Letter of Attestation

Document: 80025390

Master Contract: N/A

Project: 80025390

Date Issued: November 28, 2019

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 Module， models M52280-E and M52280-P，CSA Group hereby attests that the products identified above and described in test report 80025390 dated Nov 28, 2019 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 7 Module 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: 80025390
PROJECT: 80025390

Edition 1: November 28, 2019; Project 80025390 - Cleveland
Issued by Joseph Zhou, Reviewed by Anuj Amin

Contents:

PRODUCTS

Li-ion Battery Module, models M52280-E and M52280-P

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

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 Qualification Number:	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 — 2019-10-29 to 2019-11-01
Signature — *Date (YYYY-MM-DD)*

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

Joseph Zhou — 2019-11-15
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: Contemporary Amperex Technology Co., Limited ☐ Unit:
Brand name / Trademark	☐ Cell: ☒ Module: N/A ☐ Unit:
Model Number	☐ Cell: ☒ Module: M52280-E, M52280-P ☐ Unit:
Date of receipt of test sample(s)	2019-10-29 (YYYY-MM-DD)
Cell/Battery Type	Li-ion, LFP
Approximate Dimension (mm)	☐ Cell: ☒ Module: 810(W)*1152(D)*243.4(H) mm ☐ Unit:
Mass (g)	☐ Cell: ☒ Module: 304.5kg ☐ Unit:
DUT Sample/Serial Number	☐ Cell: ☒ Module: 770154-00111 ☐ Unit:
DUT Nominal Voltage Rating (V)	☐ Cell: ☒ Module: 166.4 ☐ Unit:
DUT Nominal Charge Capacity Rating (Ah)	☐ Cell: ☒ Module: 280Ah ☐ Unit:
Fire Mitigation Strategies: (For installation level testing)	☐ Water: ☐ Other (Specify): ☒ N/A
Additional Information	N/A

Model Difference:

Models M52280-E and M52280-P are identical. The difference of E and P is the rated current of connecting components, which is 200 A for E and 280 A for P. Based on the difference, test performed on model M52280-P is considered to representative of model M52280-E.

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 – Defination

- "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	Cell testing not requested by manufacturer Cell Thermal runaway methodology: 1 PCS Ceramic Heater, 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， Measured LFL:10.9%@28 ºC ， Pmax:101.3~101.5Kpa See project 80008629 for Cell Level testing data provided by manufacturer
	Section 7: Module Level Test	T	Enclosure Material: non-metallic Cell Configuration: 52S-1P Quantity of Cell: 52 Chemistry: Li-ion, LFP Capacity (Whr): 46592 Energy (Ahr): 280 Nominal Voltage: 166.4 Approximate Dimension (mm): 810(W)*1152(D)*243.4(H) Weight (g): 304.5kg(（before test),），302.5kg （(after test,), weight loss: 2kg Module Comply With UL 1973 Requirement (Yes/No) : No, on going for UL1973 certification
	Section 8: Unit Level Test	N/A	Unit Level testing not requested by manufacturer
	Section 9: Installation Level Test (With fire mitigation strategies)	N/A	Installation Level testing not requested by manufacturer

UL 9540A Third Edition, Dated June 15, 2018 - Section 7 Module Level Testing

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)			
7	Module Level Testing	See below	P
7.1	Module Sample conditioned for min 2 charge (100% SOC) - discharge (Specified end of discharge voltage) cycle as per manufacturer specified method.	Manufacture recommended charge/discharge method: Charging Procedure: CP Charging Voltage (V): 187.2 Charging Current (A): see below : 1. charge the module with 0.25P(11648W) to cell voltage 3.65V 2. charge the module with 0.1P(4659.2W) to cell voltage 3.65V 3. charge the module with 0.05P(2329.6W) to cell voltage 3.65V Charging End Condition (A): - Discharging Procedure: CP Discharging Current (A): 0.25P(11648W) End of Discharge Voltage (V): 2.5V/Cell	P
	Module under test is functional after charge discharge cycle.	☒ Conformed	P
	Ambient temperature during Module conditioning 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): 20.6 to 20.3 Humidity (% RH): 50% to 75%	P
	The tested Module has 100% SOC at the start of the test. The samples were allowed to stabilize for a minimum of one hour prior to testing.	☒ Conformed Module was stabilize for 1 hour	P
7.2	Module testing conducted under a smoke collection hood that is sized appropriately to collect the gases generated from the module	☒ Conformed	P

