DOCKETED	
Docket Number:	26-OPT-01
Project Title:	Vaca Dixon Power Center Project
TN #:	268171-2
Document Title:	Appendix V Vaca Dixon BESS Hazard Consequence Analysis_VDPC
Description:	The Hazard Consequence Analysis evaluates potential fire and safety risks for the Project, detailing mitigation measures, distances to sensitive receptors, and modeling of hazardous gas releases during thermal runaway events using UL 9540A test data and PHAST software to ensure compliance with fire codes and protect life safety. V.A SYL SU3794U3794KC UL 9540A Cell Level Test Result
Filer:	Grace Myers
Organization:	Rincon Consultants, Inc.
Submitter Role:	Applicant Consultant
Submission Date:	1/6/2026 2:55:00 PM
Docketed Date:	1/6/2026

Appendix V

Vaca Dixon BESS Hazard Consequence Analysis

COFFMAN ENGINEERS

VACA DIXON POWER CENTER PROJECT

Hazard Consequence Analysis

COFFMAN PROJECT NO. 251796

IFP SUBMITTAL

December 19, 2025

Prepared for: Vaca Dixon BESS LLC

HAZARD CONSEQUENCE ANALYSIS

FOR

VACA DIXON BESS

Vacaville, California

Project Number: 251796

Revision	Date	Description
A	10/24/2025	Issued for Review
B	12/19/2025	Issued for Permit

PREPARED BY:

COFFMAN ENGINEERS, INC.

CONTACT:

Ben Collins
Fire Protection Engineering
406-582-1936

&

Mark Gouveia, PE

Principal, Fire Protection Engineering
406-582-1936

TABLE OF CONTENTS

APPENDICES

ABBREVIATIONS

AHJ	Authorities Having Jurisdiction
BESS	Battery Energy Storage System
BMS	Battery Management System
CFC	California Fire Code
DC	Direct Current
EMS	Energy Management System
ESS	Energy Storage System
FACP	Fire Alarm Control Panel
FCC	Fire Command Center
HMA	Hazard Mitigation Analysis
HVAC	Heating, Ventilation, and Air Conditioning
IDLH	Immediately Dangerous to Life and Health
kV	Kilovolt
LFL	Lower Flammability Limit
LPC	Local Plant Controller
MW	Megawatt
MWh	Megawatt-hour
MV	Medium Voltage
NEC	National Electric Code
NESC	National Electric Safety Code
PCS	Power Conversion System
PEL	Permissible Exposure Limits
SCADA	Supervisory Control and Data Acquisition
UPS	Uninterruptible Power Supply
VDPC	Vaca Dixon Power Center

1 INTRODUCTION

This Hazard Consequence Analysis (HCA) is provided by Coffman Engineers, Inc. (Coffman) for the Vaca Dixon Battery Energy Storage System (BESS) facilities associated with the Vaca Dixon Power Center (VDPC) project located in Vacaville, California. This document is to be used in conjunction with the Emergency Response Plan (ERP) so that the Operator and First Responders understand the practices and procedures to be followed to provide immediate and effective response to emergencies that may arise.

The purpose of this HCA is to identify the distance from the project site to the nearest sensitive receptors, and identify and characterize the quantities and locations of hazardous chemicals that could be released during a thermal runaway and/or fire event. This HCA is based on the specific project system design including equipment specifications, location, and plume dispersion modeling using PHAST™ Version 8.9 software from DNV®.

Spill control and neutralization is not required as fire suppression using fire sprinkler systems interior to the Energy Storage System (ESS) enclosures is not the fire protection design approach for this site and spill control and neutralization is not required for lithium-ion battery installations per CFC § 1207.6.2. Three (3) fire hydrants are provided within the site near to the site entrances for dedicated emergency operations only.

2 PROJECT DESCRIPTION

2.1 Project Site

The Vaca Dixon BESS yard will contain 29 SYL SU3794U3794KC enclosures (including augmentation) for an approximate total energy capacity of 57 MW / 57 MWh. The BESS yard portion is located within Vacaville, California. The site will include enclosures manufactured by SYL, containing lithium-ion battery technology.

