging and at beginning of test……..……..……: Note: Ambient indoor laboratory conditions shall be 25 ±5°C (77 ±9°F) and 50 ±25% RH at the initiation of the test.	Temperature(ºC): 22. 1 to 24. 4 Humidity (% RH): 50% to 75%	P
8.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units were closed, latched and locked at the beginning and duration of the test.	☐ Conformed No access door or panel designed on both the initiating and target BESS units	N/A
	The initiating BESS unit was positioned adjacent to two instrumented wall sections	☒ Conformed	P

Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	Instrumented wall sections extend not less than 1.6 ft. (0.49 m) horizontally beyond the exterior of the target BESS units.	☒ Conformed	P
	Instrumented wall sections were minimum of 12-ft (3.66-m) tall at least 2-ft (0.61-m) taller than the BESS unit height.	☒ Conformed Height of the instrumented wall: 3.66m, Height of the BESS: 2329 mm.	P
	The surface of the instrumented wall sections were covered with 5/8-in (16-mm) gypsum wall board and painted flat black.	☒ Conformed	P
	The initiating BESS unit was centred underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.	☐ Conformed The Initiating BESS unit was centered underneath a smoke collection hood without oxygen consumption calorimeter.	N/A
	The heat release rate measurement system was calibrated using an atomized heptane diffusion burner.	☐ Conformed Un-calibrated for the heat release rate measurement system.	N/A
	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.	☐ Conformed See above	N/A
	Separation distance shown above in Section 8.1 were specified by manufacturer	☒ Conformed	P
	Wall surface temperature measurements were collected for BESS intended for installation in locations with combustible construction as defined by NFPA 220.	☒ Conformed	P
	Wall surface temperatures were measured in vertical array(s) at 6-in (152-mm) intervals for the full height of the instrumented wall sections	☒ Conformed	P

Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	24-gauge Type-K exposed junction thermocouples were be used to measure wall surface temperatures.	☒ Conformed	P
	Thermocouples were secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires. The thermocouple tip is to 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.	☒ Conformed	P
	Wall surface temperature measuring thermocouple arrays were horizontally positioned in the wall locations anticipated to receive the greatest thermal exposure from the initiating BESS unit.	☒ Conformed	P
	Heat flux were measured with the sensing element of a water-cooled Schmidt-Boelter gauge at the surface of each instrumented wall	See below	N/A
	- Collinear with the vertical thermocouple array	☐ Conformed Water-cooled Schmidt-Boelter gauge was installed on the surface of the instrumented wall collinear with the vertical thermocouple array.	N/A
	- Positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and	☐ Conformed No fire ignited during the testing. The gauge was installed at the height estimated to receive the greatest heat flux due to thermal runaway of the initiating module.	N/A
	- Positioned at the elevation estimated to receive the greatest heat flux during potential propagation of	☐ Conformed No fire ignited during the testing. One gauge was installed at the height of the initial BESS unit	N/A

Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	thermal runaway within the initiating BESS unit.	enclosure which was estimated to receive the greatest heat flux within the initiating BESS unit.	
	Heat flux were measured with a water-cooled Schmidt-Boelter gauge at the surface of each adjacent target BESS unit that faces the initiating BESS unit	☐ Conformed No fire ignited during the testing. Gauge was installed at the surface of the No.2 target BESS unit which is close to the initial BESS unit.	N/A
	Heat flux gauges were positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating module	☐ Conformed Gauge was set up at the elevation estimated to receive the greatest surface heat flux. No fire ignited no heat fluxed during the testing.	N/A
	Twenty-four (24) gauge Type-K exposed junction thermocouples were installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the module. Each module enclosure were instrumented with at least one thermocouple	☒ Conformed	P
	An internal fire condition was created within a single module in the initiating BESS unit	See below	P
	- The position of the module was selected to present the greatest thermal exposure to adjacent modules (e.g. above, below, laterally), based on the results from the module level test	☒ Conformed	P
	- The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module was same as that used to initiate and propagate thermal runaway within the module level test (Section 7); and	☒ Conformed	P

Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	- A minimum of two 24-gauge Type-K thermocouples were placed within each module to provide data to monitor the thermal conditions within non-initiating modules.	☒ Conformed 2 thermocouples were placed in each module of the initiating BESS unit	P
	- Additional thermocouples were be placed to account for convoluted enclosure interior geometries in non-initiating modules.	☒ Conformed 1 thermocouples were placed in each module of the target BESS unit	P
	The composition, velocity and temperature of BESS unit vent gases were be measured within the calorimeter's exhaust duct.	☒ Conformed	P
	Gas composition was measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm^{-1} and a path length of at least 6.6 ft. (2.0 m), or equivalent gas analyser.	☒ Conformed GC-MS was used for gas composition measurement	P
	Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.	☐ Conformed No fire ignited, no propagation occurred with the DUT	N/A
	The hydrocarbon content of the vent gas was measured using flame ionization detection	☐ Conformed GC-MS used, the gas composition was measured off line.	N/A
	Test Terminated at following test condition	See below	P
	- Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;	☒ Conformed	P

Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	- The fire propagates to adjacent units or to adjacent walls; or	☐ Conformed No fire ignited, no propagation occurred between adjacent cells in the initiating module.	N/A
	- Condition hazardous to test staff or the test facility requires mitigation.	☐ Conformed No condition hazards to the test staff or the facilities	N/A

Section 8.3	**TD19-0237**
Sample No	TD-0196
Open Circuit Voltage of Initiating BESS Before Test(Vdc):	1404.4
Thermal runaway initiation Method:	External Heating
Location of Initiating module within BESS:	Module No.5. In 1# BESS from the BMS controller box ） Refer to page 22 for target module location and cell location in the initial BESS.

Heat Release Rate

The convective heat release rate shall be calculated using the following equation:

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

In which:
HRRc = The convective heat release rate (kW)
Ve = The exhaust velocity (m/s)
A = The exhaust duct cross sectional area (m2)
Te = The temperature at the location where exhaust velocity is measured (K)
353.22/Te = The density of air at the velocity measurement location (kg/m3)
To = 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, in which:
A0 = 0.9950
A1 = -5.29933E-05
A2 = 3.21022E-07
A3 = -1.22004E-10

Heat Release Rate Calculation: The heat release rate equals to almost 0 KW in the stage when the unit was forced into thermal runaway as no fire ignited and no propagation occurred between adjacent cells after thermal runaway forced during the whole testing.

Observation of Flying Debris or Explosive Discharge of Gases

No flying debris or explosion triggered during unit level thermal runaway testing. See video records for further information.

Flammable Gas Generation and Composition Data

See Note

Activation of Integral Fire Protection System.

N/A, no fire protection system designed on the battery rack.

