



CSA GROUP
Laboratory Test Data - UL 9540A

Master Contract: 304186

Report: 80202416

Project: 80202416

Feb 05, 2025

Mr. Taibing Gong,
Project Manager
ZhongTian Energy Storage Technology Co., Ltd.
No.36, East Hongxing Road, NETDA
Nantong, Jiangsu 226015
China Subject: Lithium-Ion Rechargeable Cell, model ZTT71173204 (UL 9540A Test Report)

Dear Mr. Taibing Gong:

We are pleased to inform you that testing of your product per UL 9540A has been completed. Applicable test(s) was witnessed at facility ChuWeiNeng Testing Technology (Shanghai) Co.Ltd by CSA –Address: Building 3, No.1065 Beihe Highway, Jiading District, Shanghai. Cell level of test(s) was conducted on the sample you provided and the results are enclosed in the test report.

Note: This Test Report is not an Authorization to apply the CSA Mark to the product. The results contained in the report(s) provided are contingent upon the characteristics of the actual sample(s) used in the investigation. In the absence of a continuing inspection service, CSA provides no assurance, expressed or implied, that the contents of the report are applicable to reproductions of the sample(s). Use or reproduction of the CSA name, logo, or trademark is not permitted without the prior written consent of CSA. No references can be made to this report when using the results of this investigation for the purposes of advertising, promotion or litigation, without the prior written consent of CSA.

Please examine the enclosed documents and contact me if you have any questions or would like us to make any changes.

On behalf of CSA, I would like to thank you for your business and offer our services for your future needs.

Yours truly,

Marvin Peng
CSA –CCIC-CSA International Certification Co., Ltd. Kunshan Branch
2F-1, Building C12, No 555 Dujuan Road, Kunshan Economic & Technical Development Zone, Kunshan,
Jiangsu, China 215331

Encl. [UL 9540A Test Report]
Att.1 - Critical components and material information_ 80202416
Att.2 - Cell charge/discharge conditioning graphs
Att.3 - Photos
Att.4 - Cell temperature/voltage graph during testing
Att.5 - Cell gas analysis report
Att.6 - Video (separated file)



ORIGINAL TEST DATA

The results relate only to the items tested.

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Master Contract:	304186	Model:	ZTT71173204	Page number 1 of 33
Project / Network:	80202416	Description:	Li-ion battery cell	

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:	2F-1, Building C12, No 555 Dujuan Road, Kunshan Economic & Technical Development Zone, Kunshan, Jiangsu, China 215331
Testing Program:	Custom Test : Cover Latter ☒ , Testing Only ☐

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

Testing Laboratory Name:	ChuWeiNeng Testing Technology (Shanghai) Co. Ltd
Address:	Building 3, No.1065 Beihe Highway, Jiading District, Shanghai, China
Facility Qualification Number:	N/A

Customer:	As above / or describe otherwise ZhongTian Energy Storage Technology Co., Ltd
Address:	No.36,East Hongxing Road,NETDA Nantong, Jiangsu 226015 China

Tested By:	Jiaming Huang	
	Name, Title	
	Jiaming Huang	2024-10-08 - 2024-12-03
	Signature	Date (YYYY-MM-DD)
☒ Reviewed by:	Marvin Peng	
☒ Witnessed by:	Name, Title	
	Miyu Chen/Marvin Peng	2024-10-08 - 2024-12-03
	Signature	Date (YYYY-MM-DD)

Version 6.1 : 2022-08-02



CSA GROUP
Laboratory Test Data - UL 9540A Checklist and Test Result (Cell Level)
ORIGINAL TEST DATA

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Project / Network:	80202416	Description:	Li-ion battery cell	

Cell Level Test Summary	
Manufacturer:	ZhongTian Energy Storage Technology Co., Ltd.
Brand name / Trademark:	N/A
Model number:	ZTT71173204
Nominal cell voltage, (V)	3.2
Cell capacity, (Ah)	314
Cell chemistry:	LFP
Physical format of cell:	Prismatic
Approximate dimension, (mm)	L×W×T: 71.65±0.8×174.26±0.8×207.01±0.8
Mass, (kg)	5.49±0.3
Cell certification available? (Yes/No)	Yes
Standard(s) used to certify product:	ANSI/CAN/UL1973:2022, 3rd Edition
Certification organization name and its certificate number:	Under certification, Report number 80202415
Method used to initiate thermal runaway:	External Flexible heater
Average temperature at which cell first vented excluding gas collection sample, (°C)	165.5
Average temperature prior to thermal runaway excluding gas collection sample, (°C)	231.4
Location of maximum temperature:	202410008-2: Near vent 202410008-1,3 4,5: Cell large surface of cell under the heater
Flammable gas generation, (Liter)	146.9
Total gas generation, (Liter)	206.3
Lower flammability limit (LFL) at ambient temperature (25 ± 5°C), (%)	7.5
Lower flammability limit (LFL) at average gas vent temperature, (%)	6.5
Burning velocity, (cm/sec)	60.7
Maximum pressure P _{max} , (psig)	107.2



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Project / Network:	80202416	Description:	Li-ion battery cell	

Gas composition:

Gas Component	Gas Type	Gas Volume in percentage (%)
CH ₄	Methane	4.594
C ₂ H ₆	Ethane	0.762
C ₂ H ₄	Ethylene	1.856
C ₃ H ₈	Propane	0.230
C ₃ H ₆	Propylene	0.987
C ₄ H ₁₀	Isobutane	0.011
C ₄ H ₁₀	Butane	0.074
C ₂ H ₂	Acetylene	0.108
C ₄ H ₈	1-butene	0.326
C ₄ H ₈	Isobutene	0.153
C ₅ H ₁₂	Isopentane	0.004
C ₅ H ₁₂	n-Pentane	0.038
C ₅ H ₁₀	1-pentene	0.040
H ₂	Hydrogen	46.223
CO	Carbon Monoxide	15.650
CO ₂	Carbon Dioxide	28.943
Total	---	100



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Master Contract:	304186	Model:	ZTT71173204	Page number 4 of 33
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Performance - Cell Level Test		
Requirement	Comments	Verdict
Thermal runaway cannot be induced in the cell.	Thermal runaway induced on cell using film heater	F
Cell does not present a flammability hazard when mixed with any volume of air, as determined in accordance with ASTM E918 at both ambient and vent temperature.	Cell presented flammability hazard when tested in accordance with ASTM E918, module and unit level test required	F
Summary of Result: Module level testing is required based on above performance condition indicated in Section 7.7 of UL 9540A 4 th Edition.		

Possible test case verdicts:

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

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Master Contract:	304186	Model:	ZTT71173204	Page number 5 of 33
Project / Network:	80202416	Description:	Li-ion battery cell	

Clause	Requirement + Test	Result - Remark	Verdict
Construction			
5	General	---	---
5.1	Cell	---	---
5.1.1	Cell chemistry:	Li-ion (LFP)	---
	Physical format of cell:	Prismatic	---
	Nominal voltage rating, (V)	3.2	---
	Nominal capacity rating, (Ah)	314	---
	Approximate dimension, (mm)	L*W*T: 71.65±0.8×174.26±0.8×207.01±0.8	---
	Mass, (kg)	5.49±0.3	---
5.1.2	Cell certification available?(Yes/No)	No, in progress	---
	Standard(s) used to certify product:	ANSI/CAN/UL1973:2022, 3rd Edition	---
5.1.3	Cell Level Test Report	See below report content	---
Performance			
7	Cell Level	---	---
7.1	General	---	---
7.1.1	Establish effective method by forcing a cell into a thermal runaway in a repeatable manner.	Test Method: Film heater	P
	Vent gas composition was gathered and analyzed.	See Table 4 for details	P
	Cell temperature was monitored to determine the temperature when cell vents.	See below See Table 3 for details	P
	Cell temperature was monitored to determine thermal runaway as defined in UL 9540A 4 th Edition.	See below See Table 3 for details	P
7.2	Sample	---	---
7.2.1	Prior to testing, cell samples were conditioned for minimum 2 charge (100% SOC) - discharge (Specified end of discharge voltage) cycle as per manufacturer specified method.	See Attachment 2	P
	Cells were functional after minimum 2 charge discharge cycle.	Confirmed	P
	During conditioning a relationship between open circuit voltage and SOC was determined through measurement of voltage and SOC.	Confirmed, client declared charge/discharge procedure followed, see Attachment 2	P
	Ambient temperature during cell conditioning.	Confirmed	P
7.2.2	The tested cells had 100% SOC at the start of the test. The samples were	Confirmed	P