The details of the Vaca Dixon BESS facilities associated with the project are discussed in the Hazard Mitigation Analysis (HMA) in detail and summarized in this section. A separate HMA will be prepared for the Arges BESS facilities associated with the project. A vicinity map is provided in Figure 2.1(a). The site will include twenty-nine (29) SYL SU3794U3794KC enclosures (including augmentation enclosures) installed over a footprint of approximately 4.25 acres within a 10-acre parcel (APN 0133-060-060). The Arges 400 MWh BESS site is located to the north within the same parcel and occupies approximately 5.75 acres. The Arges BESS 400 MWh BESS project is assessed in a separate report. The project site will be provided with fire department access, three (3) fire hydrants, transformers, and the necessary infrastructure for connection to the utility.

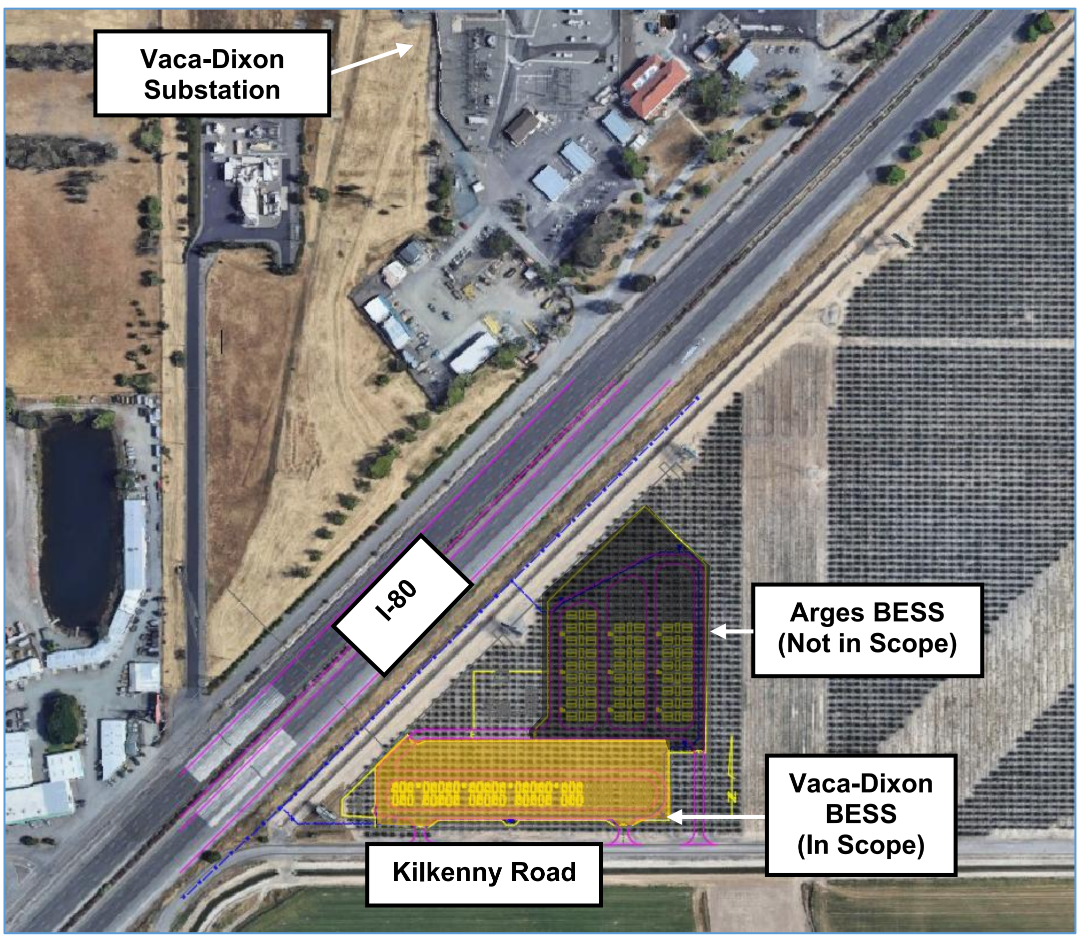


Figure 2.1(a) - Vaca Dixon Energy Storage Vicinity Map (North ↑)