Temperature Measurement

Thermocouple Location	Temperature Limit (ºC)	Measured Maximum Temperature (ºC)
Ambient Temperature Before Test	-	23.8
Wall Surface Temperature	119.8	19.5（T25）
Maximum Target BESS Temperature	143.3	21.6（2# BESS, T5）
Maximum Surface temperature of Module within Target BESS	143.3	21.6（2# BESS, T5）

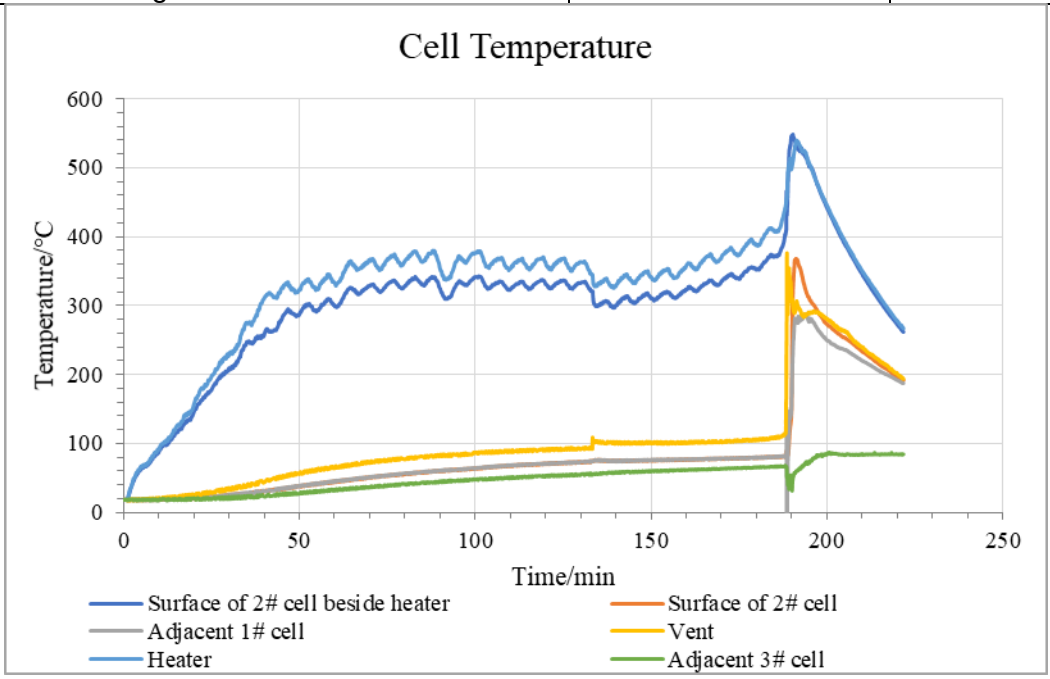


Fig.1 Cell Temperature during Unit Level Testing

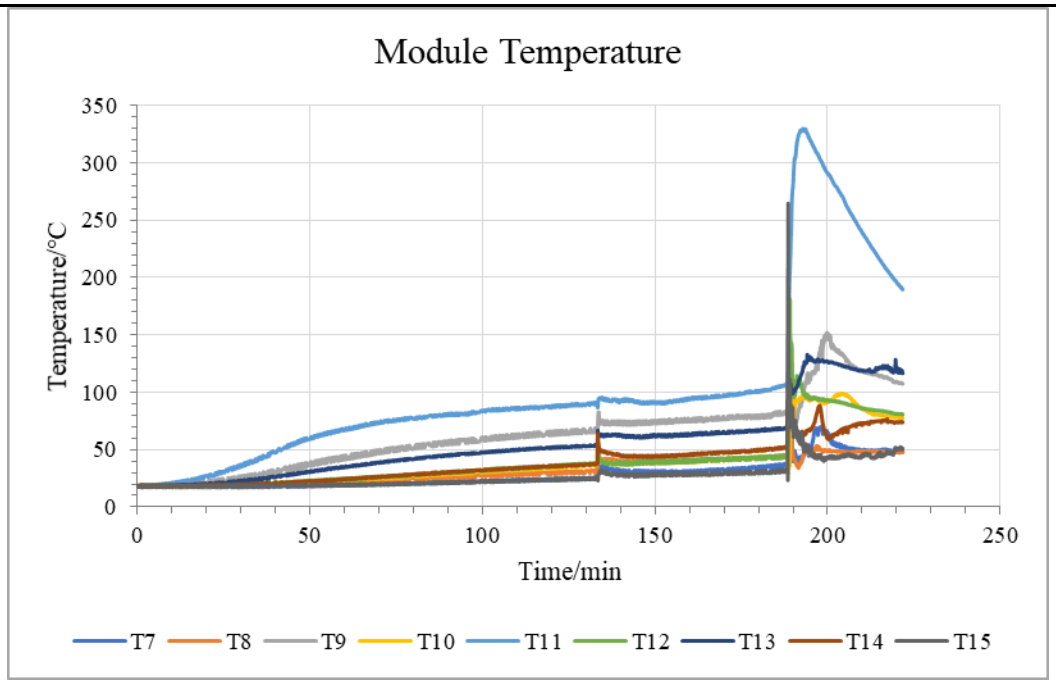