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)			
	The position of cell forced into thermal runaway selected to present the greatest thermal exposure to adjacent cells not forced into thermal runaway.	☒ Conformed	P
	Following factor consider when selecting location of cell failure within the module.	See below	P
	- Heat transfer is maximized to other cell	Yes, the cell located near the center of the module, can make sure heat transferred maximized to the other cell	P
	- Cooling by ventilation is restricted or limited	No ventilation fan	N/A
	- Detection and suppression discharge points are remote	No remote detection and suppression system	N/A
	- Other (Specify)	-	N/A
	Methodology used to determine thermal runaway within module	External heating method was used for module thermal runaway testing	P
	Occurrence of thermal runaway shall be verified by sustained temperature above the cell surface temperature at the onset of cell thermal runaway.	☒ Conformed	P
	Module placed on non-combustible horizontal surface in the same orientation as is intended in its final installation.	☒ Conformed	P
	The chemical heat release rate of module in thermal runaway measured with oxygen consumption calorimetry	☐ Conformed No fire ignited, no propagation occurred with the DUT	N/A
	Chemical heat release rate of module measured for duration of the test	☐ Conformed No fire ignited, no propagation occurred with the DUT	N/A
	The chemical heat release rate measured by a measurement system consisting of a paramagnetic oxygen analyser, non-dispersive infrared carbon dioxide and carbon monoxide analyser, velocity probe, and a Type K thermocouple.	☐ Conformed Velocity probe and type K thermocouple were provided	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)			
	The instrumentation located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influence of bends or exhaust devices.	☐ Conformed No fire ignited, no propagation occurred with the DUT	N/A
	Vent gas composition 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 m), or equivalent gas analyser, and velocity and temperature measurements respectively in the exhaust duct.	☒ Conformed GC-MS was used for gas composition measurement during the cell venting and thermal runaway stage.	P
	The hydrocarbon content of the vent gas measured using flame ionization detection	☐ Conformed Hydrocarbon content were measured using the GC-MS for composition analysis	N/A
	Module weight loss shall be measured.	304.5kg(before test), 302.5kg （after test）, weight loss: 2kg	P

Section 7.3	**TABLE: Module Level Test**
Sample No	770154-00111
Open Circuit Voltage Before Test (Vdc):	174.9
Cell Failure Method:	External Heating using one ceramic heater, rated 220/230V, 500W, secured on the left side on the cell surface, using the heat insulation film to prevent the heater from heating the adjacent cell. Test started at about 18: 36 PM on Oct 30, 2019, during the heating process, power supply for the external heater was adjusted to make sure the heating rate of the cell surface can maintain within 5~7°C per minute, cell vented at about 21:14:48S PM with the vent temperature 92.3°C, continue heating, and cell forced thermal runaway at 22:25:29S PM, with the measured cell surface temp 123.9°C.

Heat Release Rate

Heat release rate was calculated at each of the flows as follows:

$$HRR_t = \left[E \times \varphi - (E_{CO} - E) \times \frac{1-\varphi}{2} \times \frac{X_{CO}}{X_{O_2}} \right] \times \frac{\dot{m}_e}{1 + \varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^{\circ}_{H_2O}) \times X^{\circ}_{O_2}$$

In which:
HRR_t = total heat release rate, as a function of time (kW)
E = Net heat released for complete combustion per unit of oxygen consumed (adjusted for oxygen contained within cell chemistry, 13,100 kJ/kg)
E_{CO} = Net heat released for complete combustion per unit of oxygen consumed, for CO (adjusted for oxygen contained within cell chemistry, 17,600 kJ/kg)
ϕ = Oxygen depletion factor (nondimensional), in which:

$$\varphi = \frac{X^{\circ}_{O_2} \times [1 - X_{CO_2} - X_{CO}] - X_{O_2} \times [1 - X^{\circ}_{CO_2}]}{X^{\circ}_{O_2} \times [1 - X_{O_2} - X_{CO_2} - X_{CO}]}$$

X_{CO} = Measured mole fraction of CO in exhaust flow (nondimensional)
X_{CO_2} = Measured mole fraction of CO_2 in exhaust flow (nondimensional)
$X^{\circ}_{CO_2}$ = Measured mole fraction of CO_2 in incoming air (nondimensional)
$X^{\circ}_{H_2O}$ = Measured mole fraction of H_2O in incoming air (nondimensional)
X_{O_2} = Measured mole fraction of O_2 in exhaust flow (nondimensional)
$X^{\circ}_{O_2}$ = Measured mole fraction of O_2 in incoming air (nondimensional)
〈 = Combustion expansion factor (nondimensional; normally a value of 1.105)
M_a = Molecular weight of incoming and exhaust air (29 kg/kmol)
M_{O_2} = Molecular weight of oxygen (32 kg/kmol)

$\dot{m}_e$ = Mass flow rate in exhaust duct (kg/s), in which:

$$\dot{m}_e = C \times \sqrt{\Delta p / T_e}$$

or

$$\dot{m}_e = 26.54 \times \frac{A \times k_c}{f(Re)} \times \sqrt{\Delta p / T_e}$$

C = Orifice plate coefficient (in $kg^{1/2}m^{1/2}K^{1/2}$)
⊗P = Pressure drop across orifice plate or bidirectional probe (Pa)
T_e = Combustion gas temperature at orifice plate or bi-directional probe (K)
A = Cross sectional area of the duct (m^2)
k_c = Velocity profile shape factor (nondimensional)
f(Re) = Reynolds number correction (nondimensional)