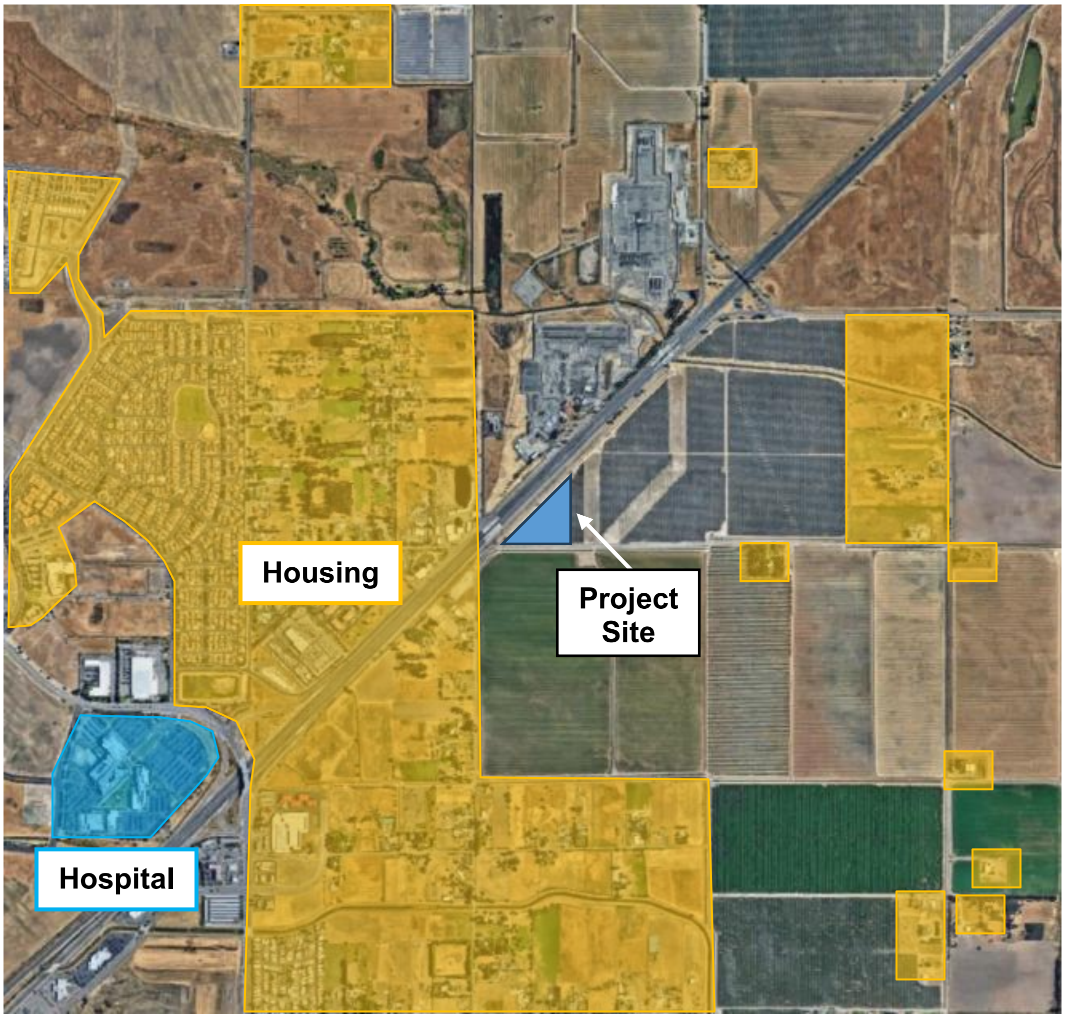


Figure 2.1(b) – Sensitive Receptors within 1 Mile of ESS Yard (North ↑)

2.2 Surrounding Area

The BESS yard is located in a mixed agricultural, commercial, and residential area within Vacaville, California. The landscape is typical of the Central Valley with low foliage, agricultural fields, and scattered trees. The adjacent properties are zoned for Agriculture, Business Park, and Public/Institutional uses. Additional occupancies including schools and hospitals are discussed later in the document.

Select nearby locations of sensitive receptors beyond one mile away from the site are provided below including approximate straight-line distances with compass headings. A zero-degree heading starts at magnetic North and rotates clockwise. Sensitive receptors are considered within this document as children, elderly, or others at a heightened risk of negative effects because of air pollutants.