Fig.2 Cell Temperature in target module during Unit Level Testing

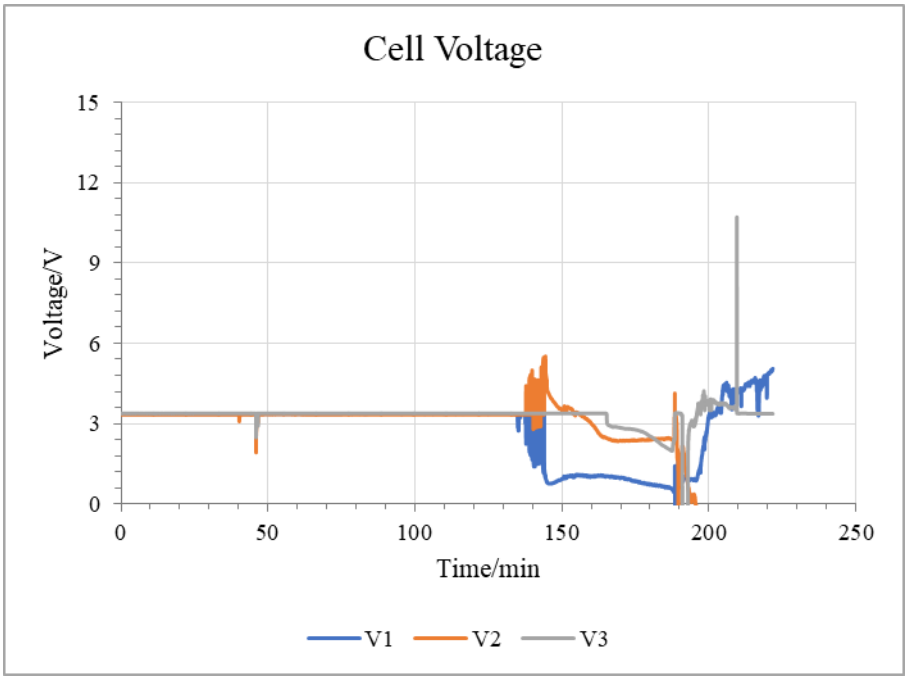


Fig.3 Cell Voltage in target module during Unit Level Testing

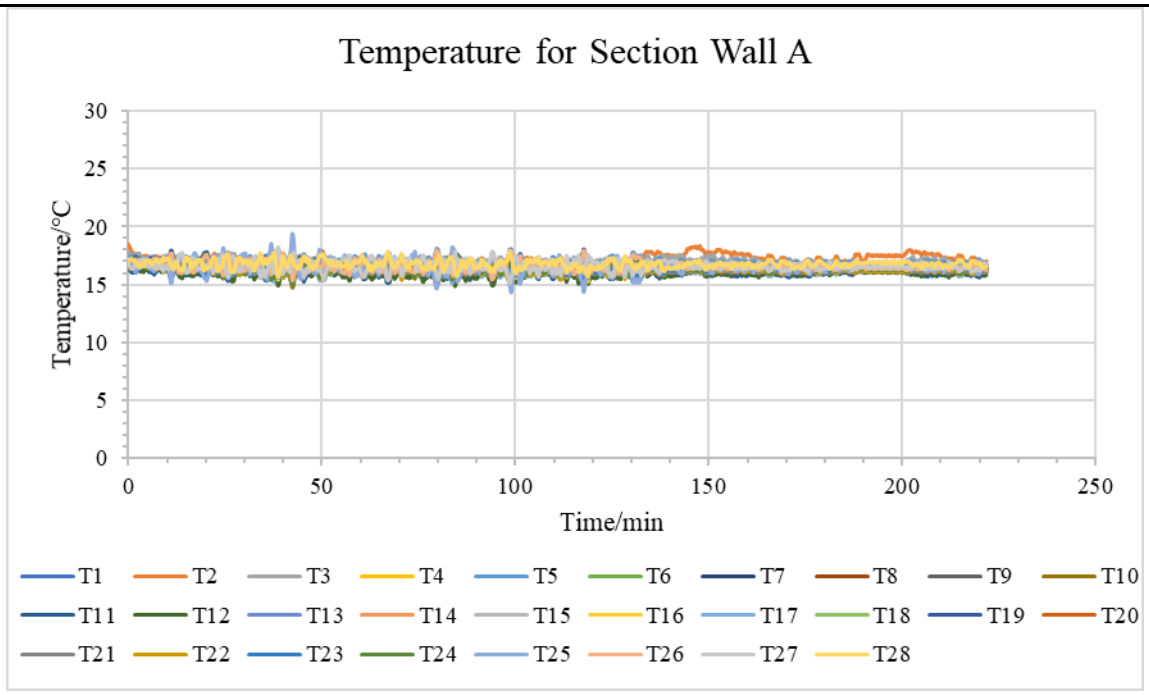


Fig. 4 Temperature of Section Wall A

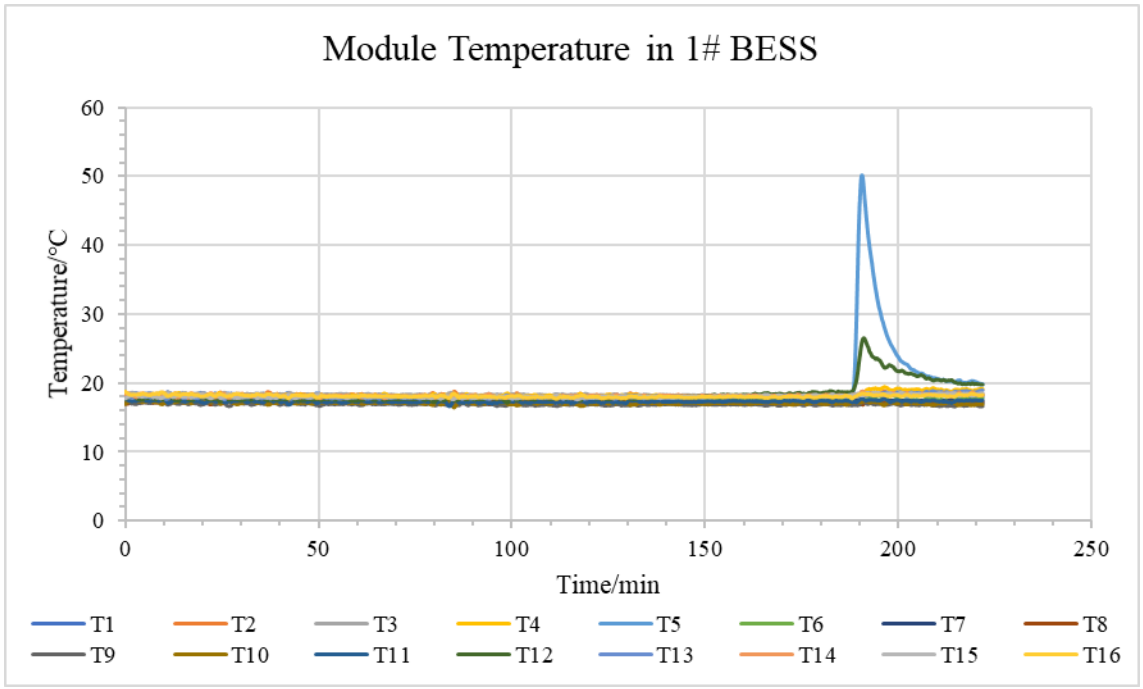


Fig. 5 Module Temperature in 1# BESS

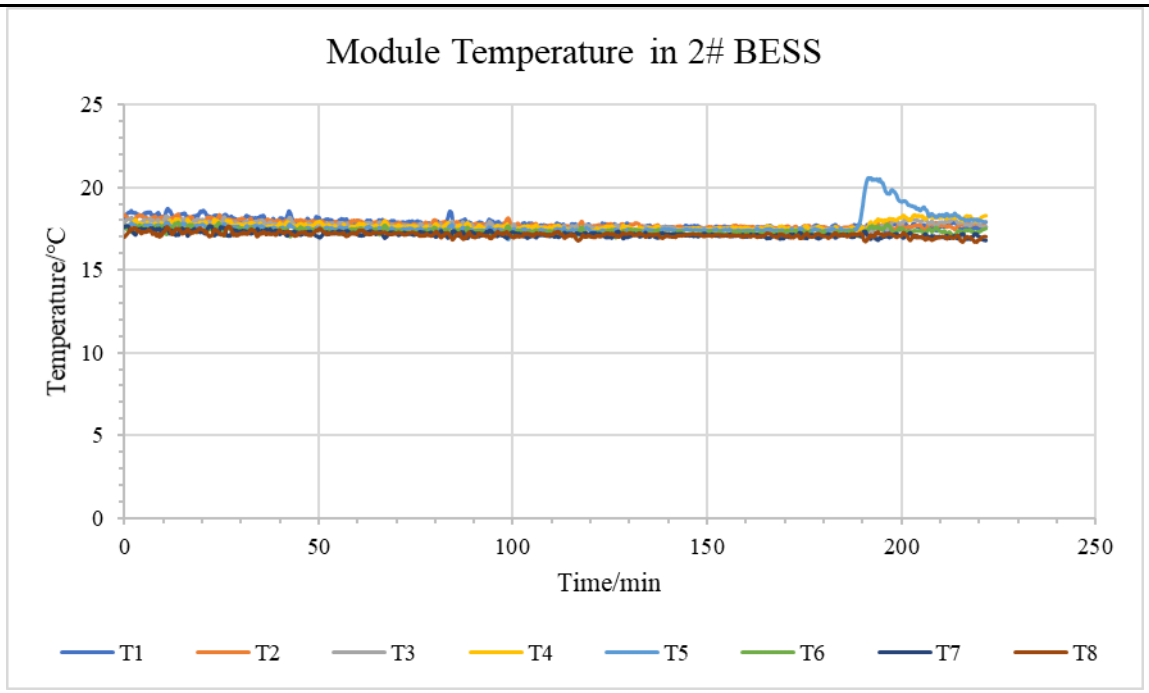


Fig. 6 Module Temperature in 2# Target BESS

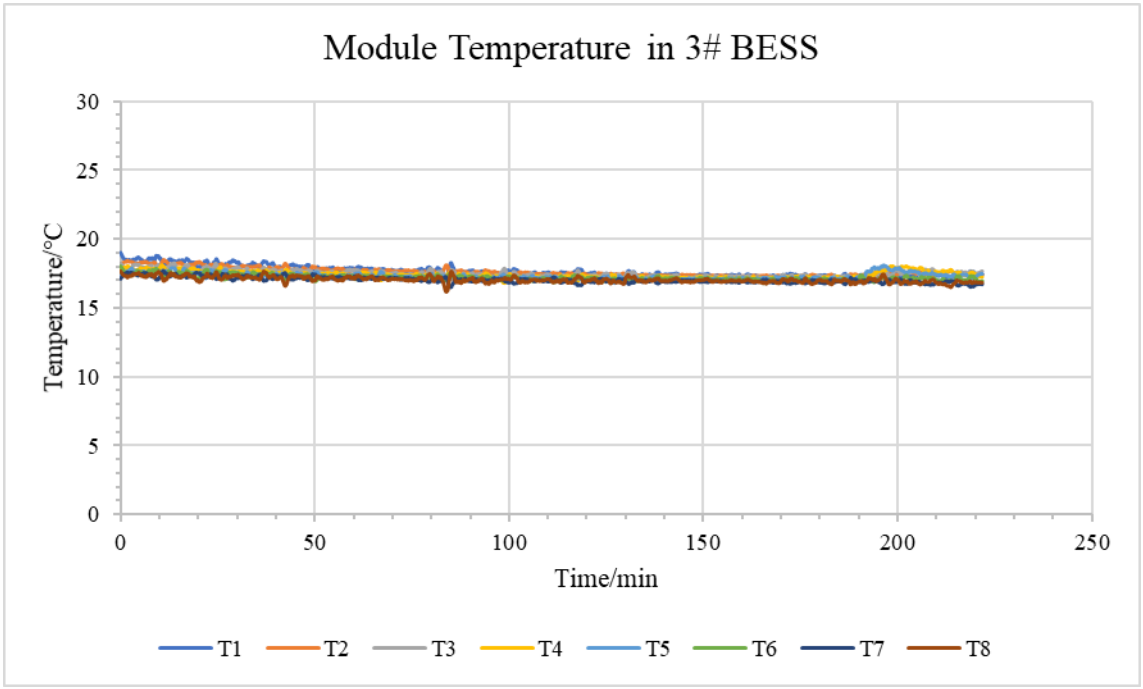


