CELL TEST REPORT
UL 9540A
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (AACD)

Project Number.....:	**4791099276**
Date of issue .....:	**2024-02-22**
Total number of pages.....:	**37**
UL Report Office .....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name.....:	**EVE POWER Co., Ltd.**
Address .....:	No. 68, Jingnan Avenue, Jingmen Hi-tech Zone Jingmen, Hubei Sheng 448000 China
Test specification:	4th Edition, Section 7, November 12, 2019
Standard .....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure.....:	7.1, 7.2, 7.3.1, 7.4, 7.5, 7.6.1, 7.7
Non-standard test method .....:	N/A

General disclaimer:

The test results presented in this report relate only to the sample tested in the test configuration noted on the list of the attachments.

UL LLC did not select the sample(s), determine whether the sample(s) was representative of production samples, witness the production of the test sample(s), nor were we provided with information relative to the formulation or identification of component materials used in the test sample(s).

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Cell level information	
Model No.....:	MB31
Ratings (Vdc, Ah).....:	3.2Vdc, 314Ah
Chemistry of test item……:	$LiFePO_4$
Original Equipment Manufacturer (OEM):	EVE POWER Co., Ltd.
Branding Manufacturer (if not OEM):	N/A
Was the cell certified? ……:	Yes
Standard test item certified to ……. …..:	UL 1973
Organization that certified test item …….:	UL, MH63503
Average cell surface temperature at gas venting, °C:	154
Average surface temperature at thermal runaway, °C:	225
Gas Volume: L	192.5
Lower flammability limit (LFL), % volume in air at the ambient temperature	7.75
Lower flammability limit (LFL), % volume in air at the venting temperature	7.14
Burning velocity (S_u) cm/s:	75.90
Maximum pressure (P_{max}) psig:	95.40

Cell Gas composition

Gas	Measured %
CO	13.775
CO_2	24.315
H_2	49.427
CH_4	5.765
C_2H_2	0.158
C_2H_4	3.583
C_2H_6	1.006
C_3H_6	0.842
C_3H_8	0.295
C4 (Total)	0.538
C5 (Total)	0.129
C6 (Total)	0.038
C_7H_{14}	0.024
$C_3H_6O_3$	0.011
$C_4H_8O_3$	0.093
Total	**100**

Cell failure test method performed (summary of method and test clause):

☒ External heating using thin film with 4°C to 7°C thermal ramp.

☐ Nail Penetration

☐ Overcharge

☐ External short circuit (***X*** Ω *external resistance*)

☐ Flow Battery with 2 active electrolyte methods

☐ Flow Battery with 1 active electrolyte methods

☐ Others

Description of method used to fail cells if other than external thin film heater with thermal ramp,: N/A

Description of test methods used for flow battery testing: N/A

Summary of testing:

Performance Criteria in accordance with Clause 7.7 and Figure 1.1:

[ ] Thermal runaway was not induced in the cell; and

[ ] The cell vent gas did not present a flammability hazard when mixed with any volume of air, as determined in accordance with ASTM E918 at both ambient and vent temperatures.

Necessity for a module level test

[X] The performance criteria of the cell level test as indicated in 7.7 of UL 9540A 4th edition has not been met, therefore a module level testing in accordance with UL 9540A will need to be conducted on a complete module employing this cell.

[ ] The performance criteria of the cell level tests as indicated in 7.7 of UL 9540A 4th edition has been met, therefore a module level testing in accordance with UL 9540A need not be conducted.

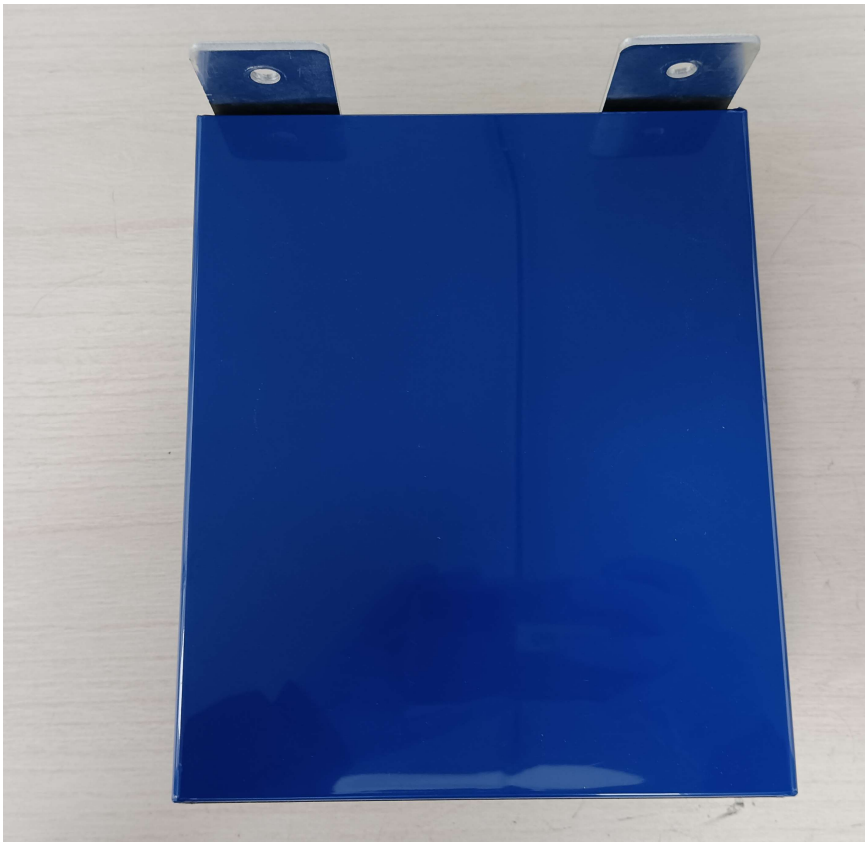
Testing Laboratory information

Testing Laboratory and testing location(s):

Testing Laboratory:	UL(Changzhou) Quality Technical Service Co., LTD	
Testing location/ address ..... :	21 Longmen Rd, National High-Tech Industrial Development District, Wujin, Changzhou, Jiangsu, China	
Tested by (name, signature)..... :	Yangyang Zhu, Wei Zhang	
Witnessed by (for 3rd Party Lab Test Location) (Name, signature) ..... :	NA	NA
Project Handler (name, signature)..... :	Jerome Mo	Jerome Mo
Reviewer (name, signature) ……..:	Benjamin Liu	Benjamin Liu

List of Attachments (including a total number of pages in each attachment):

Photo of cell/Stack:



Test Item Charge/Discharge Specifications:	
• **Charge power, W:**	502.4
• **Standard full charge voltage, Vdc:**	3.65
• **Charge temperature range, °C:**	0~60
• **End of charge voltage, V:**	3.65
• **Discharge power, W:**	502.4
• **End of discharge voltage, Vdc:**	T>0°C, 2.5 T≤0°C, 2.0
• **Discharge temperature range, °C:**	-30~60

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

Test item particulars:	
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)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Date of receipt of test item .....:	2023-12-05
Date (s) of performance of tests .....:	2023-12-08 to 2023-12-17

General remarks:
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report. **Throughout this report a point is used as the decimal separator.**

Manufacturer's Declaration of samples submitted for test:	
The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided ..... :	☒ **Yes** ☐ **Not applicable**
Name and address of factory (ies):	Factory 1: EVE POWER Co., Ltd. No. 68 Jingnan Avenue, High-Tech Zone, Duodao District, Jingmen City, Hubei Province, China Factory 2: Jiangsu EVE Linyang Energy Storage Technology Co., Ltd. No.608, Huashi Road, Qidong Economic Development Zone, Nantong, Jiangsu Province, China

General product information and other remarks:

The tested cell is a Lithium-ion battery cell, Model MB31. The cell has a capacity of 314 Ah and nominal voltage of 3.2 Vdc.