2.2.1 Schools:

- The Academy of 21st Century Learning – 0.92 miles away Southwest at a 249-degree heading
- Vacaville Unified School District – 2.66 miles away Southwest at a 218-degree heading
- Edwin Markham Elementary School – 3.39 miles away Southwest at a 240-degree heading
- Browns Valley Elementary School – 3.22 miles away Southwest at a 255-degree heading
- Golden Hills School – 3.63 miles away Southwest at a 235-degree heading
- Cooper Elementary School – 2.81 miles away Southwest at a 202-degree heading

2.2.2 Hospitals/Health Centers:

- Kaiser Permanente Vacaville Medical Center – 0.77 miles away Southwest at a 236-degree heading

2.2.3 Daycare Facilities:

- Growing Cubs Daycare – 1.24 miles away Northwest at a 301-degree heading
- Millenium Child Development Center – 2.98 miles away West at a 260-degree heading
- Childtime of Vacaville – 3.01 miles away Southwest at a 219-degree heading
- Paula's Happy Vacaville Daycare – 2.88 miles away South at a 197-degree heading

2.2.4 Residential Housing:

- There are concentrated and dispersed housing areas in all directions around the project site, with the closest ones being located 0.24 miles away to the west

3 CODE STUDY

3.1 Applicable Codes

The Authority Having Jurisdiction (AHJ) for the Vaca Dixon BESS facility is the Vacaville Fire Department. The applicable codes with regards to fire protection and life safety, with local amendments, are listed below.

- CFC, California Fire Code, (2025 Edition), as adopted by the City of Vacaville
- NFPA 72, National Fire Alarm and Signaling Code (2025 Edition)
- NFPA 70, National Electrical Code (NEC) (2023 Edition)
- NFPA 855, Standard for the Installation of Stationary Energy Storage Systems (2023 Edition)
- UL 9540, Standard for Energy Storage Systems and Equipment (2023 Edition)
- UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (2019 Edition)

The following standards, not adopted by the CFC are used as guidance:

- Pre-incident planning per NFPA 1620, Standard for Pre-incident Planning (2020 Edition)

4 SYSTEM EQUIPMENT

4.1 Main ESS Components

The following section provides a description of the SYL SU3794U3794KC (referred to in this document as “enclosure”) is 8-ft wide x 19.9-ft long x 9.5-ft tall. Enclosures are in groups of 4, together with the ancillary equipment (e.g., transformers). See the figure below for an image of a SYL SU3794U3794KC enclosure. Figure 4.1(a) below provides a visual of the general arrangements. The ESS enclosures are organized in rows with fire department access roads as shown in Figure 4.1(b).

Figure 4.1(a) – SYL SU3794U3794KC Enclosure

Each enclosure is self-contained with its own integrated battery modules, battery management systems, thermal management systems, and explosion prevention system. A simplified arrangement of the Vaca Dixon Energy Storage facility for reference is shown below in Figure 4.1(b) with the Fire Command Center (FCC). Note that an FCC has the same function as a First Responder Station.