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

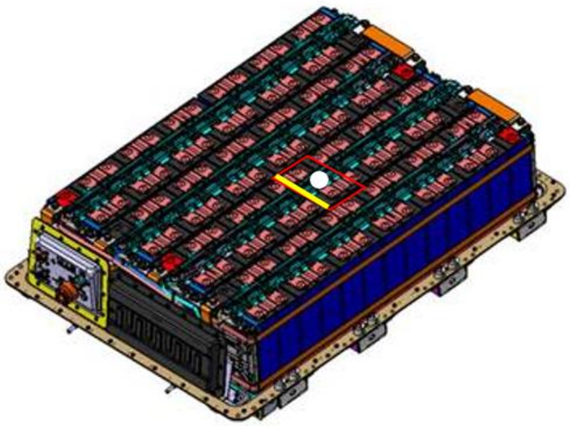
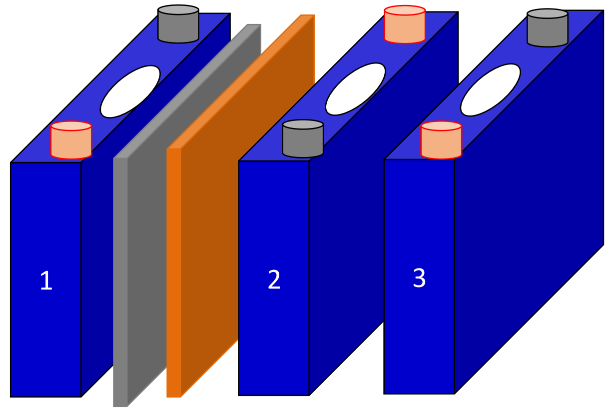
Observation of Flying Debris or Explosive Discharge of Gases

Summary: The DUT swelled with a lot of smoke released when the selected cell was forced thermal runaway, during the whole testing, no fire or explosion occurred, no propagation observed between the adjacent cells of the module For supplementary information, see test video and the following pictures for details.

Sample Before Testing:

Figure. 1 Top View of the DUT

Figure. 2 Front View of the DUT

	
Sample During Testing:	
Figure.3 Heater Location of the DUT	Figure. 4 Heater Location
	
Sample After Testing	
Figure.5 DUT During Testing	Figure.6 DUT During Testing

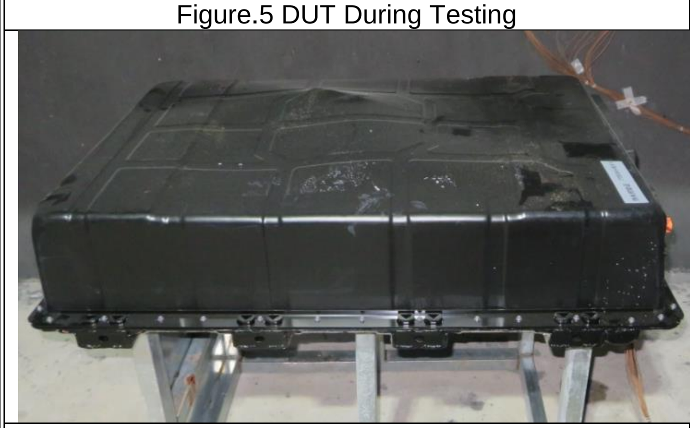
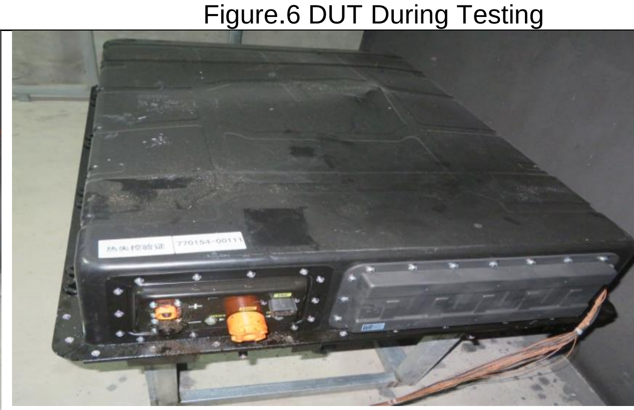

	