The overall dimensions of cell are 207.2±1mm by 173.7±1mm by 71.7±1mm.

The weight of cell is 5600±300g.

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict

5.0	**CONSTRUCTION**		**Verdict**
5.1. 5.4	**Cell/Stack Construction**		—
5.1.1, 5.4.1	Generic Chemistry:	$LiFePO_4$	—
	Electrolyte Chemistry:	$LiPF_6$, EC/EMC	—
	Flow Battery Electrolyte No. 1 Chemistry:	N/A	—
	Max volume of system electrolyte No. 1, L:	N/A	—
	Flow Battery Electrolyte No. 2 Chemistry:	N/A	—
	Max volume of system electrolyte No. 2, L:	N/A	—
	Separator Melt Temperature, °C:	128~139	—
	Format: Cylindrical /Prismatic /Pouch Flow Battery Stack	Prismatic	—
	Overall Dimensions, mm	207.2±1 by 173.7±1 by 71.7±1	—
	Cell Weight, g	5600±300	—
5.1.2	Cell Certification:		—
	Standard Used for Cell Certification:	UL 1973	—
	Organization that Certified Cell:	UL, MH63503	—
5.1.1, 5.4.1	Cell/Stack Ratings:		—
	• Nominal Voltage, Vdc	3.2 Vdc	—
	• Nominal Capacity, Ah	314 Ah	
5.4.1	Flow Battery: No. of Cells per Stack:	N/A	—
	Flow battery system manufacturer:	N/A	—
	Flow battery system model:	N/A	—
	Flow battery system ratings, Vdc, Ah:	N/A	—
5.4.2	Flow battery system certified to UL 1973:	N/A	—
	Organization that certified flow battery system:	N/A	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		C
7.2	**Samples**		C
7.2.1	Samples conditioned through charge discharge cycling a minimum of 2 cycles.	See Attachment A for profiles See Table 1 for specifications	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
7.2.2	100% SOC and stabilize from 1h to 8 h before testing	See Table 2	
7.2.3	Pouch Cells constrained per end use during testing.		N/A
7.3	**Determination of thermal runaway methodology**		C
7.3.1	**General**		C
7.3.1.1	Ambient indoor laboratory conditions: 25 ±5°C (77 ±9°F) ≤50 ±25% RH at the initiation of the test.	See Table 3	C
7.3.1.2	Heat the cell to thermal runaway by externally applied flexible film heaters	See Attachment B	C
	Heater Dimension	152.4 mm by 203.2 mm, two pieces provided, attached on the two largest surfaces of the cell	
	A surface heating rate of 4° C (7.2° F) to 7° C (12.6° F) per minute was applied to the cell.	See Attachment C and D See Table 4	C
	Maximum surface end point temperature, °C	Not used, the cells are heated until the thermal runaway achieved.	
	The following method(s) was employed to cause thermal runaway: ☐ Mechanical (e.g., nail penetration) ☐ Electrical stress in the form of overcharging, ☐ Electrical stress in the form of over discharging ☐ Electrical stress in the form of external short-circuiting ☐ Use of alternate heating sources (e.g. oven). ☐ Other (explain)	Only external heating in the form of using flexible thin film heaters to cause thermal runaway	N/A
7.3.1.3	Detail of test method when using another cell abuse method to initiate thermal runaway		N/A
7.3.1.4	Monobloc batteries such as a lead acid battery		N/A
7.3.1.5	Estimated surface temperature at which internal short circuiting within the cell will occur that could lead to a thermal runaway condition.		N/A
7.3.1.6	The cell was heated until thermal runaway has occurred.	Refer to Attachment C	C
	Another external heating method was used to cause cell thermal runaway		N/A
7.3.1.7	The cell's exterior surface temperature was measured	See Attachment B	C

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Clause	Requirement + Test	Result - Remark	Verdict
7.3.1.8	The temperature at which the cell case vents due to internal pressure rise was documented.	See Table 4 See Attachment C and D	C
7.3.1.9	The temperature at the onset of thermal runaway was documented.	See Table 4 See Attachment C and D	C
	If cell venting occurs first, the cell was heated continuously until thermal runaway occurs.	See Attachment C	C
7.3.1.10	When using methods other than the heater method, the stresses were applied to the cell until thermal runaway occurs.		N/A
7.3.1.11	3 additional samples were tested using the same method and exhibited thermal runaway	See Table 3, 4 and 5 See Attachment C, D	C
7.3.2	**Flow battery thermal runaway determination tests**		N/A
7.3.2.1	The test methods of 7.3.2.2 through 7.3.2.6 were used for the flow battery technology.		N/A
7.3.2.2	The flammability of the electrolytes was determined		N/A
	For liquids with anticipated higher flashpoints and viscosities at or below 9.5 × 10−6 m2/s (9.5 cSt) at 25°C (77°F): • ASTM D3828 or • ASTM D93 was used.		N/A
	The flash point temperature was recorded for each electrolyte tested.		N/A
7.3.2.3	For flow battery systems with two electrolytes, each electrolyte was subjected to the appropriate test method outlined in 7.3.2.2.		N/A
	The test of 7.3.2.4 was conducted if a flash point had been observed in 7.3.2.2		N/A
7.3.2.4	The energy reservoir in a test flow battery assembly was charged to 100% SOC, and then the two electrolyte materials were mixed in a closed container within approximately 1 min. The mixed solution temperature was measured during the test.		N/A
	A test battery representative of the flow battery system was subjected to an overcharge test and short circuit test in accordance with UL 1973, the temperature of the energy reservoirs during the testing were recorded.		N/A