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Clause	Requirement + Test	Result - Remark	Verdict
	allowed to stabilize for a minimum of one hour and a maximum of 8 h before the start of the test.		
7.2.3	Cells with flexible laminate casings were constrained during test in manner that simulate constraint in the BESS module to prevent excessive swelling during test.	Prismatic cell with jig to constrain cells when testing	P
7.3	Determination of thermal runaway methodology	---	---
7.3.1	General	See below	P
7.3.1.1	Ambient temperature during cell testing.	See Table 3	P
7.3.1.2	Propensity of cell to exhibit thermal runaway demonstrated by externally applied film heater.	Heater type: Film heater Heater dimension (mm): 190×160 Number of heaters used: 2	P
	A surface heating rate of 4° C (7.2° F) to 7° C (12.6° F) per minute shall be applied to the cell.	☒ 5 ° C/min heating ramp was used for testing	P
	Maximum surface temperature endpoint criteria was determined based on cell design and cell chemistry.	Considered	P
	Thermal runaway method used, when external heating with flexible heater was not able to cause the cell to exhibit thermal runaway.	☐ Mechanical: ☐ Electrical Stress: ☐ Alternate heating sources: ☐ Other(explain):	N/A
7.3.1.3	Detail of thermal runaway test method when another method used as reference in 7.3.1.2.	Film heater was used for testing	N/A
7.3.1.4	Monobloc battery such as lead acid or nickel cadmium, was treated as individual cell for this testing.	Li-ion battery cell	N/A
7.3.1.5	Surface temperature at which internal short circuiting within the cell will occur that could lead to thermal runaway.	See below	N/A
	Surface temperature hold point. For lithium ion cell, hold point was between 5°C (9°F) and 15°C (27°F) greater than the melting temperature of the cell separator material as determined from differential scanning calorimetry (DSC) data of the separator in accordance with UL 2591 (UL 746A).	Cell was heated directly until thermal runaway initiated following UL 9540A Certification Requirement Decision	N/A
	If thermal runaway is not achieved at holding temperature after period of 4h,	See above	N/A

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Clause	Requirement + Test	Result - Remark	Verdict
	heating rate according to 7.3.1.3 was reestablished.		
7.3.1.6	If cell is susceptible to thermal runaway by external heating, cell was heated until thermal runaway has occurred.	Confirmed, film heater method used for testing	P
	If cell is not susceptible to thermal runaway by external heating, another method included in 7.3.1.2 was used.	See above	N/A
	If using another external heating method, temperature ramp and maximum surface temperature as outlined in 7.3.1.2 and 7.3.1.5 was used.	See above	N/A
7.3.1.7	Cell's exterior surface temperature was measured continuously, averaging over every 60 seconds	Confirmed	P
	The maximum of these averages was documented for each thermocouple location.	Confirmed	P
	Location of thermocouple during test.	☒ Below the heater film at centre of cell surface: T1, T2, T3, T4 ☒ Near positive cell terminal: T8 ☒ Other(explain): Near vent: T7 Side surface: T5,T6 Large surface not covered by heater: T9 Ambient: T10 Refer to Figure 8 for details	P
7.3.1.8	The temperature at which the cell case vents due to internal pressure rise.	Confirmed	P
	The thermocouple located below the heater film at the center of the cell surface is used for this measurement.	The thermocouple located at the center of the cell surface which not covered by heater is used for this measurement.	P
	If using the other cell abuse methods, the thermocouples would be located at the same locations on the cells as noted in 7.3.1.7.	See above	N/A
7.3.1.9	The temperature at the onset of thermal runaway was documented.	See Table 3 for details	P
	Onset of thermal runaway was determined by the point at which the rate of change of the surface temperature of the cell exceeds that of the externally applied heat input if utilizing the external heater method.	Considered, see Table 3 for the onset temperature for thermal runaway.	P

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Clause	Requirement + Test	Result - Remark	Verdict
	In cases where cell venting may occur first, cell was heated continuously until thermal runaway occurs.	Confirmed	P
	With other stress methods, it was necessary to continue applying the stress such as mechanical or electrical stress until onset of thermal runaway occurs.	External heating method used	N/A
	Separator information was available or at the manufacturer's discretion, the thermal ramp was conducted continuously without a hold point until thermal runaway.	Thermal ramp was conducted continuously without holding point considered	P
7.3.1.10	When using methods other than the heater method, the stresses (i.e. electrical or mechanical) were applied to the cell until thermal runaway occurs.	Film heater method used	N/A
7.3.1.11	If the cell exhibits thermal runaway behavior (using any method), 3 additional samples were tested using the same method and exhibit thermal runaway to demonstrate repeatability.	See Table 3 for details	P
	The vent temperature and thermal runaway onset temperatures were averaged over the tested samples (Excluding the gas vent capture sample).	See Table 3 for details	P
7.3.2	Flow battery thermal runaway determination tests	Li-ion battery cell	N/A
7.4	Cell vent gas composition test	---	---
7.4.1	Cell vent gas was generated and captured by forcing a cell into thermal runaway with the methodology developed in 7.3, inside a pressure vessel, which is large enough to accommodate cells, but not so large as to influence measurement of the gas composition.	Confirmed: 98L pressure vessel used for testing.	P
	The test was initiated with an initial condition of atmospheric pressure and less than 1% oxygen by volume.	See Table 4 for details	P
	The initial atmospheric conditions prior to testing was noted.	See Table 4 for details	P
7.4.2	Cell vent gas composition was determined using Gas Chromatography (GC)	See Table 4 for details	P
	Hydrogen gas was measured with a sensor capable of measuring in excess of 30% by volume.	See Table 4 for details	P

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Clause	Requirement + Test	Result - Remark	Verdict
	The initial atmospheric conditions prior to testing was noted.	See Table 4 for details	P
7.4.3	The lower flammability limit of the cell vent gas was determined in accordance with ASTM E918, testing at both ambient and cell vent temperatures.	See Table 4 for details	P
7.4.4	The burning velocity of the cell vent gas was determined in accordance with Annex in ISO 817.	See Table 4 for details	P
7.4.5	The P_{max} of the cell vent gas was determined in accordance with EN 15967.	See Table 4 for details	P
7.5	Off gas composition for flow battery systems.	---	---
7.5.1	The off gas composition from the flow battery testing of 7.3.2 shall be determined by conducting the test method of 7.3.2.2: 1. In a closed container and capturing the off gasses generated, and 2. By collecting the off gasses generated at vent openings and vent ducts during the overcharge and short circuit testing of 7.3.2.4 and 7.3.2.6 as applicable to the flow battery technology	Li-ion battery cell	N/A
	Composition of these captured gases and their flammability limit shall be determined through the methods outlined in 7.4.2 and 7.4.3 at both ambient temperature and the maximum temperature measured.	Li-ion battery cell	N/A
7.5.2	The volume of flammable gases measured during the testing were scaled to the maximum energy reservoir for the intended flow battery system.	Li-ion battery cell	N/A
7.6	Cell level test report	---	---
7.6.1	Cell level report include information indicated in item a) through m)	Confirmed	P
7.6.2	Flow battery report include information indicated in item a) through k)	Li-ion battery cell	N/A

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Table 1 – Cell charge/discharge specification

Charging method	CC-CV	Discharging method	CC
Charge current, (Adc)	157	Discharge current, (Adc)	157
Charge voltage, (Vdc)	3.65	---	---
Charge end current, (Adc)	15.7	Discharge end voltage, (Vdc)	2.5
Manufacturer recommended charge temperature, (°C)	0~+60	Manufacturer recommended discharge temperature, (°C)	-20~+60

Table 2 – Cell rest duration

Sample Number	Final charge end time		Test start time	
	Date (YYYY-MM-DD)	Time (HH:MM AM/PM)	Date (YYYY-MM-DD)	Time (HH:MM AM/PM)
202410008-1	2024-11-26	14:54 PM	2024-11-26	18:08 PM
202410008-2	2024-11-29	13:27 PM	2024-11-29	16:18 PM
202410008-3	2024-10-14	09:54 AM	2024-10-14	11:51 AM
202410008-4	2024-10-16	09:29 AM	2024-10-16	11:35 AM
202410008-5	2024-10-31	08:39 AM	2024-10-31	12:58 AM

Ambient temperature during cell conditioning

Ambient Lab Temperature, (°C)	Relative Humidity, (%RH)
20.3 to 22.7	42 to 47

Table 3 – Determination of thermal runaway methodology

Sample Number	Note 1				Note 2
	202410008-1	202410008-2	202410008-3	202410008-4	202410008-5
Open circuit voltage before test, (Vdc)	3.386	3.443	3.505	3.484	3.496
Cell charge capacity after final charge cycle, (Ahr)	314.40	310.26	340.48	336.66	334.31
External film heater ramp rate, (°C/min)	5	5	5	5	5
Temperature at which gases are first vented, (°C)	148.7	177.9	170.9	164.6	147.3
Temperature prior to thermal runaway, (°C)	198.0	229.1	249.5	248.8	182.4
Location of maximum temperature prior to thermal runaway	Cell large surface not under heater	Cell large surface not under heater	Cell large surface not under heater	Cell large surface not under heater	Cell large surface not under heater
Average temperature at which gases are first vented, (°C)	165.5				---

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Table 3 – Determination of thermal runaway methodology

Average temperature prior to thermal runaway, (°C)	231.4	---
Other method used to initiate thermal runaway: N/A		
Note: The capacity of sample 202410008-2 was within the manufacturer's declaration.		