Fig. 7 Module Temperature（3# BESS）

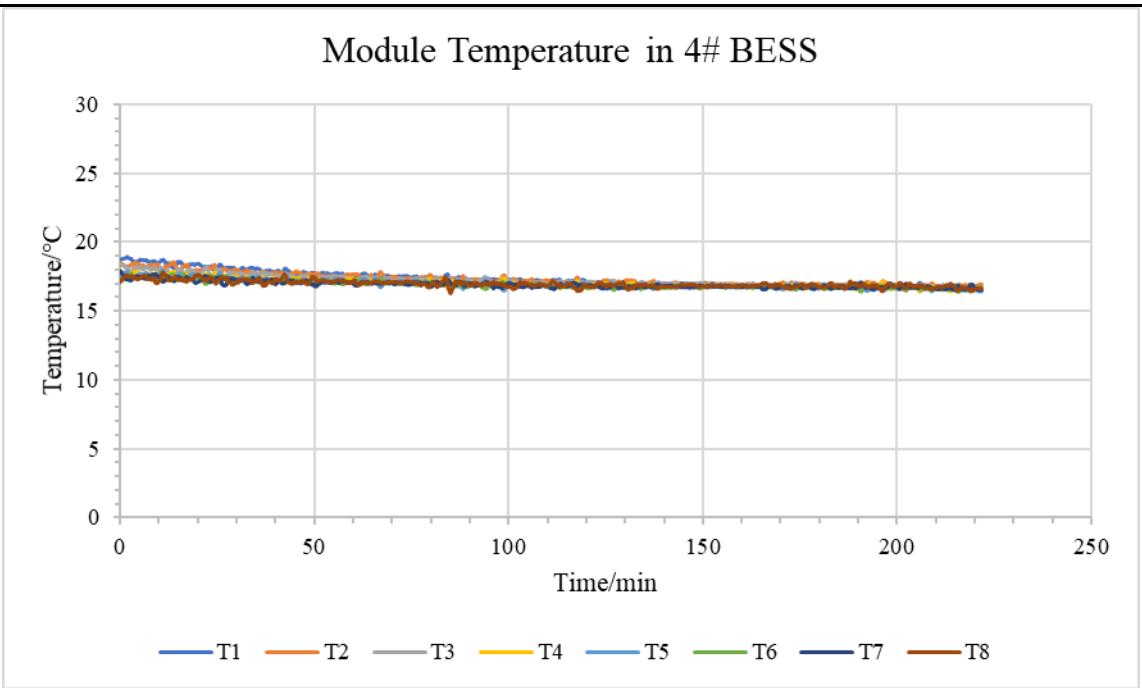


Fig. 8 Module Temperature（4# BESS）

Heat Flux Measurement

Heat flux Location	Measured Maximum Heat Flux (kW/m^2)
Target Wall 1	N/A, see note
Target Wall 2	N/A, see note
Target BESS Unit 1	N/A, see note
Target BESS Unit 2	N/A, see note

Supplementary information:

Note: Heat was not measured on above heat flux location, as no fire ignited during the whole testing.