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
7.3.2.5	For flow battery technologies with one active electrolyte containing solid metal particles, the appropriate test method of 7.3.2.2 was conducted to determine the flash point temperature		N/A
	If a flash point had been observed in 7.3.2.2, the propensity for thermal runaway was demonstrated by the test methods of 7.3.2.6		N/A
7.3.2.6	If a flash point had been observed, a test battery representative of the flow battery system was subjected to an overcharge test and short circuit test in accordance with UL 1973, and the maximum temperature of the energy reservoir during testing was recorded.		N/A
7.4	**Cell vent gas composition test**		C
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	Size of pressure vessel used: 100 L Refer to Attachment E	C
	The test was initiated with an initial condition of atmospheric pressure and less than 1% oxygen by volume.	Refer to Attachment E Atmospheric pressure (psig): 0.09	C
		Oxygen concentration measured (% volume): 0.20	
		Inert gas used: Nitrogen	
7.4.2	Cell vent gas composition was determined using Gas Chromatography (GC)	Refer to Table 8 Refer to Attachment F	C
	Hydrogen gas was measured	Refer to Table 8	C
	The initial atmospheric conditions prior to testing were noted.		C
7.4.3	The lower flammability limit of the cell vent gas was determined on samples of the synthetically replicated gas mixture in accordance with ASTM E918, testing at both ambient and cell vent temperatures.	Refer to Table 9 to 10	C
7.4.4	The gas burning velocity of the synthetically replicated cell vent gas was determined in accordance with the Method of Test for Burning Velocity Measurement of Flammable Gases Annex in ISO 817.	Refer to Table 9 to 10	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
7.4.5	P_{max} of the synthetically replicated cell vent gas was determined in accordance with EN 15967.	Refer to Table 9 to 10	C
7.5	**Off gas composition for flow battery systems**		N/A
7.5.1	The off gas composition from the flow battery testing of 7.3.2 was determined by conducting the test method of 7.3.2.2: • In a closed container and capturing the off gasses generated, and • 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.		N/A
	Gas composition and flammability limit were determined through the methods outlined in 7.4.2 and 7.4.3 at both ambient temperature and the maximum temperature measured.		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		N/A
7.6	**Cell Level Test Report Information**		C
7.6.1	Minimum information provided in the report for items a) through m)		C
7.6.2	Minimum information of items a) through k) was provided in the report for flow battery		N/A
7.7	**Performance – cell level test**		C
7.7.1	a) Thermal runaway cannot be induced in the cell; and	Thermal runaway can be induced in the cell	F
	b) The cell vent gas does not present a flammability hazard when mixed with any volume of air, at both ambient and vent temperatures.	As a result of gas analysis, the gas generated from the cell were identified flammable	F
7.8	**Performance – flow battery thermal runaway determination tests**		N/A
7.8.1	a) The electrolyte(s) subjected to the test method in accordance with 7.3.2.2 does not ignite; or		N/A
	b) The flash point temperature(s) measured in the test of 7.3.2.2 exceed the maximum temperature measured on the energy reservoir during the overcharge and short circuit tests of 7.3.2.4 or 7.3.2.6 by at least 5°C (9°F); and		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
	c) The flash point temperature(s) measured in the test of 7.3.2.2 exceed the maximum temperature of the mixed solution measured in accordance with 7.3.2.4 by at least 5°C (9°F) for systems with two active electrolytes.		N/A

Table 1 – Specified conditioning parameters			
Charging:		Discharging	
Power (CP), W	502.4	Power (CP), W	502.4
Standard full charge voltage, Vdc	3.65	Voltage at start of discharge, Vdc	3.65
End of charge voltage, V	3.65	End of discharge voltage, Vdc	2.5
Charging Test Ambient, °C	0-60	Discharging Test Ambient, °C	-30-60
Refer to Attachment A for charge/discharge profiles for each cell.			

Table 2 – Charge completion and cell test initiation times			
Cell Test Number	**Charge Completion Date and Time**	**Cell test Date and Time**	**Stable duration before the start of the test, hours**
1	12/8/2023 14:48	12/8/2023 18:15	3.4
2	12/11/2023 9:14	12/11/2023 11:02	1.8
3	12/11/2023 10:20	12/11/2023 15:50	5.5
4	12/12/2023 8:02	12/12/2023 10:27	2.4
5	12/16/2023 10:51	12/16/2023 16:49	6.0

Table 3 - Test Initiation Details					
	Cell Test 1	**Cell Test 2**	**Cell Test 3**	**Cell Test 4**	**Cell Test 5**
Test Date	12/8/2023	12/11/2023	12/11/2023	12/12/2023	12/16/2023
Test Start Time	18:15	11:02	15:50	10:27	16:49
Initial Lab Temperature	21.3°C	22.7°C	20.3°C	21.6°C	23.5°C
Initial Relative Humidity	63.8%	71.6%	71.5%	64.4%	24.4%

Table 4 - Thermal Runaway Results					
	Cell Test 1	**Cell Test 2**	**Cell Test 3**	**Cell Test 4**	**Cell Test 5**
OCV at start of test, Vdc	3.43	3.39	3.43	3.43	3.38
Average Heating Rate, °C/min	4.5	4.5	4.5	4.5	4.5
Venting Time after the test start (hh:mm:ss)	0:39:52	0:38:23	0:39:59	0:39:18	0:40:30
Venting Temperature, °C	153	152	156	156	171
Thermal Runaway Time after the test start (hh:mm:ss)	0:57:54	0:58:23	0:59:32	0:58:15	0:55:35
Thermal Runaway Temperature, °C	215	222	234	227	229
Refer to Attachment C for surface temperature profiles during testing Temperature indicated above were taken from TC03					

Table 5 – Average Vent and Thermal Runaway Temperatures	
Average of Cell Vent Temperatures, °C	154
Average of Cell Thermal Runaway Temperatures, °C	225
#Averages of cell tests other than the gas analysis test	

Table 6 – Parameters Flow Battery
N/A

Table 7 – Results of Flammability Testing of Flow Battery Electrolyte
N/A

Table 8 – Results of Gas Analysis (Excluding O_2 and N_2)			
Gas		**Measured %**	**Component LFL [1]**
Carbon Monoxide	CO	13.775	10.9
Carbon Dioxide	CO_2	24.315	N/A
Hydrogen	H_2	49.427	4.0
Methane	CH_4	5.765	4.4
Acetylene	C_2H_2	0.158	2.3
Ethylene	C_2H_4	3.583	2.4
Ethane	C_2H_6	1.006	2.4
Propene	C_3H_6	0.842	1.8
Propane	C_3H_8	0.295	1.7
-	C4 (Total)	0.538	N/A
-	C5 (Total)	0.129	N/A
-	C6 (Total)	0.038	N/A
1-Heptene	C_7H_{14}	0.024	N/A
Dimethyl Carbonate	$C_3H_6O_3$	0.011	N/A
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.093	N/A
Total	-	100.00	-

[1] Extracted LFL values from ISO 10156-2017

Table 9 – Gas composition excluding the constituents with boiling points higher than 60°C [2]			
Gas		**Measured %**	**Component LFL**
Carbon Monoxide	CO	13.798	10.9
Carbon Dioxide	CO_2	24.355	N/A
Hydrogen	H_2	49.509	4.0
Methane	CH_4	5.774	4.4
Acetylene	C_2H_2	0.159	2.3
Ethylene	C_2H_4	3.589	2.4
Ethane	C_2H_6	1.008	2.4
Propadiene	C_3H_6	0.843	1.8
Propylene	C_3H_8	0.295	1.7
-	C4 (Total)	0.539	N/A
-	C5 (Total)	0.129	N/A
Total		100	-

[2] The constituents with a higher boiling point were excluded for the flammability characteristic analysis as these components will turn into a liquid state at room temperature and will not release from the gas bottle as a homogenous mixture.