Ambient temperature during cell testing

Ambient Lab Temperature, (°C)	Relative Humidity, (%RH)
20.3 to 22.7	42 to 47
Note 1: Sample tested outside pressure vessel	
Note 2: Sample tested inside pressure vessel for cell vent gas composition test	

Table 4 – Cell vent gas composition test

Sample Number:	202410008-5
Pressure vessel volume (liter):	98
An initial condition of atmospheric pressure (kPa):	0
An initial condition of oxygen by volume (%):	0.27
Flammable gas generation volume(Liter):	127.2
Total gas generation volume (Liter):	206.3
LFL limit at ambient temperature (%):	7.5
LFL limit at cell vent temperature (%):	6.5
Burning velocity (cm/sec):	60.7
Maximum pressure P _{max} (kPa):	739.1

Ambient temperature during cell testing

Ambient Lab Temperature, (°C)	Relative Humidity, (%RH)
20.3 to 22.7	42 to 47

Gas composition

Gas composition:

Gas Component	Gas Type	Gas Volume in percentage (%)
CH ₄	Methane	4.594
C ₂ H ₆	Ethane	0.762
C ₂ H ₄	Ethylene	1.856



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Table 4 – Cell vent gas composition test

C_3H_8	Propane	0.230
C_3H_6	Propylene	0.987
C_4H_{10}	Isobutane	0.011
C_4H_{10}	Butane	0.074
C_2H_2	Acetylene	0.108
C_4H_8	1-butene	0.326
C_4H_8	Isobutene	0.153
C_5H_{12}	Isopentane	0.004
C_5H_{12}	n-Pentane	0.038
C_5H_{10}	1-pentene	0.040
H_2	Hydrogen	46.223
CO	Carbon Monoxide	15.650
CO ₂	Carbon Dioxide	28.943
Total	---	100



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Attachments

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Attachment 1 - Critical components and material information

Object/ part No.	Manufacturer/ trademark	Type/ Model	Technical Data	Standard No. and Edition year	Marks of Conformit y
Cell	ZhongTian Energy Storage Technology Co., Ltd.	ZTT7117 3204	3.2Vd.c., 314Ah	-	-
Electrolyte	Henan Farnlet New Energy Technology Co., Ltd.	30160EL A0031	DMC, EMC, EC	-	-
Separator	Shenzhen Senior Technology Material Co.,Ltd.	30140G MB0004	PE, L×W ×T: 33170mm×197mm×0.0 11mm, for one core, total four cores	-	-
Positive electrode	ZhongTian Energy Storage Technology Co., Ltd.	30120ZJ A0025	LiFePO ₄ , Conductive Additive, PVDF, Collector: Aluminum Foil, Size: 15060.0mm×187.5mm× 0.178mm, for one core, total two cores	-	-
Insulation coating on positive electrode	ZhongTian Energy Storage Technology Co., Ltd.	30120ZJ A0026	Al ₂ O ₃ W×T 2mm*0.08mm	-	-
Negative electrode	ZhongTian Energy Storage Technology Co., Ltd.	30110FJ A0033	Carbon, Conductive Additive Collector: Copper Foil L×W ×T: 15412mm×190.5mm×0. 134mm, for one core, total two cores	-	-
Positive electrode tab	ZhongTian Energy Storage Technology Co., Ltd.	30120ZJ A0027	Aluminum belt, L×T ×W: 40mm×0.013mm×52m m	-	-
Negative electrode tab	ZhongTian Energy Storage	30110FJ A0034	Copper belt,	-	-



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Attachment 1 - Critical components and material information

	Technology Co., Ltd.		W ×T ×L: 40mm×0.006mm×53mm		
Insulation tap	Dongguan Xinmei Electronic Material Co., Ltd	T ×W ×L: 0.05mm×40mm×300m	PET 40mm×0.05mm	-	-
Case	Xiamen Zongling Precision Manufacturing Co., Ltd	71173	Thickness: 0.6mm Aluminum	-	-
Top case and Venting	Jiangxi BSL New Energy Technology Co., LTD	71173	Thickness: 0.3mm Aluminum, Pressure: (0.6±0.2)MPa	-	-



ORIGINAL TEST DATA

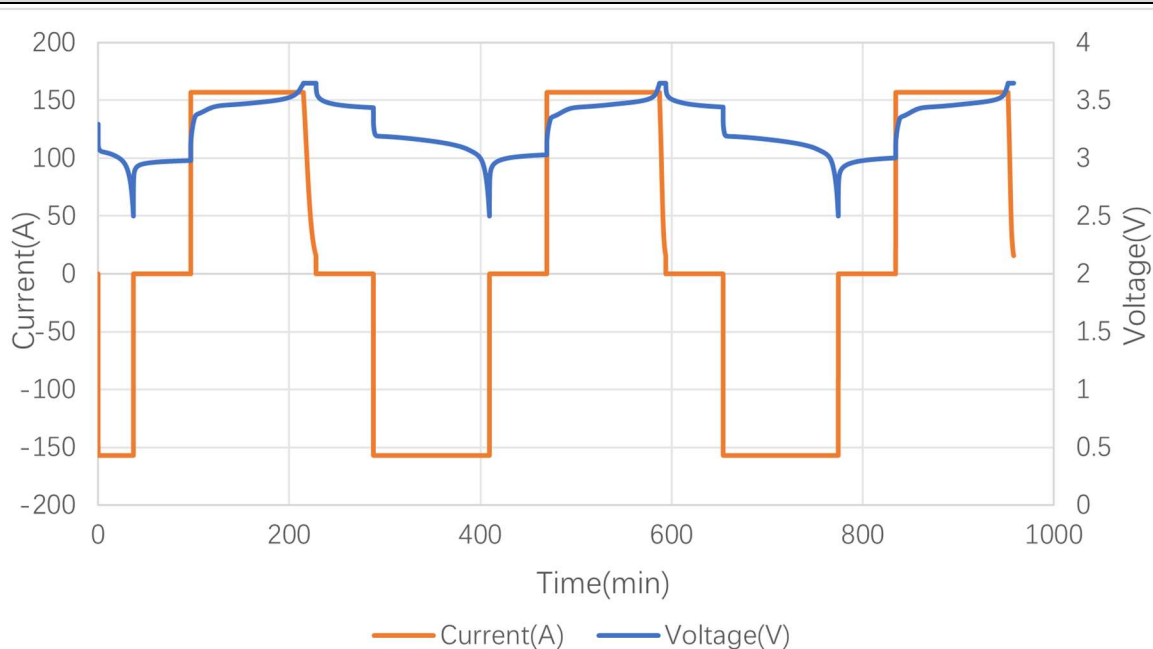
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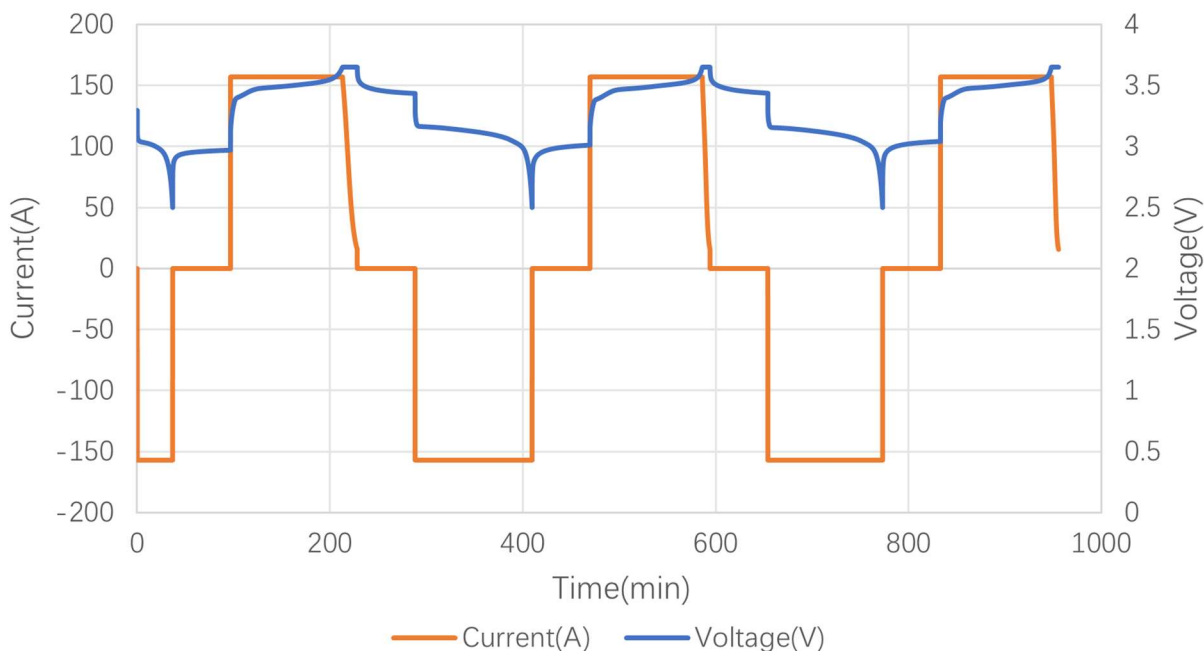
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Attachment 2 - Cell charge/discharge conditioning graphs