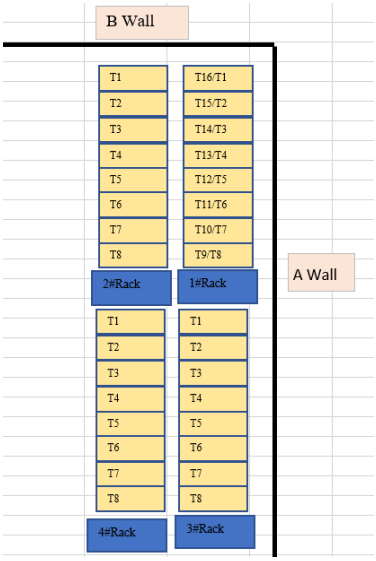


Fig 9 Module Temp in BESS

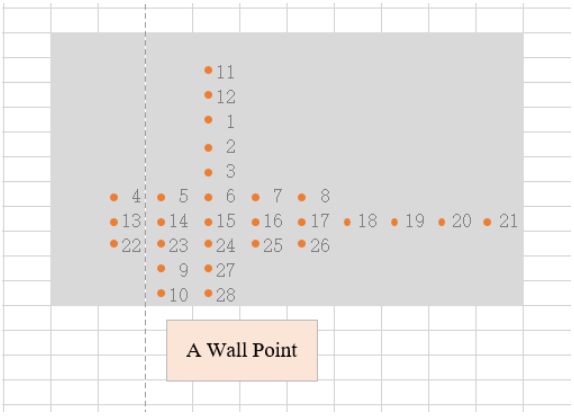


Fig. 10 Section Wall Temp

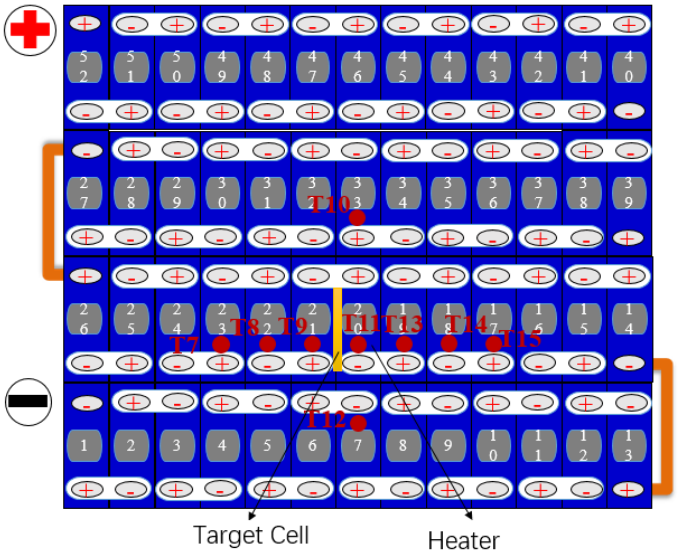


Fig. 11 Heater Location in Module

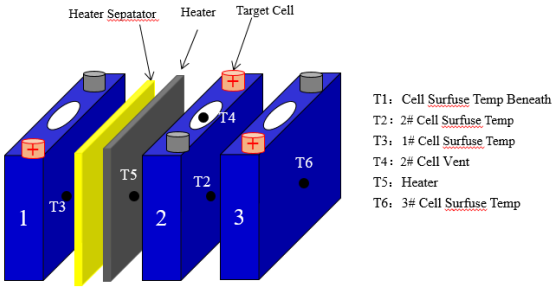


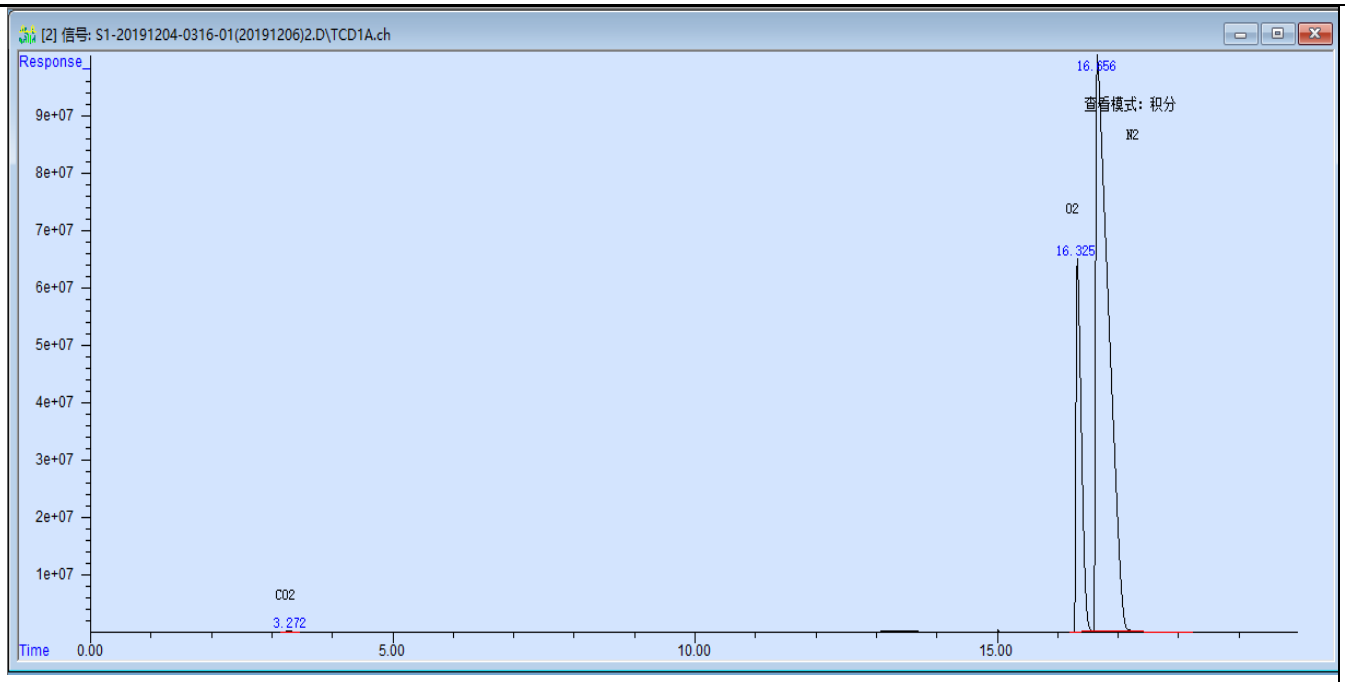
Fig. 12 Thermal Couple Location on Cell

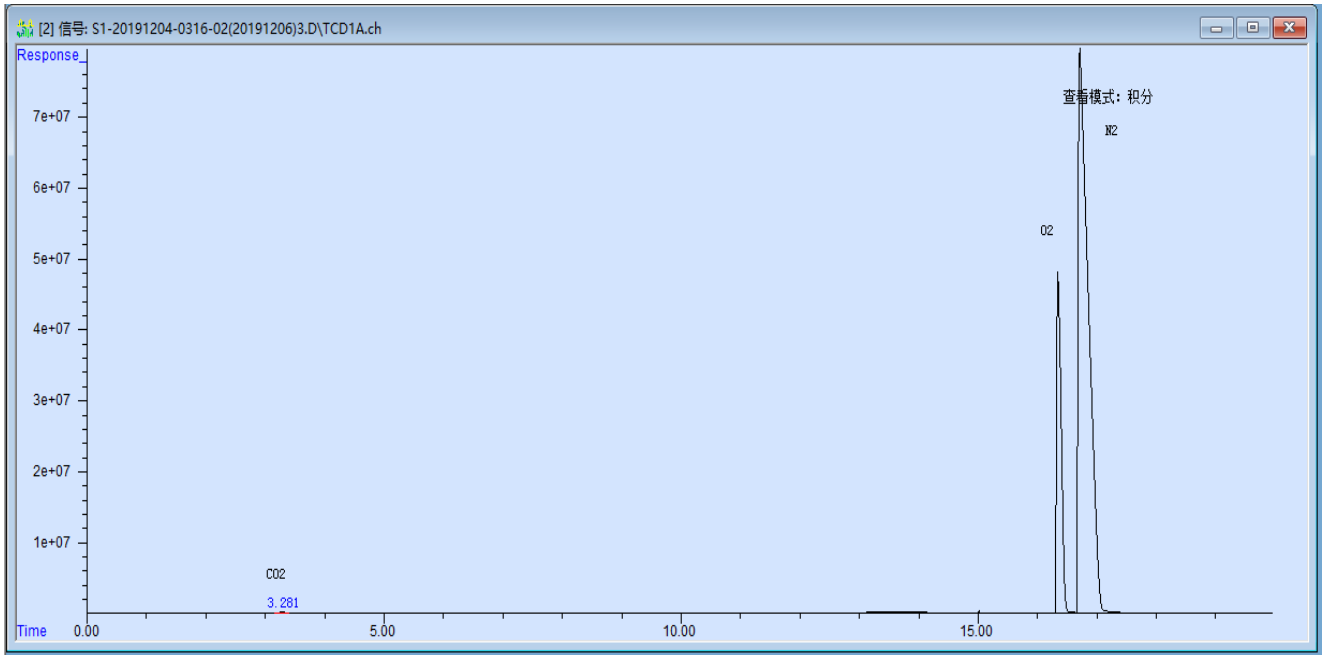