Table 10 – Properties of Vent Gas Analysis	
Lower Flammability limit at Ambient Temperature, 25°C (% vol in air)	7.75
Lower Flammability limit at Vent Temperature, [154°C] (% vol in air)	7.14
Burning Velocity Measurement, S_u cm/sec	75.90
Maximum Pressure P_{max}, psig	95.40

	TABLE: Critical components information				
Object / part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cell Model	EVE POWER Co.,Ltd.	MB31	3.2Vdc, 314Ah	UL1973	UL, MH63503
Separator	Shenzhen Senior Technology Material Co.,Ltd	SH11B	Material: PE W*T:(195.5±2) mm*(13.5±3) Thickness: 13.5±3.0 μm	-	-
Electrolyte	-	-	$LiPF_6$, EMC, PC, EC	-	-
Case	-	-	Material: Aluminum Thickness: Flat: (0.8±0.2) mm Side: (0.6±0.2) mm	-	-
Insulators/ location in cell	-	-	Top insulator: PC Mylar: PP Outer protective film: PET Bottom protective film: PC Bottom gasket insulator: PP Terminal insulation: PPS	-	-
Vent	-	-	Material: MFX2-O Vent pressure: (0.65-0.95) MPa	-	-

Attachment A: Cell Conditioning (Charge/discharge) Profiles - (*Pages 19 through 21)*