Sample Number: 202410008-1



Sample Number: 202410008-2



ORIGINAL TEST DATA

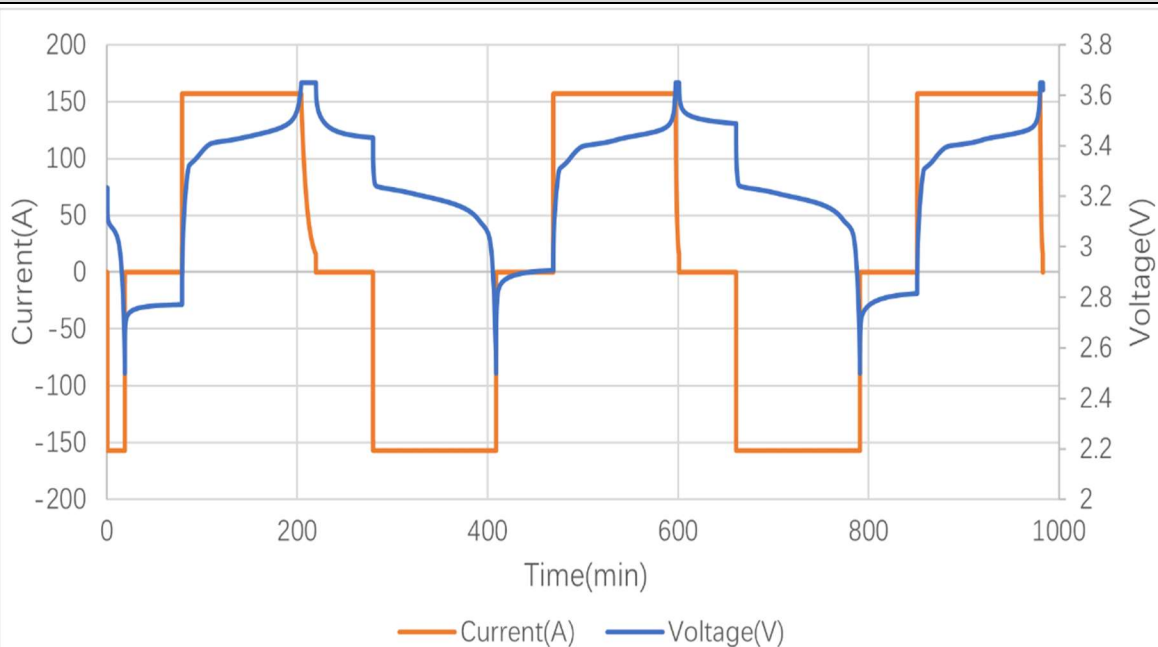
The results relate only to the items tested.

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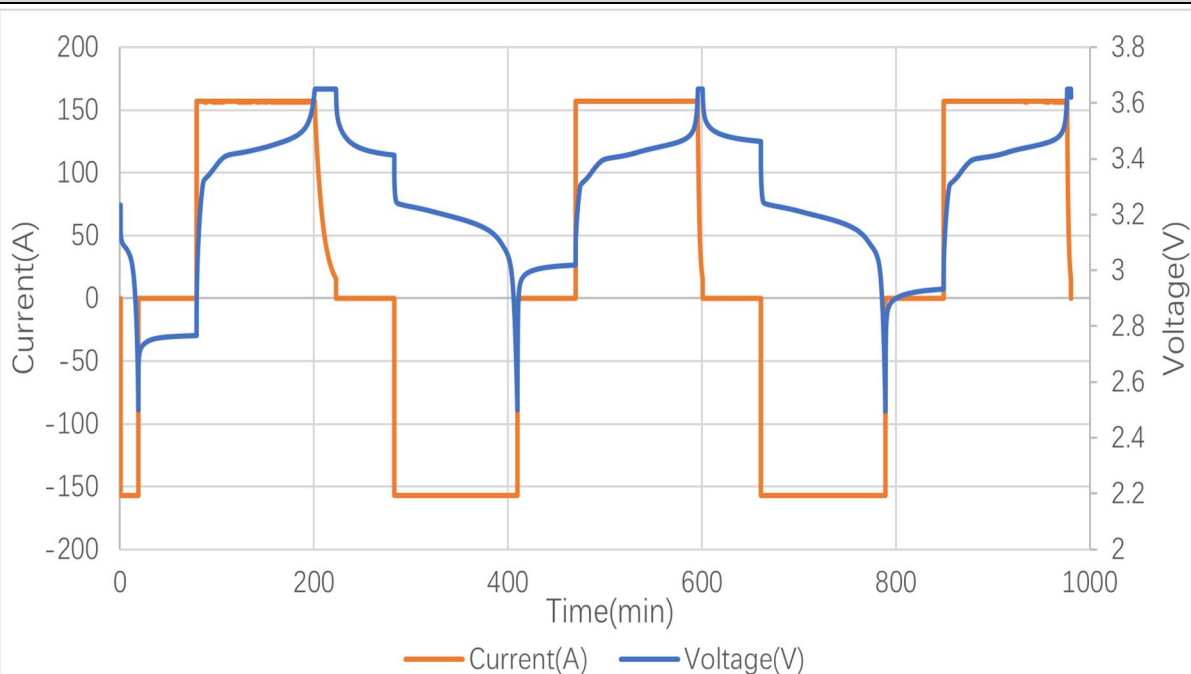
Master Contract: 304186	Model: ZTT71173204	Page number 17 of 33
Project / Network: 80202416	Description: Li-ion battery cell	

Attachment 2 - Cell charge/discharge conditioning graphs

Sample Number: [202410008-3](#)



Sample Number: [202410008-4](#)





ORIGINAL TEST DATA

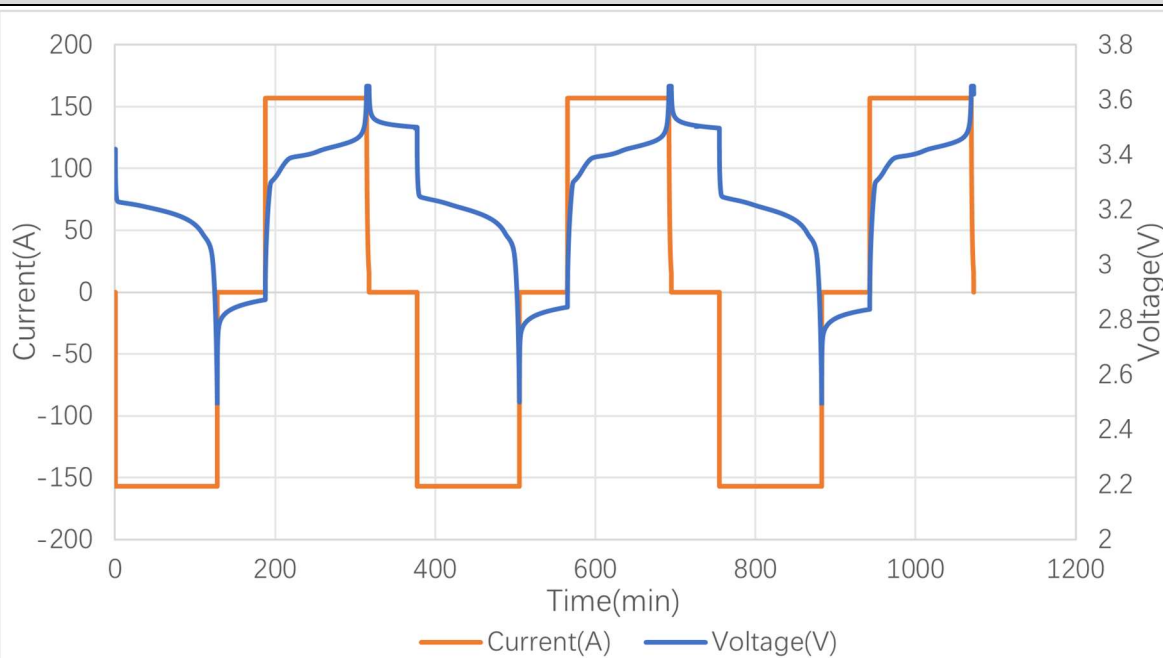
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Master Contract:	304186	Model:	ZTT71173204	Page number 18 of 33
Project / Network:	80202416	Description:	Li-ion battery cell	

Attachment 2 - Cell charge/discharge conditioning graphs

Sample Number: 202410008-5



ORIGINAL TEST DATA

The results relate only to the items tested.