Figure. 7 Side View of the DUT	Figure.8 Front View of the DUT

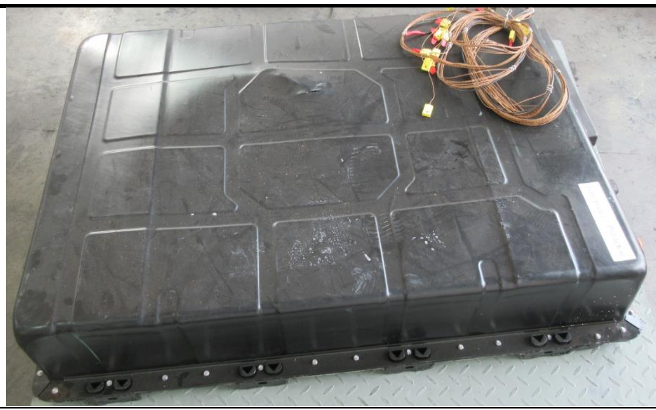
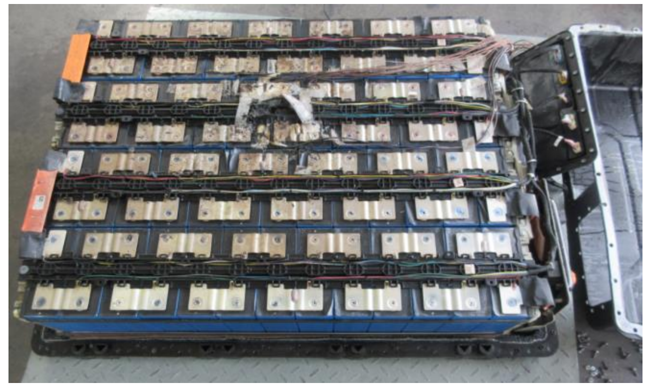
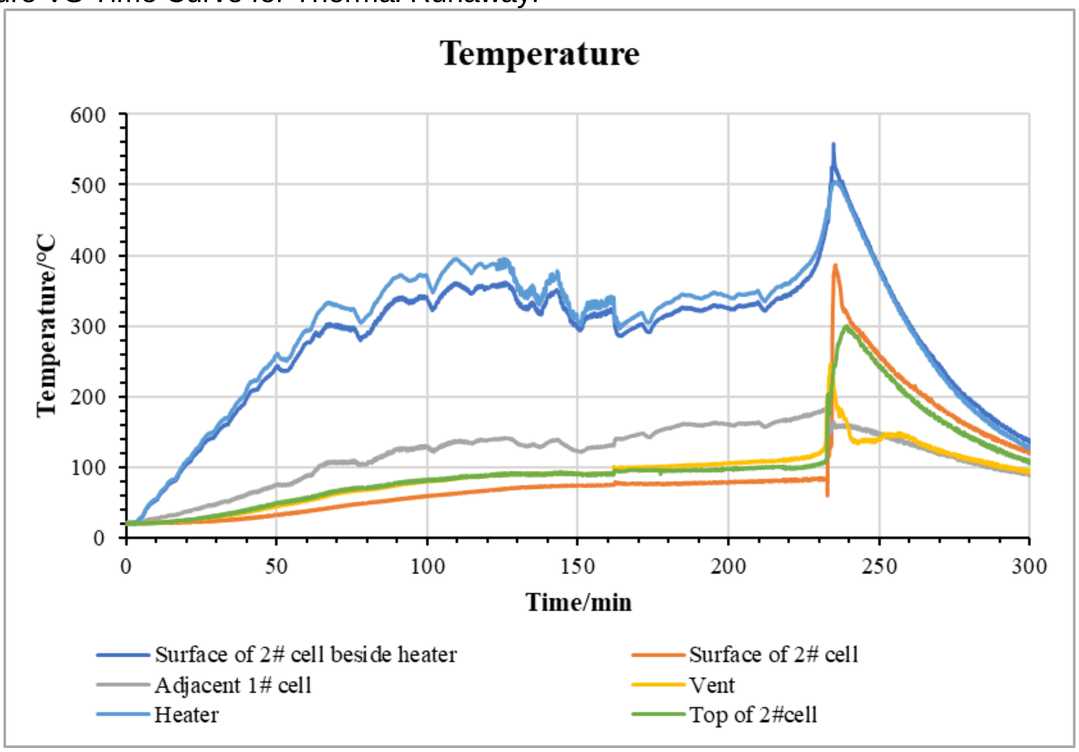
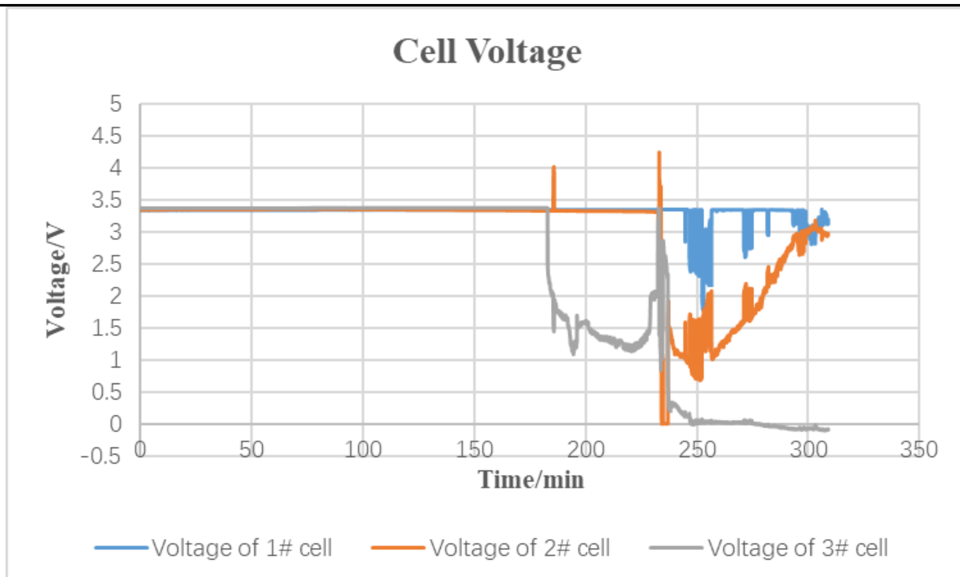
	

Figure. 9 Top View of the DUT	Figure. 10 Inside View of DUT

Temperature VS Time Curve for Thermal Runaway:



Temperature VS Time Curve for Thermal Runaway



Cell Voltage VS Time During Testing

Flammable Gas Generation and Composition Data

Sample No.	Gas Components						
	CO2	C2H4	C2H6	C3H6	O2	N2	CO
S1-20191101-0001-01	0.0553	0.0000	0.0000	0.0000	21.2036	78.7411	0.0000
S1-20191101-0001-02	0.0649	0.0017	0.0000	0.0014	21.2177	78.7134	0.0007
S1-20191101-0001-03	0.0874	0.0067	0.0014	0.0044	21.2155	78.6733	0.0112
S1-20191101-0001-04	0.0877	0.0056	0.0016	0.0039	21.2183	78.6734	0.0095
S1-20191101-0001-05	0.0745	0.0022	0.0000	0.0015	21.2220	78.6998	0.0000
S1-20191101-0001-06	0.0684	0.0018	0.0000	0.0009	21.2321	78.6937	0.0032
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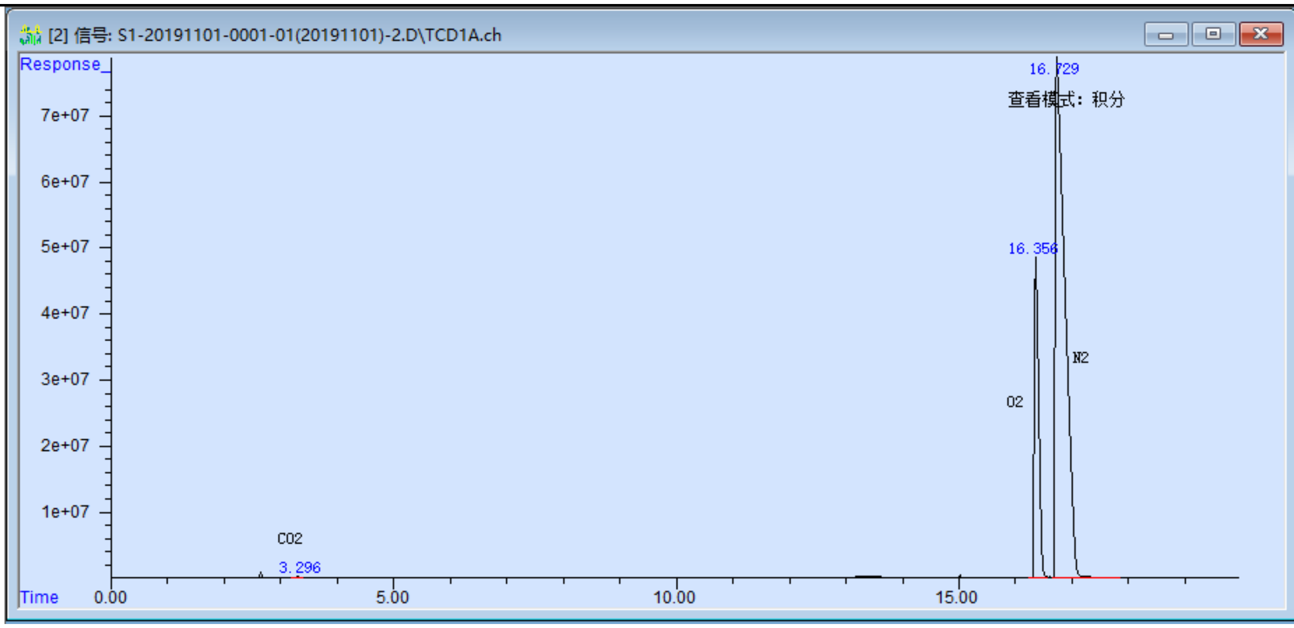
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Time
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CO2
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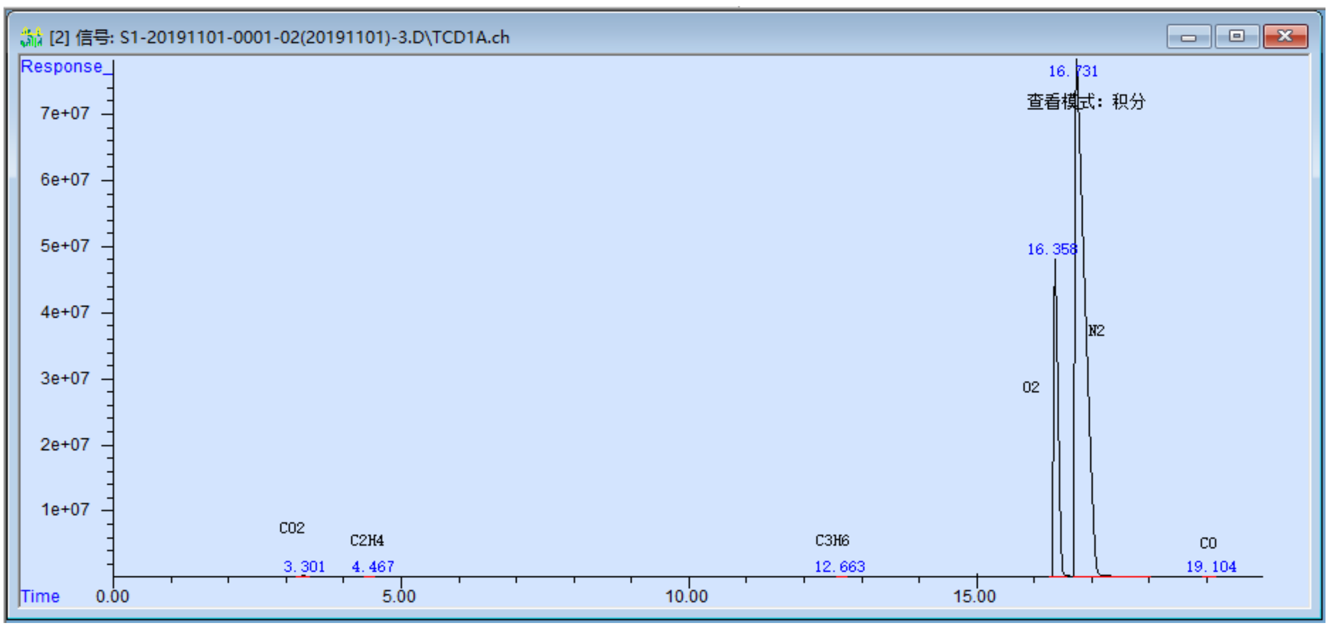
O2
16.729
N2
查看模式: 积分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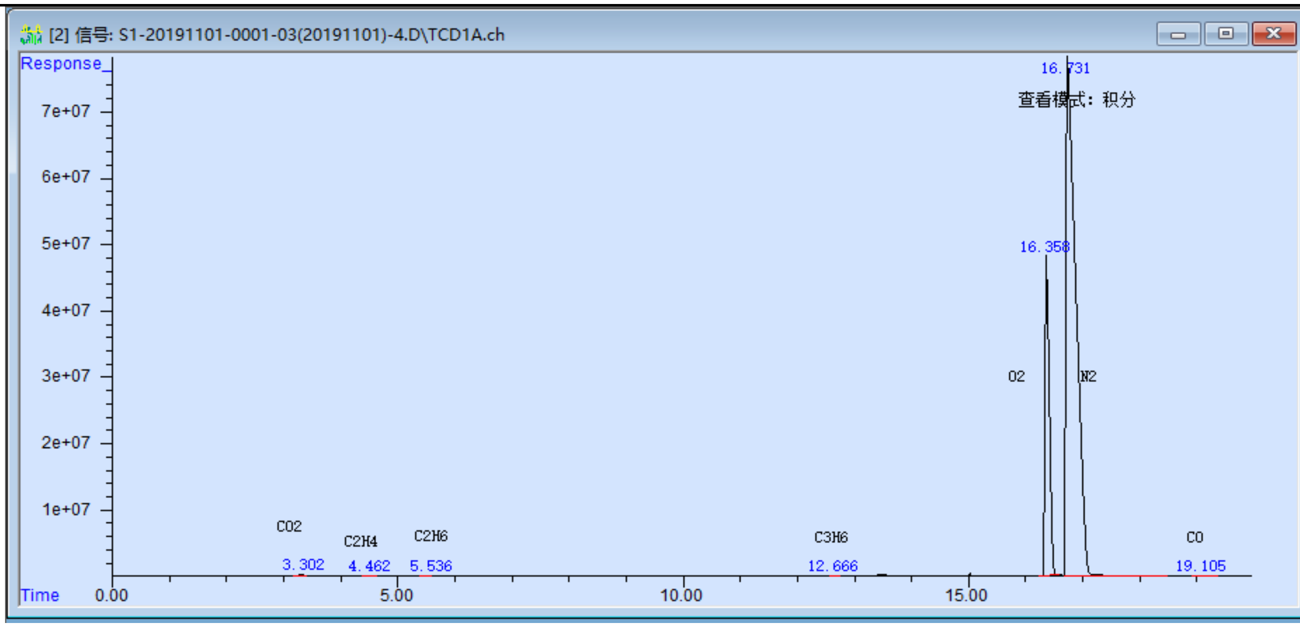
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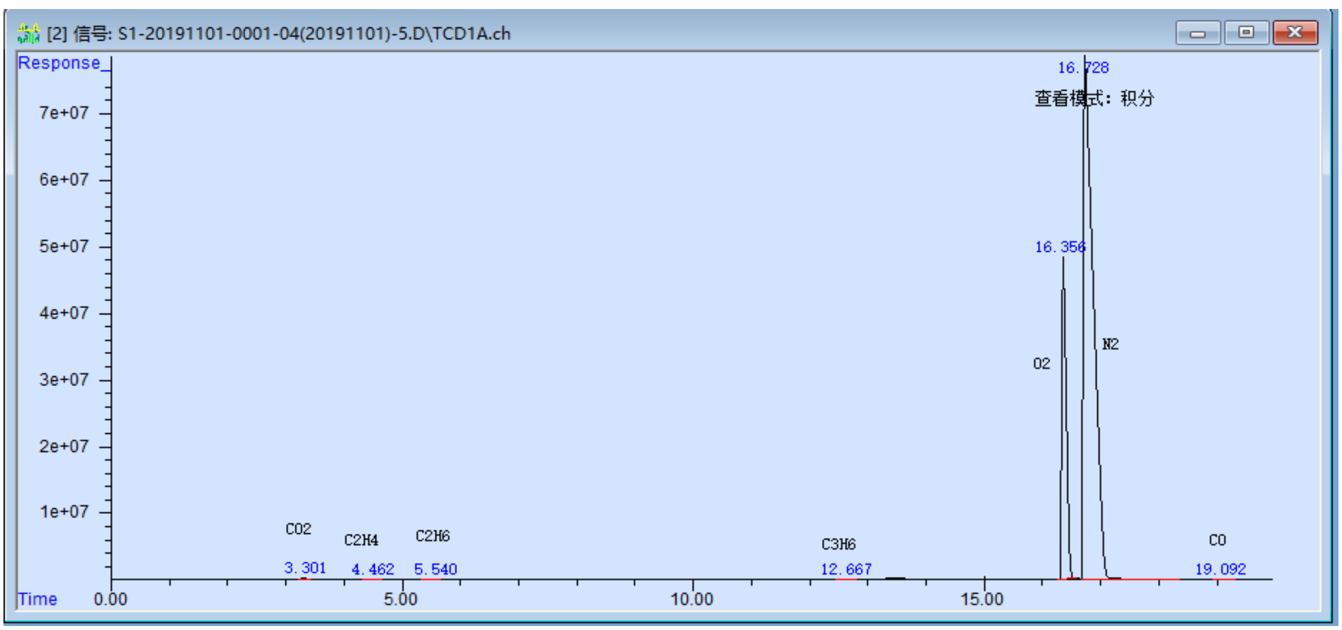
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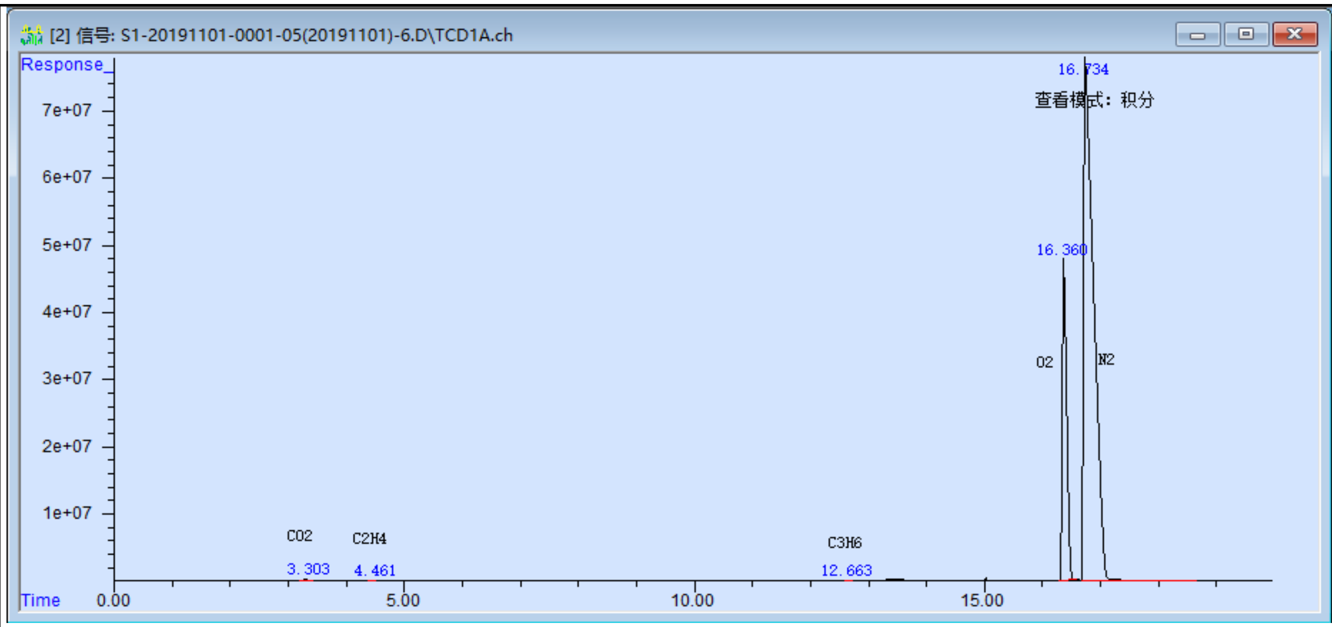
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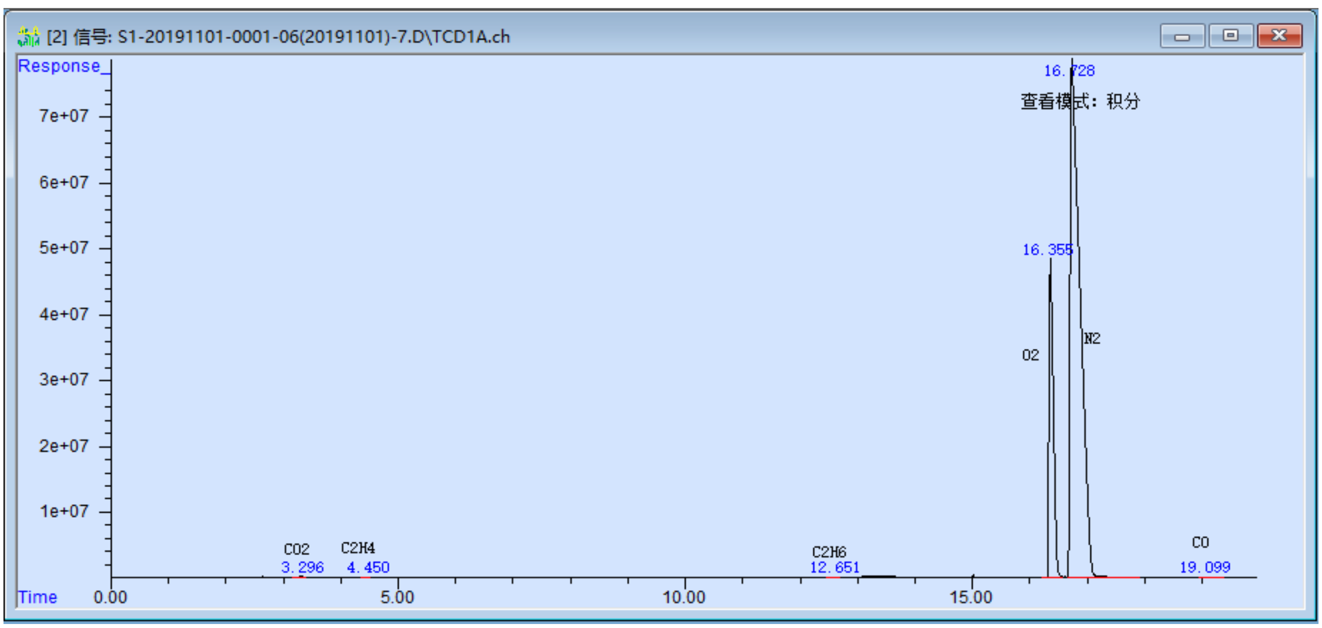