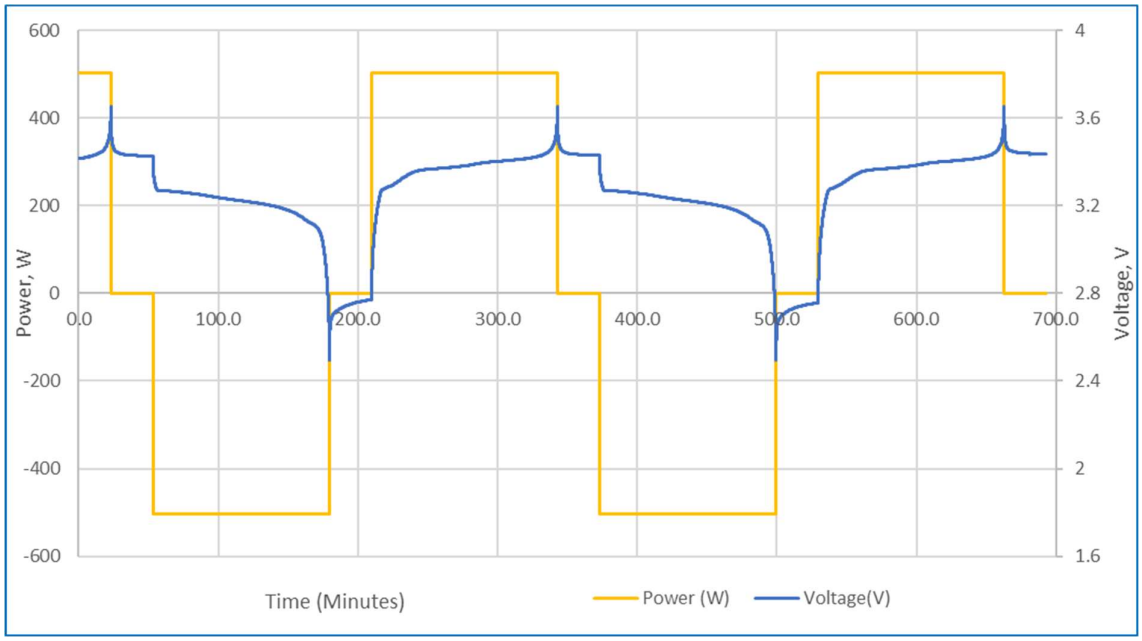


Figure 1: Cell 1 Conditioning (Charge/discharge) Profiles

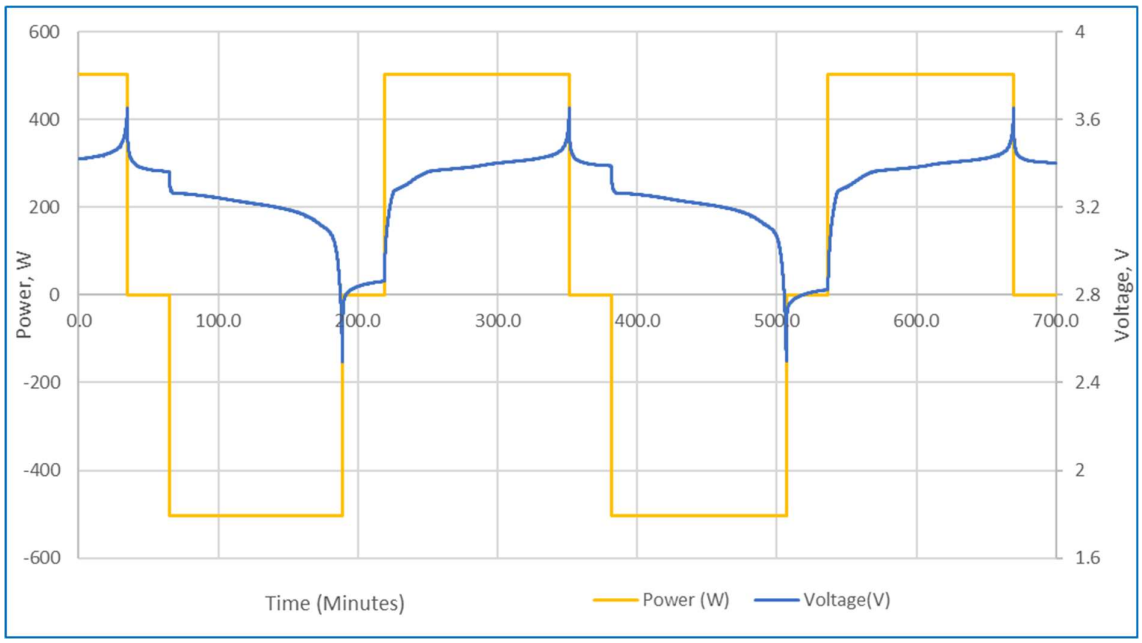


Figure 2: Cell 2 Conditioning (Charge/discharge) Profiles

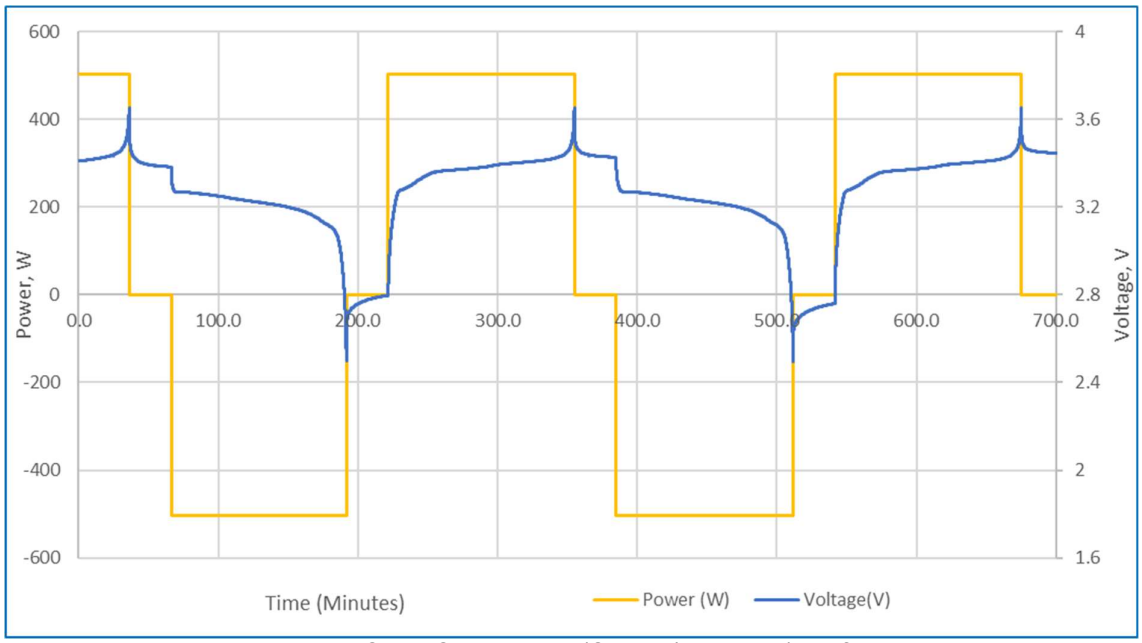