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Master Contract:	304186	Model:	ZTT71173204	Page number 19 of 33
Project / Network:	80202416	Description:	Li-ion battery cell	

Attachment 3 – Photos
General sample photos


Figure 1: Front view of cell



Figure 2: Side view of cell



Figure 3: Top view of cell

Photos with heater and thermocouple installation


Figure 4: TC location on cell wide surface

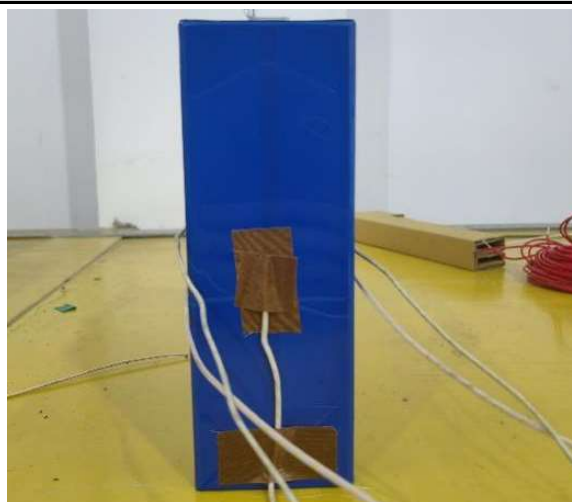


Figure 5: TC location on cell side surface

ORIGINAL TEST DATA

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Figure 6: TC location on cell wide surface not covered by heater



Figure 7: TC location near cell vent and positive node

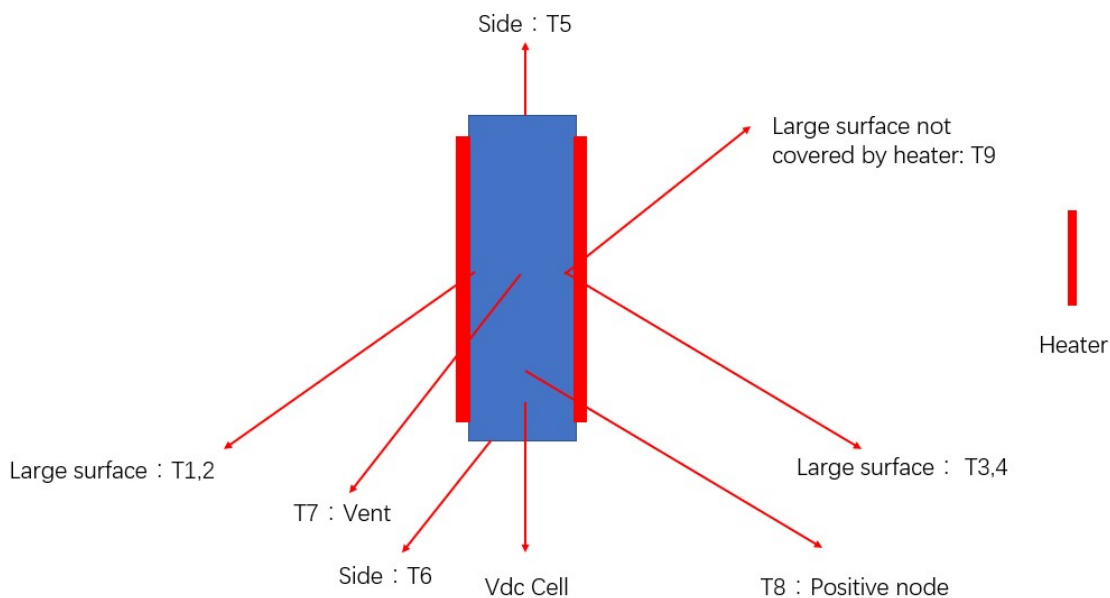


Figure 8: TC location (Top view)

ORIGINAL TEST DATA

The results relate only to the items tested.

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Sample Number: [202410008-1](#)

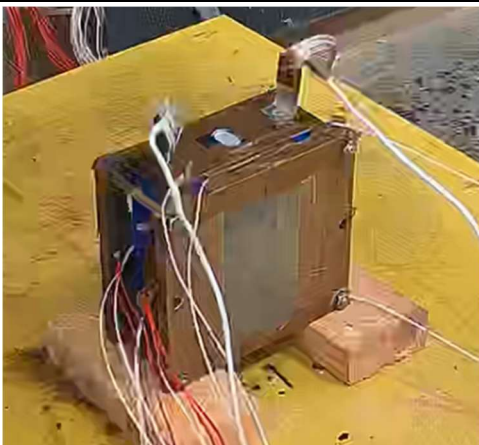


Figure 9: [At test start \(Time in 18:08\)](#)

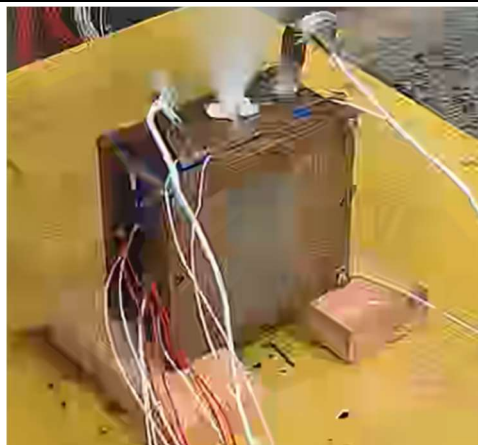


Figure 10: [During cell venting \(Time in 19:11\)](#)

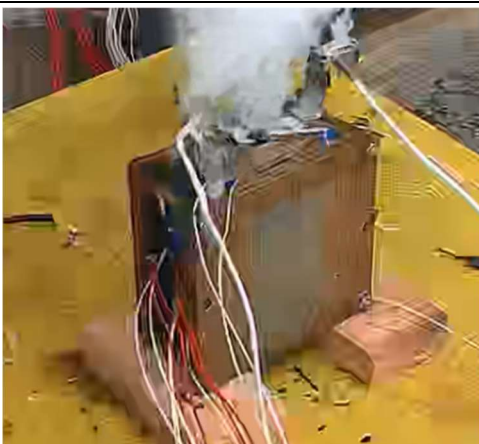


Figure 11: [During thermal runaway \(Time in 19:21\)](#)



Figure 12: [After thermal runaway-1](#)



Figure 13: [After thermal runaway-2](#)



Figure 14: [After thermal runaway-3](#)

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Sample Number: 202410008-2

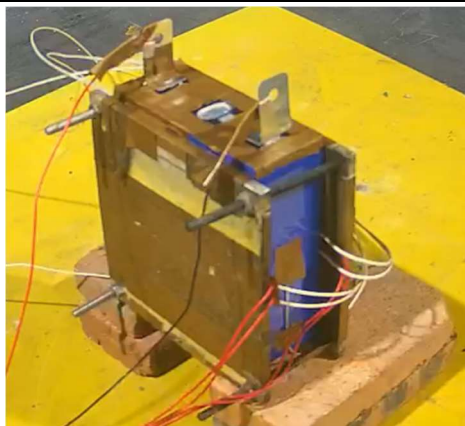


Figure 15: At test start (Time in 16:18)

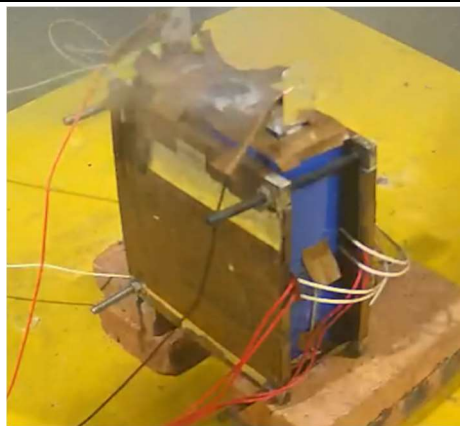


Figure 16: During cell venting (Time in 17:01)

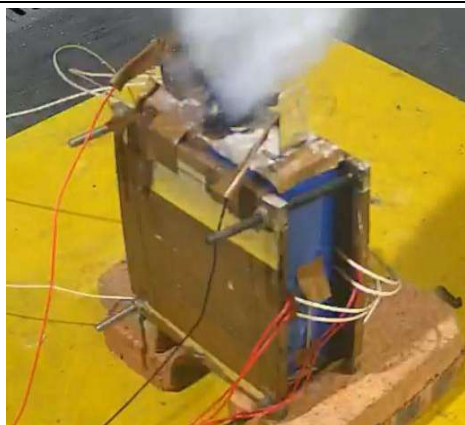


Figure 17: During thermal runaway
(Time in 17:13)