Fig 13 BESS under Test

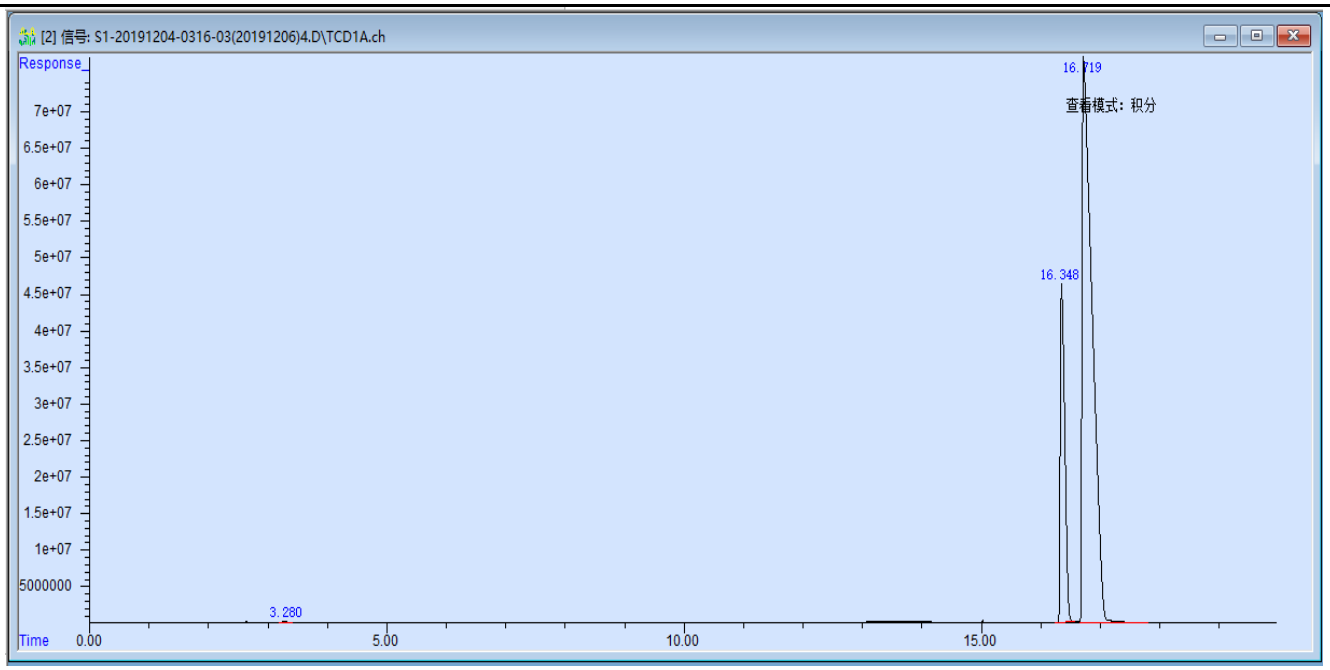
Fig.14 Initial BESS after Test

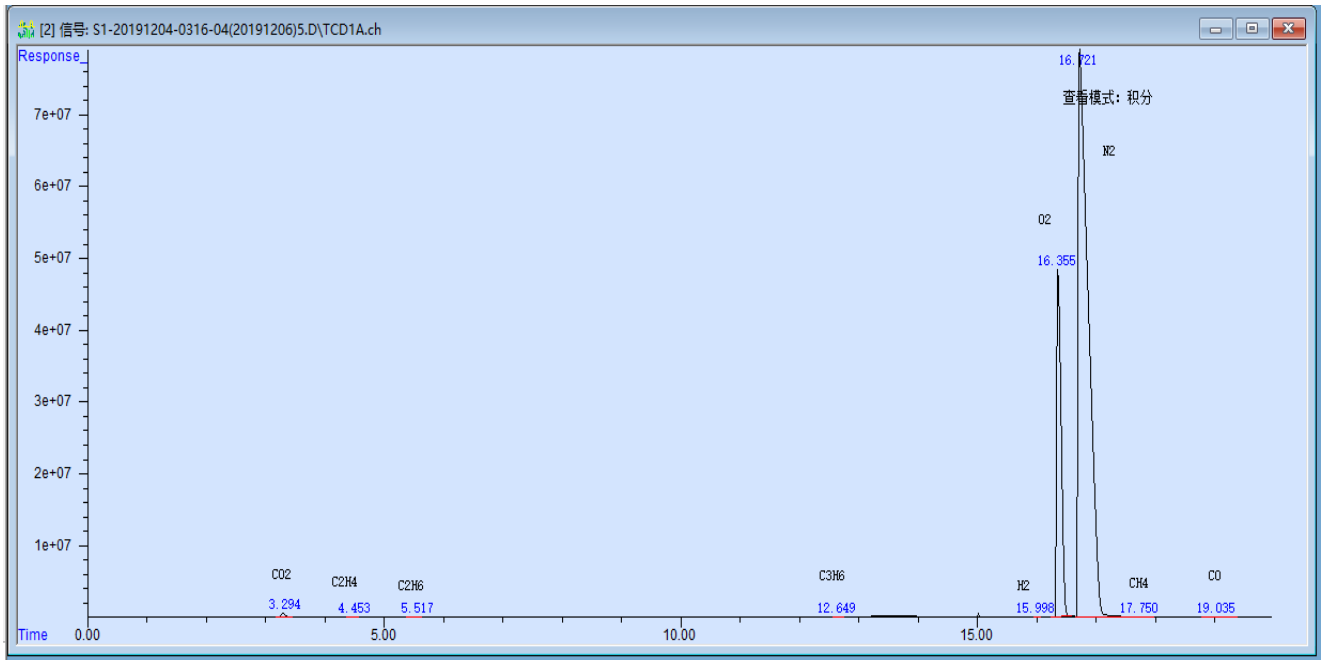
Gas composition analysis

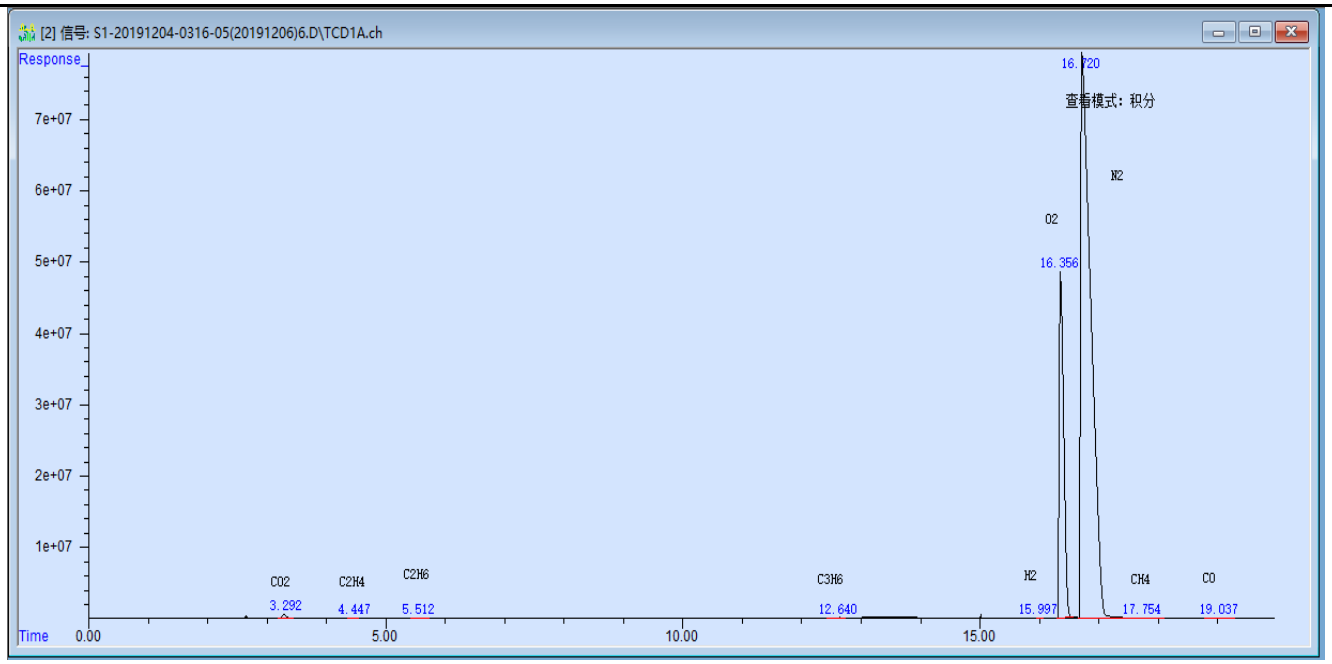
Sample No.	Gas Components									
	CO2	C2H2	C2H4	C2H6	C3H6	H2	O2	N2	CH4	CO
S1-20191204-0316-01	0.06	/	/	/	/	/	21.45	78.49	/	/
S1-20191204-0316-02	0.06	/	/	/	/	/	21.25	78.69	/	/
S1-20191204-0316-03	0.06	/	/	/	/	/	21.23	78.71	/	/
S1-20191204-0316-04	0.18	0.01	0.02	0.01	0.02	0.44	21.09	78.18	0.01	0.05
S1-20191204-0316-05	0.19	0.01	0.02	0.01	0.02	0.52	21.08	78.10	0.01	0.05
S1-20191204-0316-06	0.06	/	/	/	/	/	21.55	78.38	/	/
S1-20191204-0316-07	0.11	/	0.01	/	0.01	0.12	21.26	78.47	/	0.02
S1-20191204-0316-08	0.11	/	0.01	/	0.01	0.11	21.23	78.50	/	0.02