Figure 3: Cell 3 Conditioning (Charge/discharge) Profiles

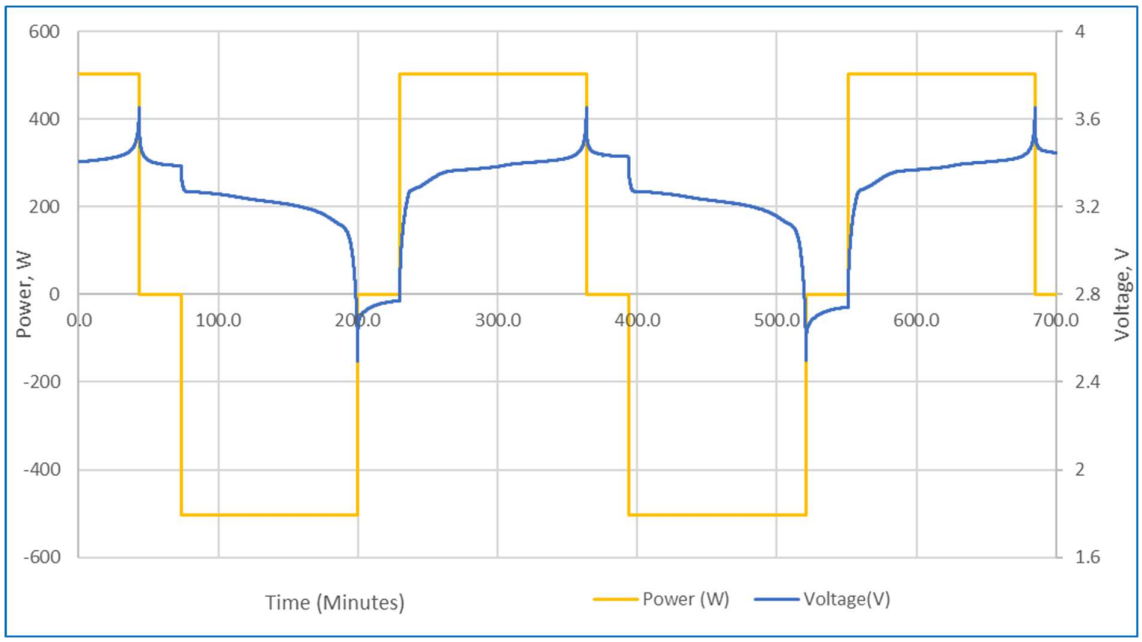


Figure 4: Cell 4 Conditioning (Charge/discharge) Profiles

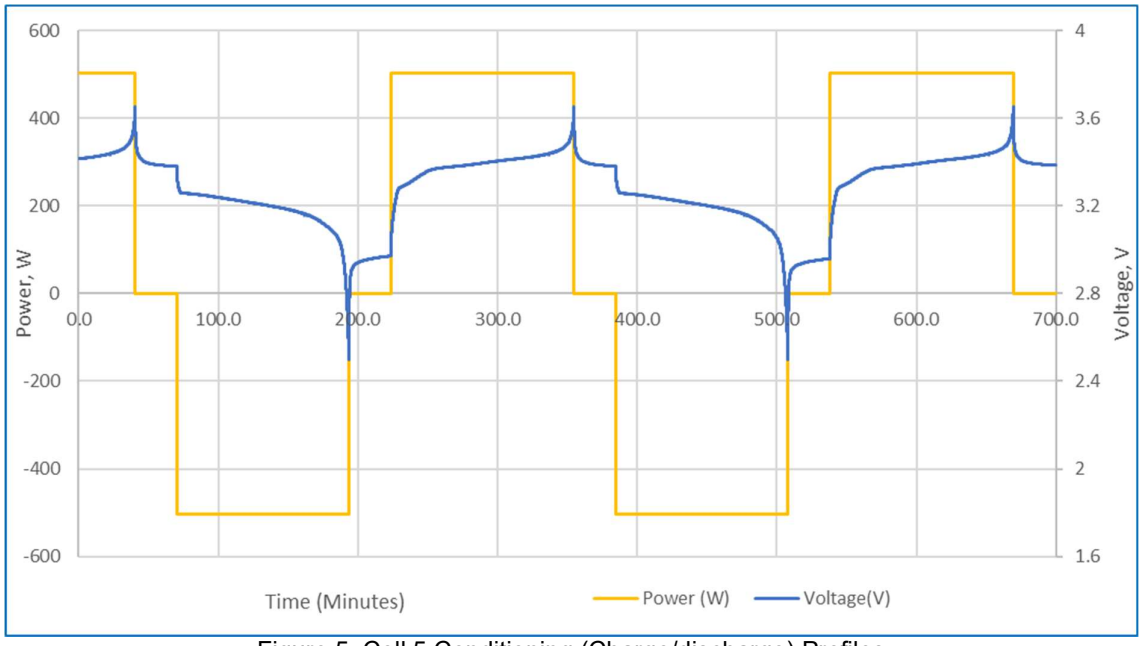
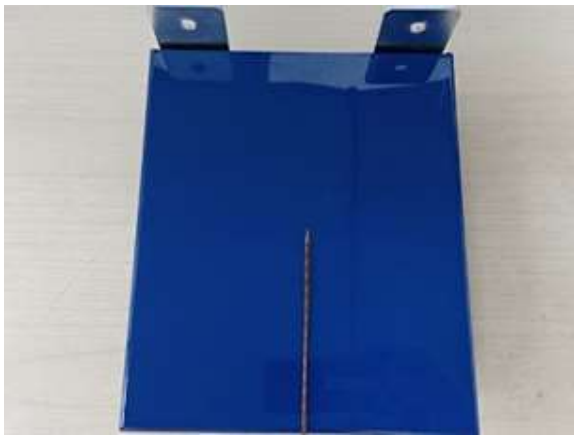
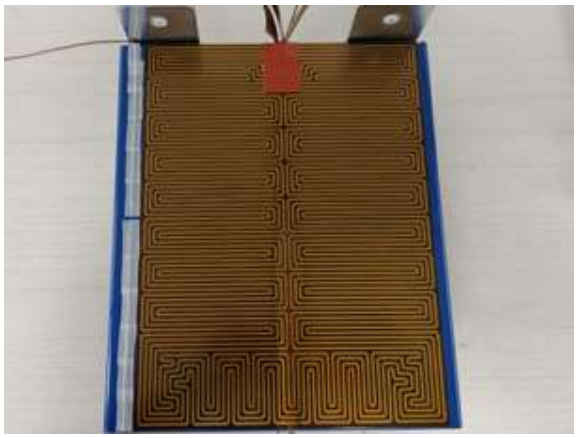