Figure 18: After thermal runaway-1



Figure 19: After thermal runaway-2



Figure 20: After thermal runaway-3

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Project / Network: 80202416	Description: Li-ion battery cell	

Sample Number: 202410008-3

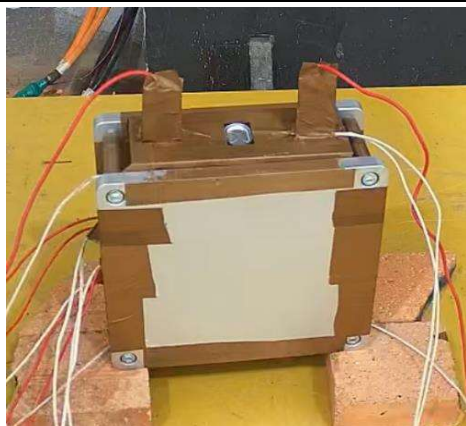


Figure 21: At test start (Time in 11:51)

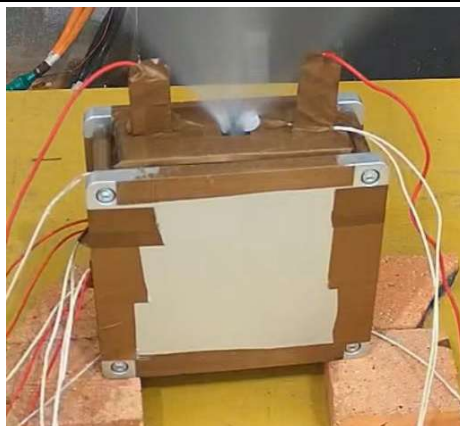


Figure 22: During cell venting (Time in 12:28)

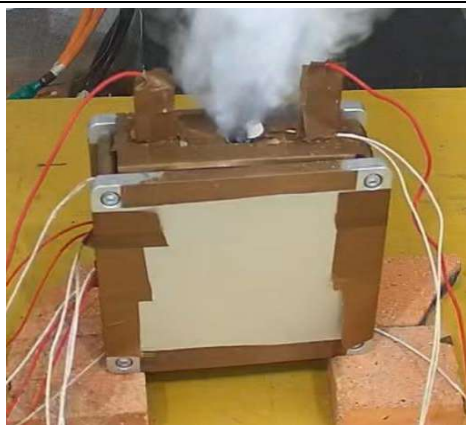


Figure 23: During thermal runaway (Time in 12:44)

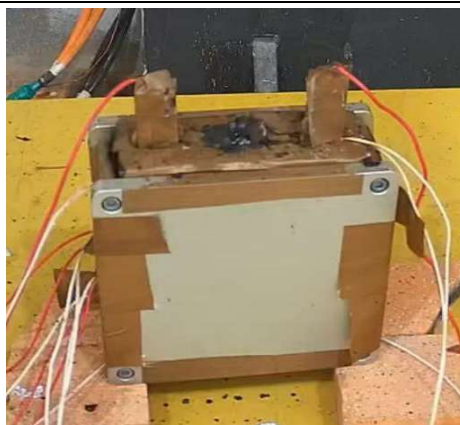


Figure 24: After thermal runaway-1



Figure 25: After thermal runaway-2



Figure 26: After thermal runaway-3

ORIGINAL TEST DATA

The results relate only to the items tested.

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Project / Network:	80202416	Description:	Li-ion battery cell	

Sample Number: 202410008-4

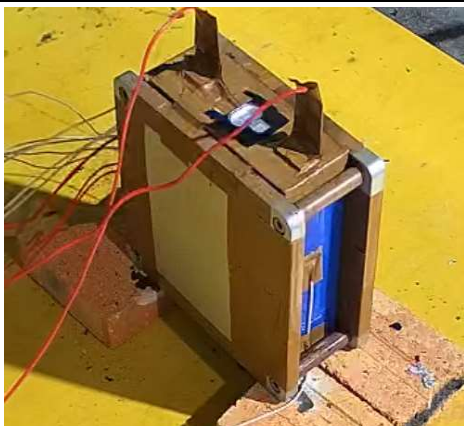


Figure 27: At test start (Time in 11:35)

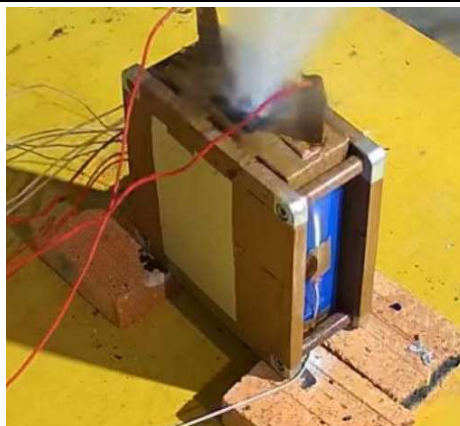


Figure 28: During cell venting (Time in 12:14)

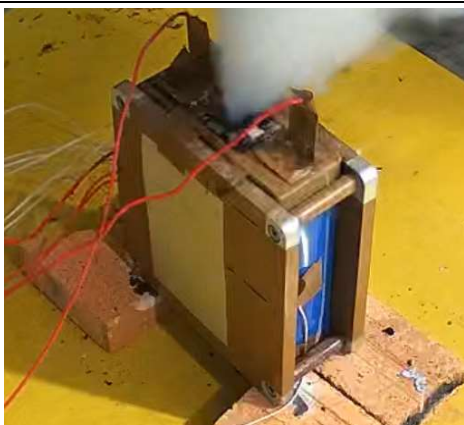


Figure 29: During thermal runaway (Time in 12:32)

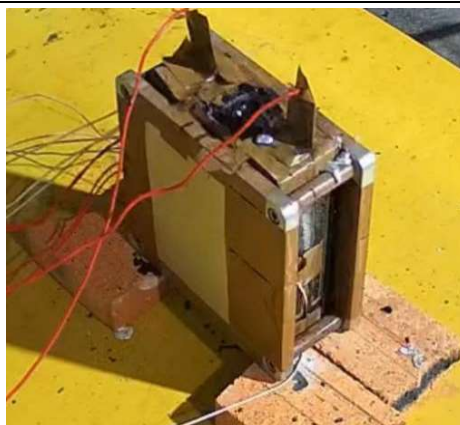


Figure 30: After thermal runaway-1



Figure 31: After thermal runaway-2



Figure 32: After thermal runaway-3

ORIGINAL TEST DATA

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Sample Number: 202410008-5



Figure 33: At test start

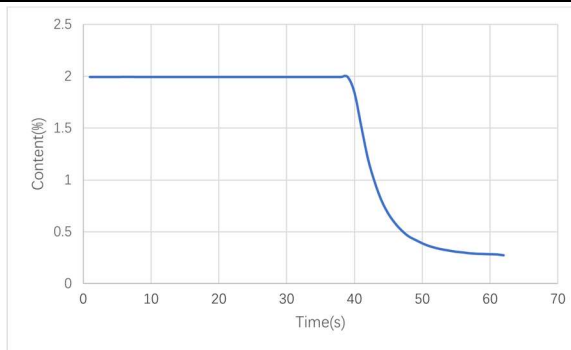


Figure 34: oxygen concentration

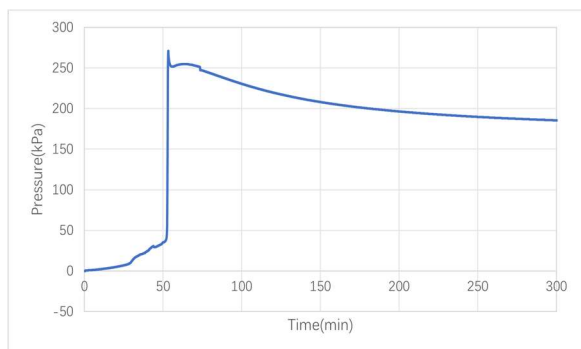


Figure 35: Gas pressure diagram



Figure 36: After thermal runaway-1



Figure 37: After thermal runaway-2



Figure 38: After thermal runaway-3

ORIGINAL TEST DATA

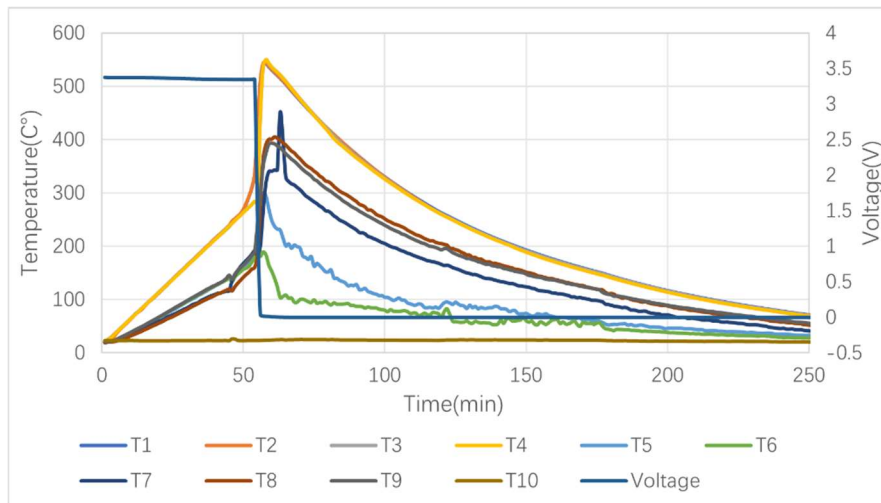
The results relate only to the items tested.