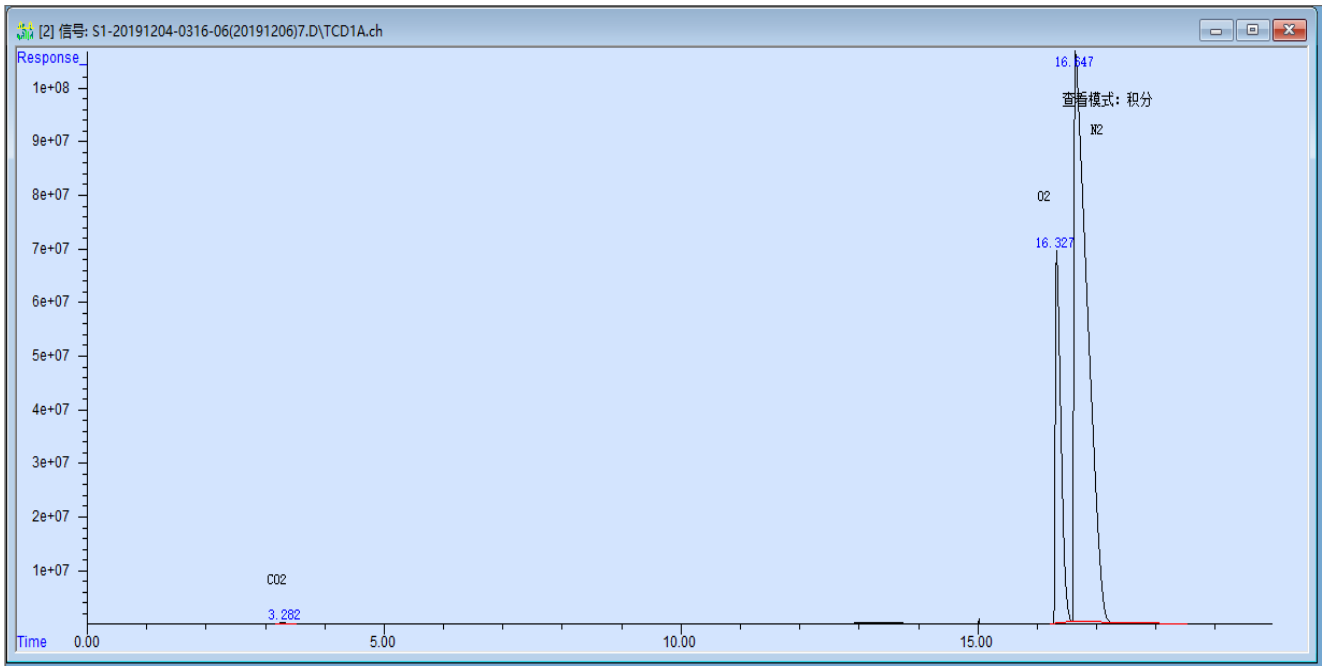


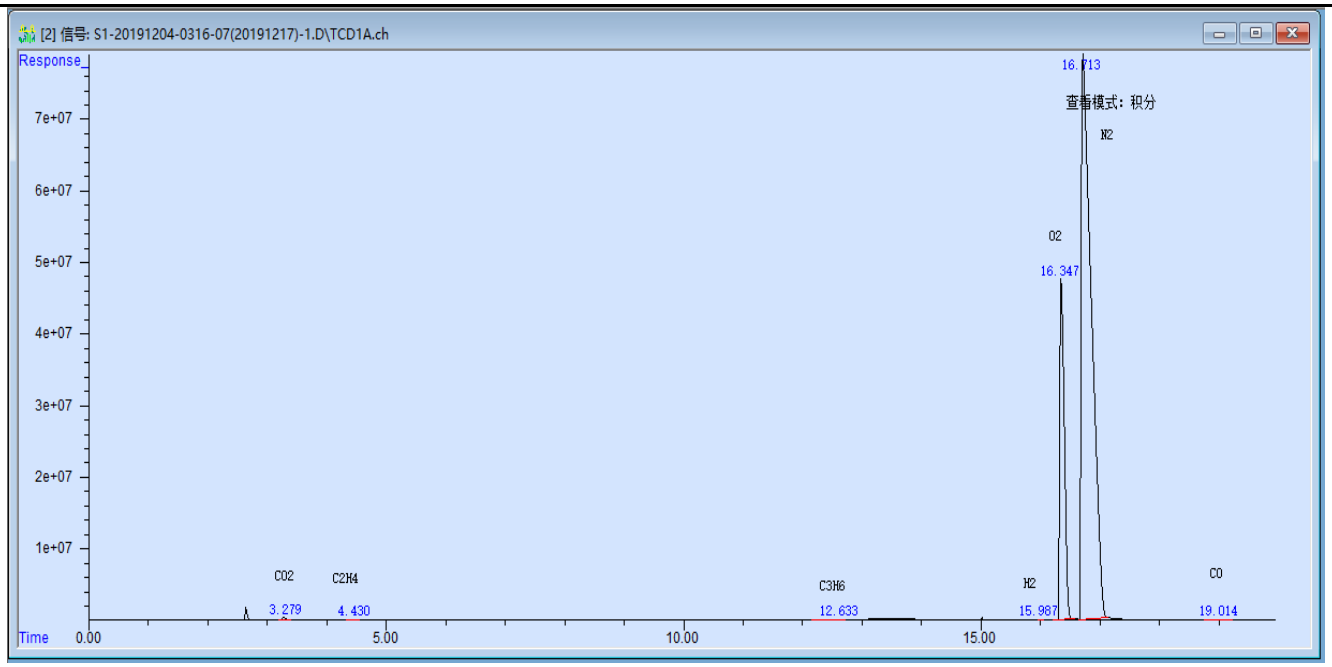


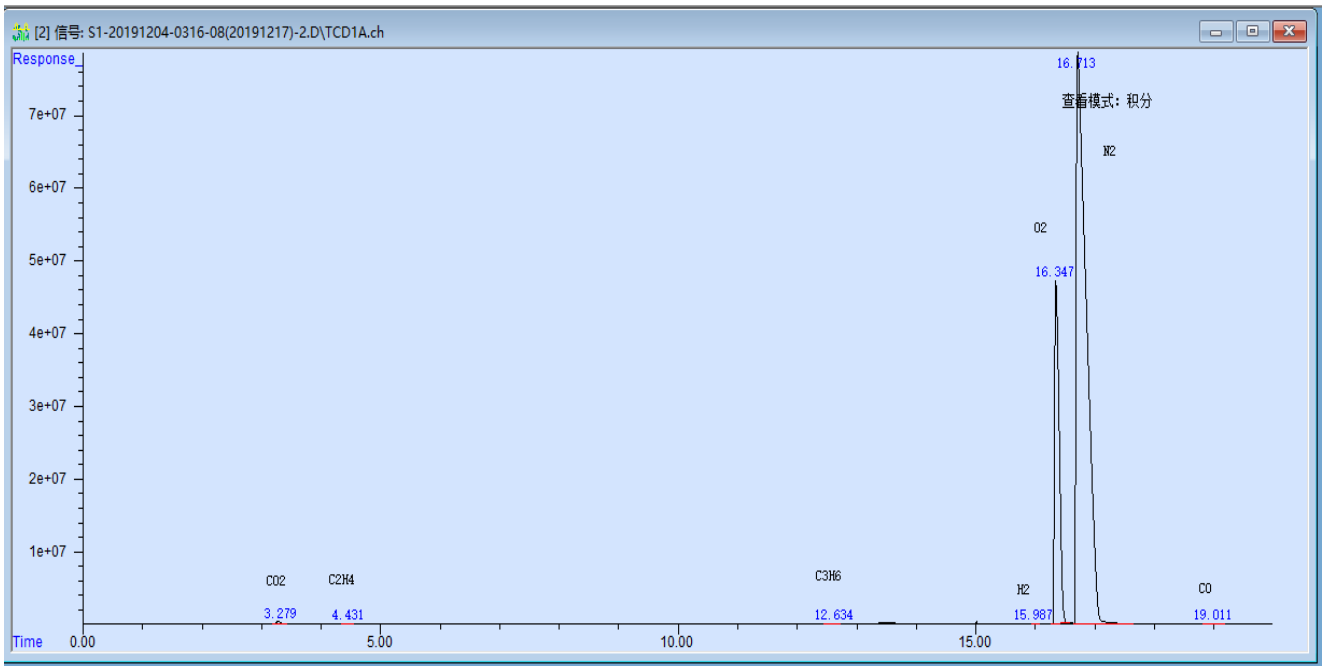












Equipment Used: Item no. 1,2,3,4,5,6
Date Start: 19/11/30 (YY/MM/DD)
Date End: 19/12/04 (YY/MM/DD)

Test Equipment

Item No.	Inventory Code / ID	Description	Mfr	Model	Range Used	Calibration Date (YYYY-MM-DD)	Next Calibration Due Date (YYYY-MM-DD)
1	73B0E01460	Chamber	/	HTP-900-40-AW-D	-40~80℃	2019-02-20	2020-02-19
2	740TE01325	Battery Charge/Discharge System	Suoying	GBBT-110/300-2	10~110V, 5~300A	2019-02-19	2020-02-18
3	73TME00069	Data Logger	HIOKI	LR8401-21	-50~300℃	2019-07-12	2020-07-11
4	L108248/GACH0006	GC-MS	Agilent	5977-7890B	-	2018-10-19	2020-10-18
5	74MUE00013	Multi-Meter	Fluke	1587C	0～600Vdc	2019-08-15	2020-08-14
6	72BAQ00359	Scale	Shanghai Mingpai	XK3190-A12+E	0～400kg	2019-05-23	2020-05-22

---End of Report---