Figure 5: Cell 5 Conditioning (Charge/discharge) Profiles

Attachment B: Cell Instrumentation Photos - (*Page 22*)





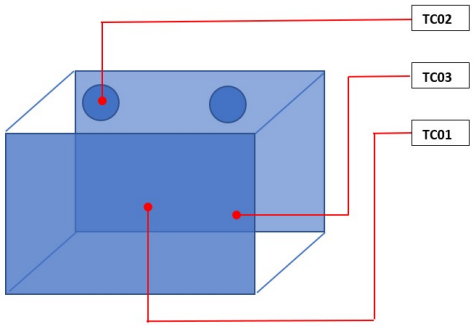


Figure 6: Sample Instrumentation Prior to Test
Note: Heaters were placed on two sides of the cell after thermocouples were instrumented.
Note: TC01 under heater; TC02 on the cell positive; TC03 on the cell body not covered by heater

Attachment C: Cell Temperature Profiles during testing - (*Pages 23 through 25*)

Note: TC01 under heater; TC02 on the cell positive; TC03 on the cell body not covered by heater; TC04 Ambient temperature; V1 cell voltage
TC01 was used to control the temperature at 4 to 7°C/min and TC03 temperatures were reported herein for the surface temperature at the onset of vent and thermal runaway.

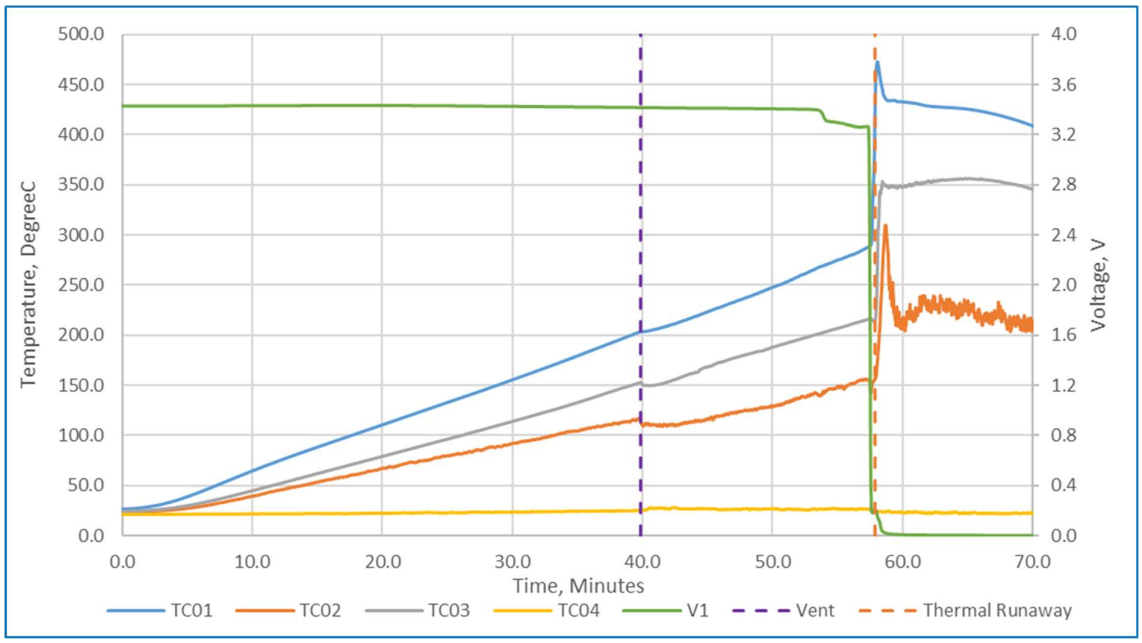


Figure 7: Cell 1 – External Heating 4.5**°C** per minute

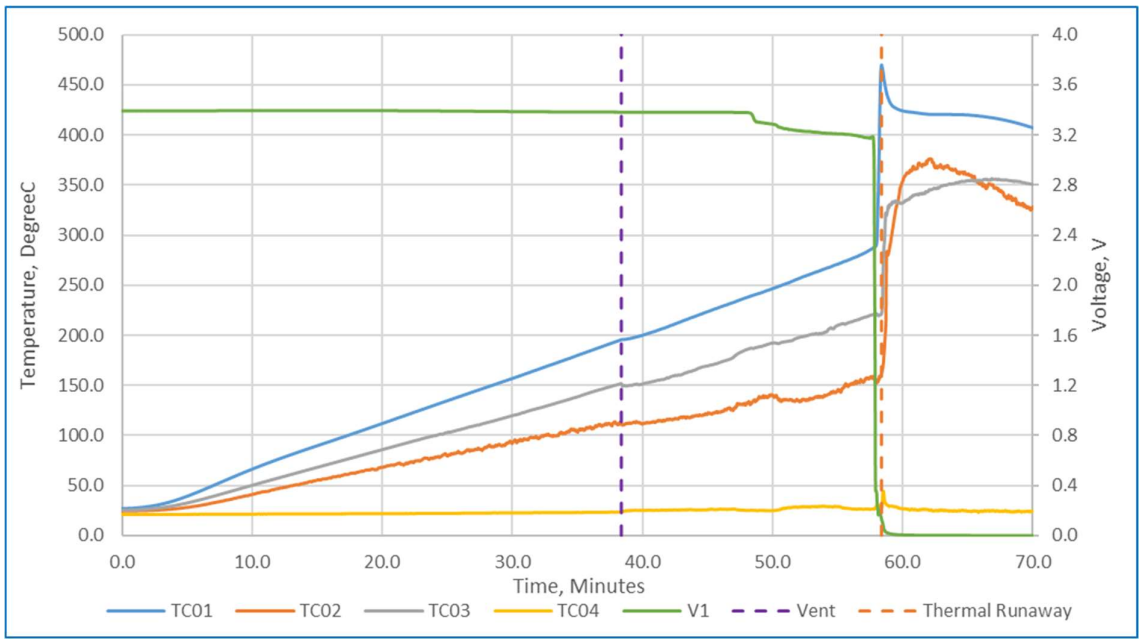


Figure 8: Cell 2 – External Heating 4.5**°C** per minute

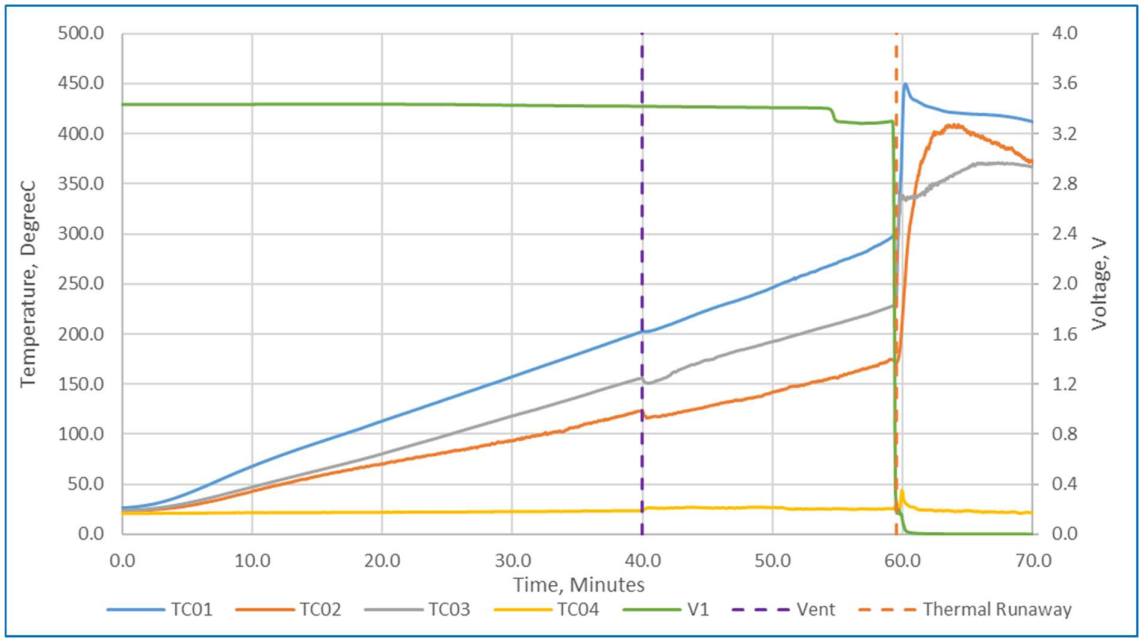


Figure 9: Cell 3 – External Heating 4.5**°C** per minute

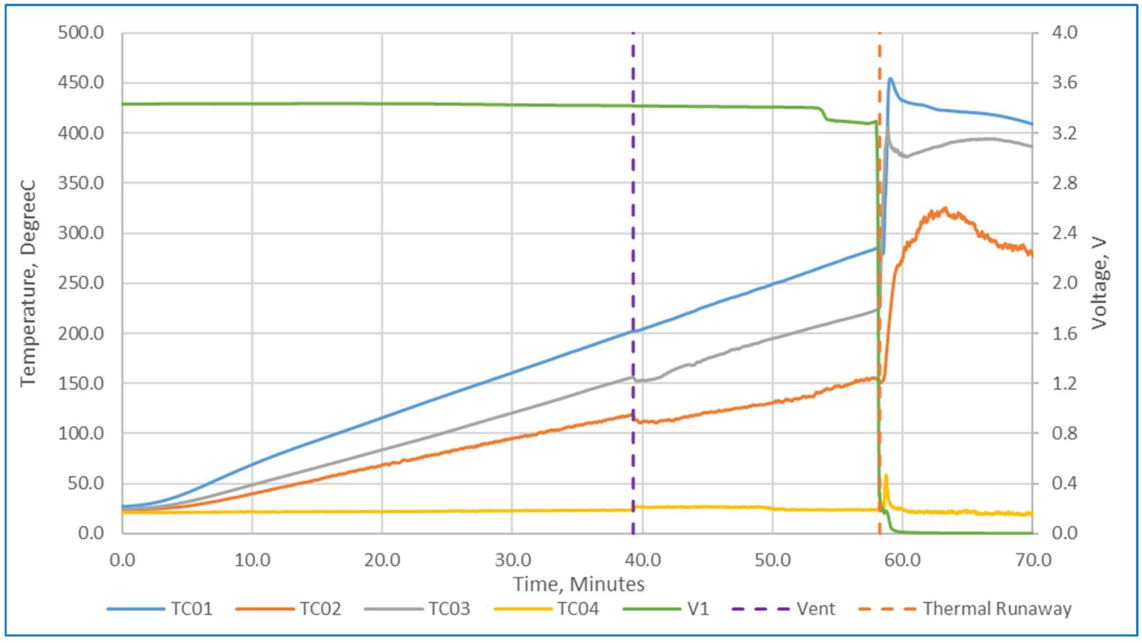


Figure 10: Cell 4 – External Heating 4.5**°C** per minute

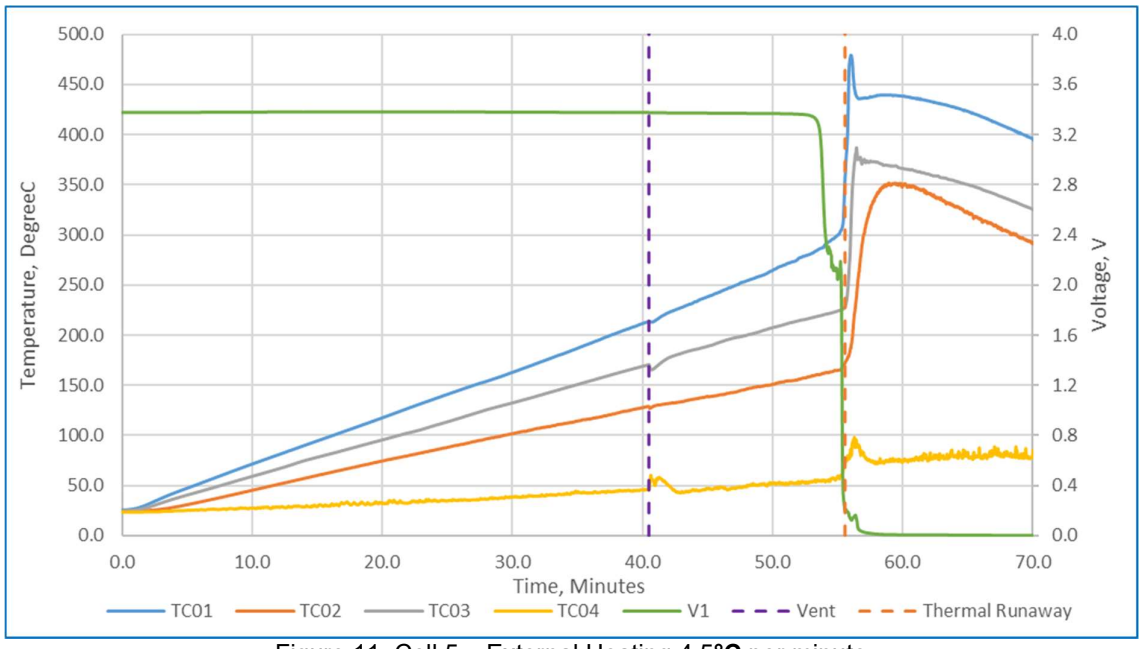


Figure 11: Cell 5 – External Heating 4.5**°C** per minute

Attachment D: Cell Testing Photos - (*Pages 26 through 35*)

Cell Sample 1 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

(a) Test Start
[00:00]

(b) Cell Venting
[39:52]

(c) Thermal runaway behavior
[57:54]

Figure 12: Highlights of Cell 1 Testing




Figure 13: Sample 1 Post Test Photos

Cell Sample 2 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

(a) Test Start
[00:00]

(b) Cell Venting
[38:23]

(c) Thermal runaway behavior
[58:23]

Figure 12: Highlights of Cell 2 Testing




Figure 13: Sample 2 Post Test Photos

Cell Sample 3 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

(a) Test Start
[00:00]

(b) Cell Venting
[39:59]

(c) Thermal runaway behavior
[59:32]

Figure 16: Highlights of Cell 3 Testing




Figure 17: Sample 3 Post Test Photos

Cell Sample 4 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.

(a) Test Start
[00:00]

(b) Cell Venting
[39:18]

(c) Thermal runaway behavior