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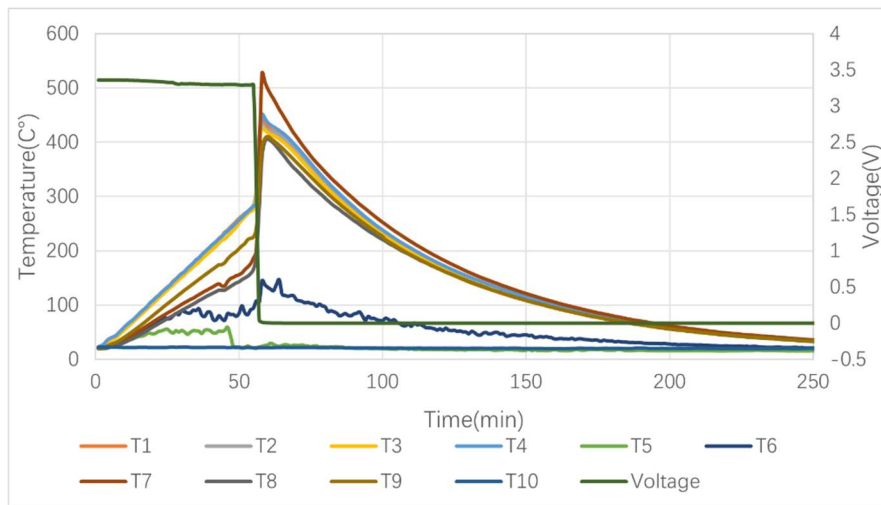
Master Contract:	304186	Model:	ZTT71173204	Page number 26 of 33
Project / Network:	80202416	Description:	Li-ion battery cell	

Attachment 4 - Cell temperature/voltage graph during testing

Sample Number: 202410008-1



Sample Number: 202410008-2



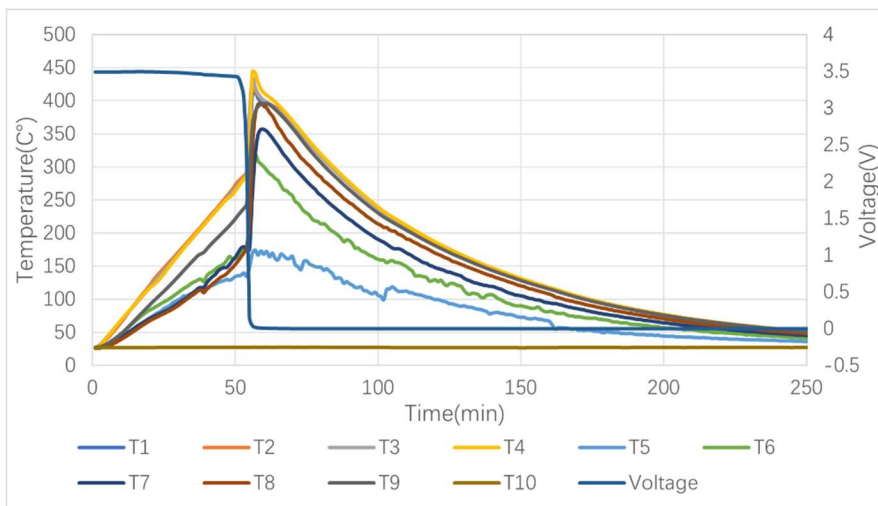
ORIGINAL TEST DATA

The results relate only to the items tested.

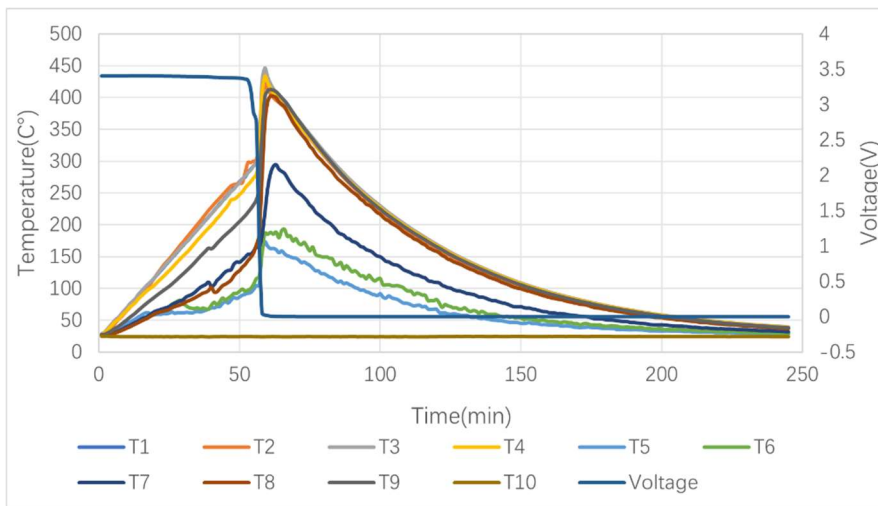
This report shall not be reproduced, except in full, without the approval of CSA Group Testing & Certification Inc.

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Sample Number: 202410008-3



Sample Number: 202410008-4



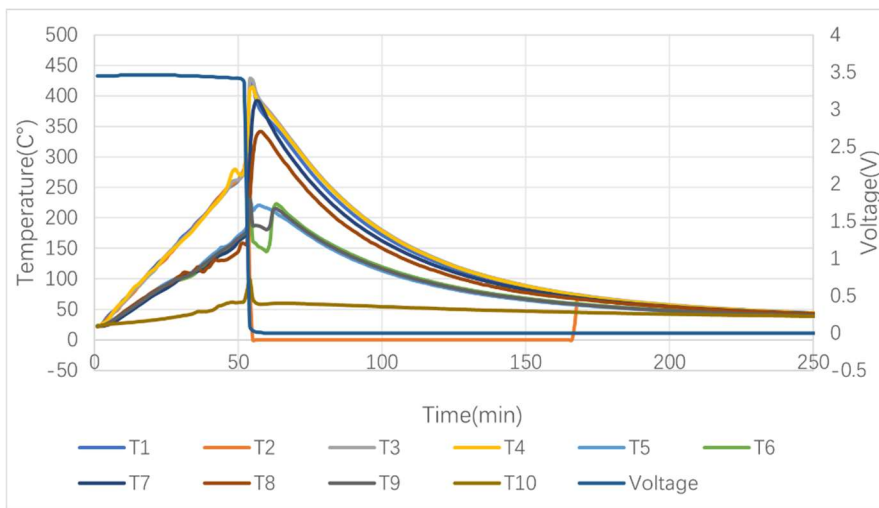
ORIGINAL TEST DATA

The results relate only to the items tested.

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Sample Number: 202410008-5



Note: Thermal couple T2 was broken during testing.

ORIGINAL TEST DATA

The results relate only to the items tested.

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Project / Network:	80202416	Description:	Li-ion battery cell	

Attachment 5- Cell gas analysis report

检测项目 Test Items	气体/蒸气燃烧（爆炸）极限-下限 Flammable (explosion) limits of gas and vapours - LFL					
检测方法 Test Method	ASTM E918-19 Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure					
备注 Remarks	c_s =样品的浓度/ Concentration of sample T_i =每次试验中的初始温度/ Initial temperature in each trial; p_i =每次试验中的初始压力/ Initial pressure in each trial; p_{ex} =每次试验中的超压/ Overpressure in each trial; L_1 =使火焰传播的最小样品浓度/ The minimum sample concentration that gives flame propagation; L_2 =不产生火焰传播的最大样品浓度/ The maximum sample concentration that does not give flame propagation; LFL=可燃性下限/ Lower flammable limit; $LFL=(L_1+L_2)/2$ 如果 $p_{ex}/p_i \geq 1.07$, 则认为爆炸发生。 It is considered explosion occurred, if $p_{ex}/p_i \geq 1.07$. 本试验中定义的浓度是指体积百分比。 Concentration defined in this report means volume percentage.					
检测条件 Test Conditions	初始温度: (24±2)°C; 初始压力: (101±3) kPa Initial Temperature: (24±2)°C; Initial Pressure: (101±3) kPa					
环境条件 Environmental Conditions	温度: (20~24)°C; 相对湿度: (32~65)% Ambient Temperature: (20~24)°C; Relative Humidity: (32~65)%					
部分测试数据/ Part of Test Data						
No.	c_s [%]	T_i [°C]	p_i [kPa]	p_{ex} [kPa]	p_{ex}/p_i	Ignition?
1	7.4	24	100.17	106.28	1.061	NO
2	7.4	24	100.25	106.44	1.062	NO
3	7.6	24	100.27	108.17	1.079	YES
4	7.6	24	100.25	107.37	1.071	YES
结果 Result	L1=7.6%, L2=7.4%, LFL=7.5% at (24±2)°C and (101±3) kPa.					