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10.00
15.00
查看模式: 积分
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O2
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CO2
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C2H4
4.450
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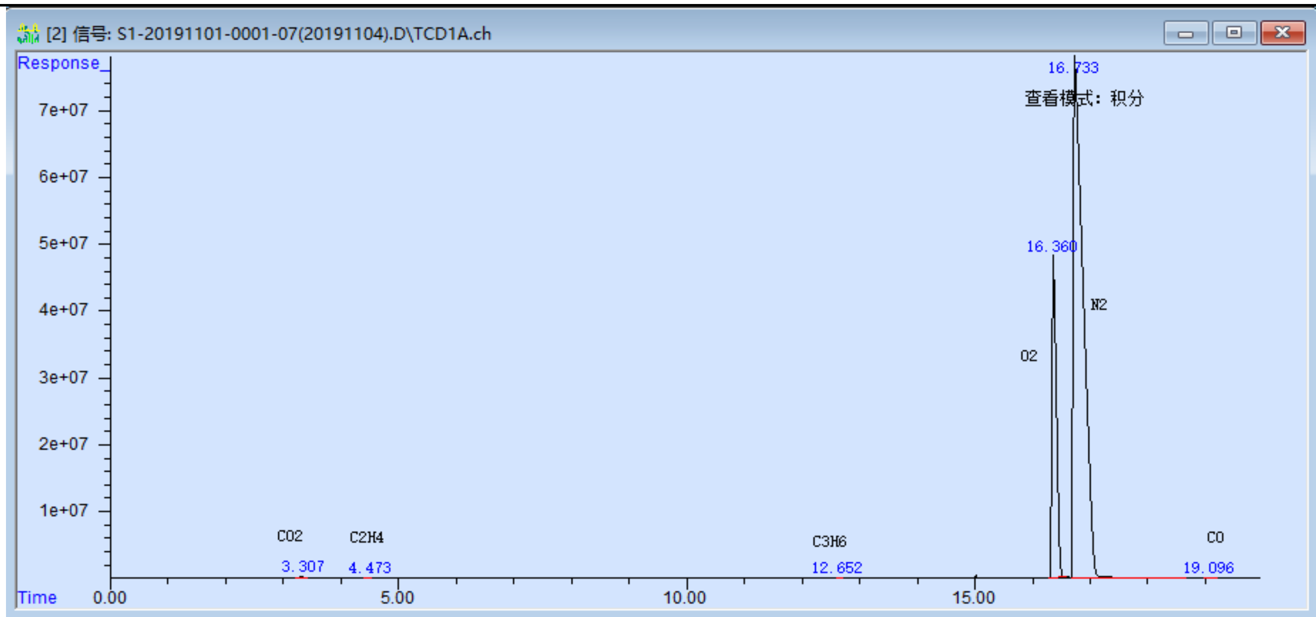
12.651
CO
19.099



Gas Component	Gas Type	Volume Released (Before thermal runaway) (Liters)	Volume Released (After thermal runaway) (Liters)
Ethylene	Hydrocarbons	N/A	See Note
Ethane	Hydrocarbons	N/A	See Note
Propane	Hydrocarbons	N/A	See Note
Carbon Dioxide	Carbon Containing	N/A	See Note
Carbon Monoxide	Carbon Containing	N/A	See Note
Hydrogen	---	N/A	See Note
Total Hydrocarbons (% propane)	Hydrocarbon	N/A	See Note

Supplementary information:

Note: Gas volume released was not measured as the module thermal runaway testing was conducted under an open condition, with gases collected using the gas collection bags. JZ 2019-11-19

Equipment Used: Item no. 1,2,3,4,5,6
Date Start: 19/10/29 (YY/MM/DD)
Date End: 19/11/01 (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	2020-02-28
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

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