[58:15]

Figure 18: Highlights of Cell 4 Testing

Figure 19: Sample 4 Post Test Photos

Cell Sample 5 – Cell venting and thermal runaway were observed.

The video screenshots perspectives are limited due to the dimension limitation in the chamber.

(a) Test Start
[00:00]

(b) Cell Venting
[40:30]

(c) Thermal runaway behavior
[55:35]

Figure 20: Highlights of Cell 5 Testing




Figure 21: Sample 5 Post Test Photos

Attachment E: Cell vent gas test chamber photo and profile of chamber gas analysis (O_2 and Pressure) - (*Page 36*)

The gas composition test was conducted with the battery inserted into the battery gas composition test chamber and the chamber was sealed. The battery gas composition test chamber is a 100 L pressure vessel and is shown in figure below.

Prior to initiating thermal runaway, the chamber's atmosphere was purged until a condition of less than 1% oxygen by volume (actual 0.20%, with initial pressure 0.09psig).

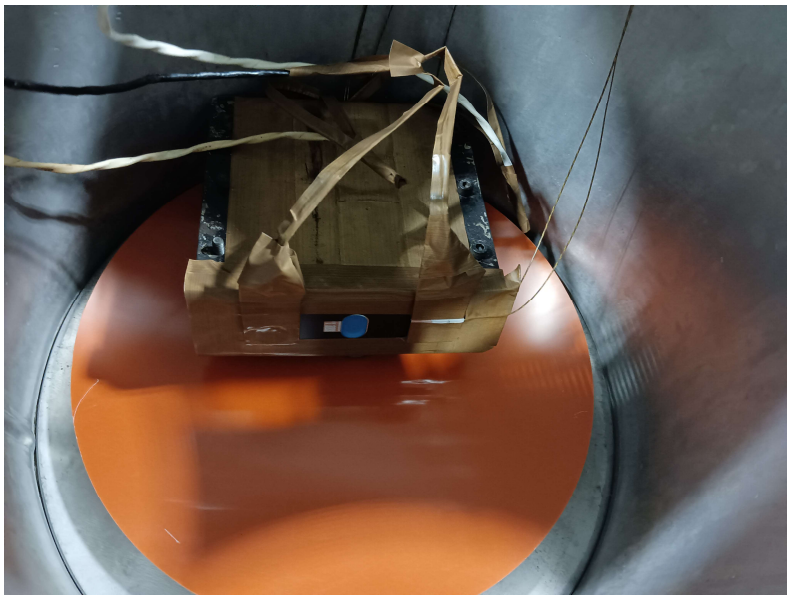


Figure 22: Sample 5 instrumented and inside gas test chamber

$\phi_{O2,\ chamber}$=	0.20	%	Pinitial,chamber=	0.09	psig

Figure 23: Profile of gas test chamber (O_2 and Pressure)

Attachment F: Cell Gas Analysis Report - (*Page 37*)

Table Re-normalized Gas Quantification, excluding N_2 and O_2, and unknown compounds.

Item	Measure	Chemical formula	Conc.(%)
1	Carbon Monoxide	CO	13.775
2	Carbon Dioxide	CO_2	24.315
3	Hydrogen	H_2	49.427
4	Methane	CH_4	5.765
5	Ethylene	C_2H_4	3.583
6	Acetylene	C_2H_2	0.158
7	Ethane	C_2H_6	1.006
8	Propane	$CH_3CH_2CH_3$	0.295
9	Propylene	C_3H_6	0.842
10	Propadiene (Allene)	C_3H_4	0.000
11	Isobutane	$CH_3CH(CH_3)CH_3$	0.000
12	Butane	C_4H_{10}	0.069
13	Isobutylene	C_4H_8	0.227
14	1-Butene	C_4H_8	0.103
15	trans-2-Butene	C_4H_8	0.067
16	cis-2-Butene	C_4H_8	0.073
17	Pentane	C_5H_{12}	0.085
18	trans-2-Pentene	C_5H_{10}	0.015
19	cis-2-Pentene	C_5H_{10}	0.019
20	1,4-Pentadiene	C_5H_8	0.010
21	Hexane	C_6H_{14}	0.018
22	1-Hexene	C_6H_{12}	0.020
23	Benzene	C_6H_6	0.000
24	1-Heptene	C_7H_{14}	0.024
25	Toluene	C_7H_8	0.000
26	Styrene	C_8H_8	0.000
27	Dimethyl Carbonate	$C_3H_6O_3$	0.011
28	Ethyl Methyl Carbonate	$C_4H_8O_3$	0.093
29	Diethyl Carbonate	$C_5H_{10}O_3$	0.000
	Total	Measurement result	100.000