ORIGINAL TEST DATA

The results relate only to the items tested.

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Master Contract:	304186	Model:	ZTT71173204	Page number 30 of 33
Project / Network:	80202416	Description:	Li-ion battery cell	

Attachment 5- Cell gas analysis report

检测项目 Test Items	气体/蒸气燃烧（爆炸）极限-下限 Flammable (explosion) limits of gas and vapours - LFL					
检测方法 Test Method	ASTM E918-19 Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure					
备注 Remarks	c_s =样品的浓度/ Concentration of sample T_i =每次试验中的初始温度/ Initial temperature in each trial; p_i =每次试验中的初始压力/ Initial pressure in each trial; p_{ex} =每次试验中的超压/ Overpressure in each trial; L_1 =使火焰传播的最小样品浓度/ The minimum sample concentration that gives flame propagation; L_2 =不产生火焰传播的最大样品浓度/ The maximum sample concentration that does not give flame propagation; LFL=可燃性下限/ Lower flammable limit; $LFL=(L_1+L_2)/2$ 如果 $p_{ex}/p_i \geq 1.07$, 则认为爆炸发生。 It is considered explosion occurred, if $p_{ex}/p_i \geq 1.07$. 本试验中定义的浓度是指体积百分比。 Concentration defined in this report means volume percentage.					
检测条件 Test Conditions	初始温度: (165.5±2)°C; 初始压力: (101±3) kPa Initial Temperature: (165.5±2)°C; Initial Pressure: (101±3) kPa					
环境条件 Environmental Conditions	温度: (20~24)°C; 相对湿度: (32~65)% Ambient Temperature: (20~24)°C; Relative Humidity: (32~65)%					
部分测试数据/ Part of Test Data						
No.	c_s [%]	T_i [°C]	p_i [kPa]	p_{ex} [kPa]	p_{ex}/p_i	Ignition?
1	6.4	165	100.27	106.74	1.065	No
2	6.4	165	100.15	106.48	1.063	No
3	6.6	165	100.27	107.38	1.071	Yes
4	6.6	165	100.38	108.12	1.077	Yes
结果 Result	L1=6.6%, L2=6.4%, LFL=6.5% at (165.5±2)°C and (101±3) kPa.					

ORIGINAL TEST DATA

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Attachment 5- Cell gas analysis report

检测项目 Test Items	气体/蒸气的最大爆炸压力 Maximum explosion pressure of gases and vapours						
检测方法 Test Method	EN 15967:2022 Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours						
检测设备 Test Apparatus	8L 封闭球体, 感应火花 Test Vessel: 8L closed sphere; Ignition System: Spark						
试验混合物的制备 Preparation of test mixtures	分压法 Partial pressure method used inside the vessel						
检测条件 Test Conditions	初始温度: (22±2)°C; 初始压力: (101±3) kPa Initial Temperature: (22±2)°C; Initial Pressure: (101±3) kPa						
环境条件 Environmental Conditions	温度: (20~24)°C; 相对湿度: (32~65)% Ambient Temperature: (20~24)°C; Relative Humidity: (32~65)%						
备注 Remarks	c_s =样品的浓度/ Concentration of sample; p_{max} =最大爆炸压力/ Maximum explosion pressure; $p_{ex,n}$ =在一定浓度下第 n 次点火试验中的爆炸超压/ p_{ex} in different trials at a certain concentration; $p_{ex,max}$ =某一浓度下 n 次点火试验中爆炸超压的最大值/The maximum value of all the $p_{ex,n}$ at a certain concentration, p_{mean} =某一浓度下爆炸超压的平均值/The average value of all the $p_{ex,n}$ at a certain concentration; p_{lowest} = 5 (或 3) 次点火试验中最低的爆炸超压/Lowest explosion pressure in 5 (resp. 3) tests; $p_{highest}$ = 5 (或 3) 次点火试验中最高爆炸超压/Highest explosion pressure in 5 (resp. 3) tests. p_{max} 是 $p_{ex,max}$ 的最大值/ p_{max} is expressed as the maximum value of $p_{ex,max}$ 本试验中定义的浓度是指体积百分比。 Concentration defined in this report means volume percentage.						
部分测试数据/ Part of Test Data							
No.	c_s [%]	$p_{ex,1}$ [bar]	$p_{ex,2}$ [bar]	$p_{ex,3}$ [bar]	$p_{ex,4}$ [bar]	$p_{ex,5}$ [bar]	p_{mean} [bar]
1	23	6.732	6.605	6.597	/	/	6.645
2	24	7.019	6.894	6.881	/	/	6.931
3	25	7.249	7.224	7.379	/	/	7.284

ORIGINAL TEST DATA

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Attachment 5- Cell gas analysis report

4	25.2	7.220	7.149	7.233	/	/	7.201
5	25.4	7.253	7.151	7.301	/	/	7.235
6	25.6	7.035	7.211	7.300	/	/	7.182
7	25.8	7.027	7.257	7.391	/	/	7.225
8	26	7.265	7.133	7.096	/	/	7.165
9	27	7.131	6.945	7.318	/	/	7.131
10	28	6.755	6.703	7.169	/	/	6.876

爆炸压力的测定/ Determination of the explosion pressure

No.	C_s [%]	P_{lwoest} [bar]	$P_{highest}$ [bar]	P_{mean} [bar]	$P_{ex,max}$ [bar]
1	23	6.597	6.732	6.645	6.732
2	24	6.881	7.019	6.931	7.019
3	25	7.224	7.379	7.284	7.379
4	25.2	7.149	7.233	7.201	7.233
5	25.4	7.151	7.301	7.235	7.301
6	25.6	7.035	7.300	7.182	7.300
7	25.8	7.027	7.391	7.225	7.391
8	26	7.096	7.265	7.165	7.265
9	27	6.945	7.318	7.131	7.318
10	28	6.703	7.169	6.876	7.169

最大爆炸压力的确定/Determination of the maximum explosion pressure

可燃物质含量/Content of flammable substance					25.8%
最小易燃物质含量增量/Smallest flammable substance content increment					0.2%
最大爆炸压力/Maximum explosion pressure					7.391bar
结果/Result	初始温度 24°C, 初始压力 101.3kPa 条件下, $p_{max}=7.391bar$ 。 $p_{max}=7.391bar$ at 24°C and 101.3kPa.				

ORIGINAL TEST DATA

The results relate only to the items tested.

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Project / Network:	80202416	Description:	Li-ion battery cell	

Attachment 5- Cell gas analysis report

检测项目 Test Items	可燃气体燃烧速度 Burning velocity of flammable gases			
检测方法 Test Method	ISO 817:2014 Refrigerants—Designation and safety classification			
检测条件 Test Conditions	初始温度: (22±2)°C; 初始压力: (101±3) kPa Initial Temperature: (22±2)°C; Initial Pressure: (101±3) kPa			
环境条件 Environmental onditions	温度: (20~24)°C; 相对湿度: (32~65)% Ambient Temperature: (20~24)°C; Relative Humidity: (40~65)%			
备注 Remarks	c_s =样品的浓度/ Concentration of sample; S_s =火焰传播速度 /Flame propagation speed; a_f = 火焰底部横截面积/Cross-sectional area of flame bottom; A_f = 火焰表面积//Flame surface area; S_u =燃烧速度/ Burning velocity. $S_u = S_s \times \frac{a_f}{A_f}$ 本试验中定义的浓度是指体积百分比。 Concentration defined in this report means volume percentage.			
部分测试数据/ Part of Test Data				
No.	c_s [%]	S_s [m/s]	a_f/A_f /	S_u [m/s]
1	23	1.16	0.42	0.487
2	24	1.36	0.43	0.585
3	25	1.41	0.42	0.592
4	26	1.32	0.46	0.607
5	27	1.29	0.44	0.568
结果 Result	S_u =0.607m/s 在室温和大气压条件下。			

End of Report....