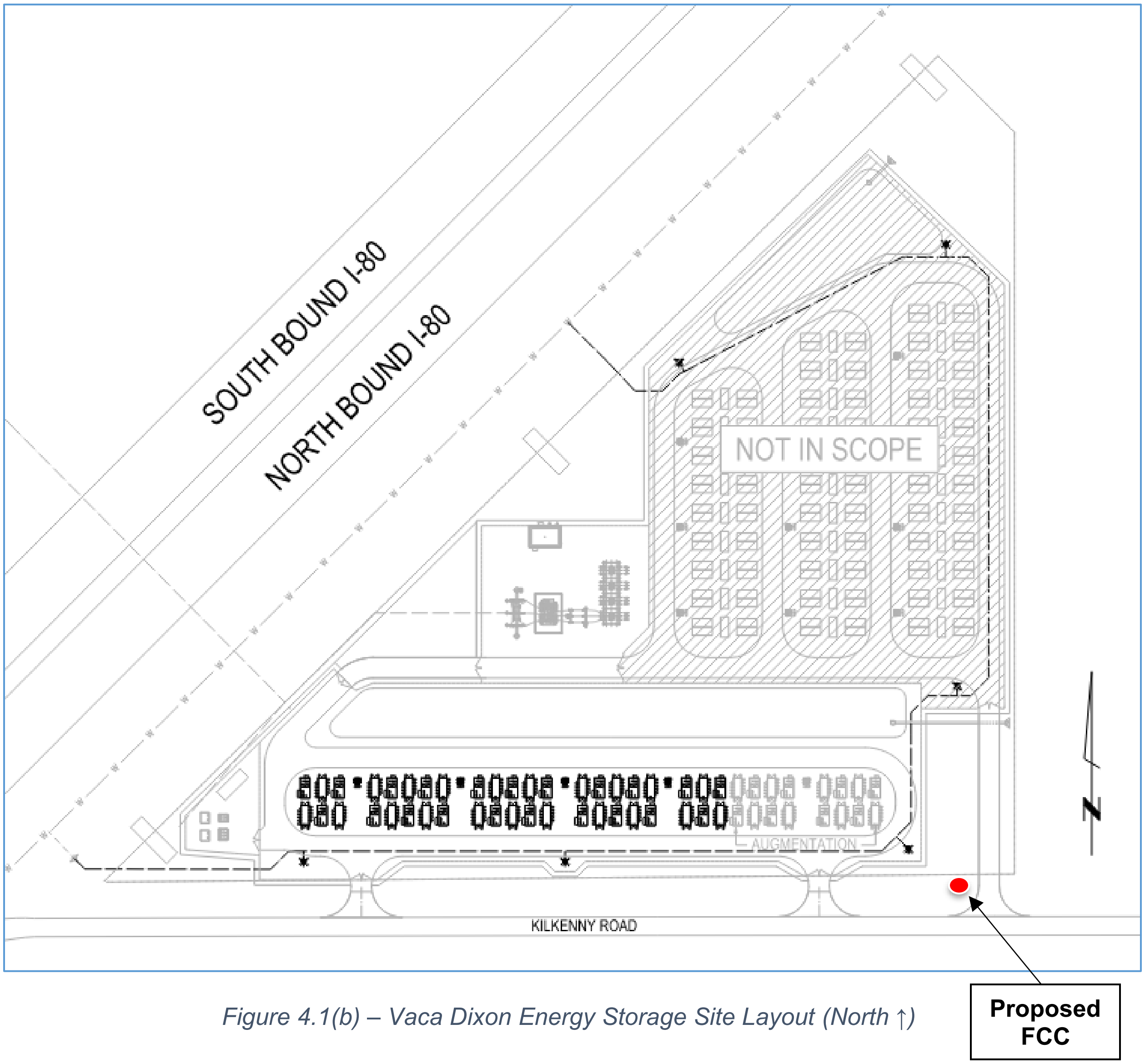


Figure 4.1(b) – Vaca Dixon Energy Storage Site Layout (North ↑)

4.2 Battery Arrangement and Quantities

The Vaca Dixon BESS portion of the Vaca Dixon Power Center (VDPC) contains 29 SYL SU3794U3794KC BESS enclosures (including augmentation). One battery bay, or the accessible portion of battery modules behind one enclosure door, is shown in Figure 4.2 below. Each SU3794U3794KC BESS enclosure has 5 battery bays, and each battery bay contains 2 racks. One rack is a collection of 4 modules and within each module there are 104 battery cells. Including augmentation, Vaca Dixon BESS will utilize 120,640 battery cells.

Figure 4.2 – View of single SYL SU3794U3794KC battery bay housing 8 modules.

5 LARGE SCALE FIRE TESTING

5.1 UL 9540A Fire Test

This HCA has been prepared after reviewing the UL 9540A test result reports. The unit-level test is included in Appendix A of this report. Tests were conducted to the 4th edition of the UL 9540A test procedures. Key results of the UL 9540A testing are shown in the following sections.

5.1.1 Cell Level Test

The cell level test document that was referenced for this report was published by UL(Changzhou) Quality Technical Service Co., LTD, Dated 12/11/2023, Test Report No. 4790838636.1.

The cell test included the same test repeated 5 times with a separate cell each time. Each time, the single cell was forced into thermal runaway by inducing heat via a single film heater at a rate between 4°C/min and 7°C/min.

- On average, cell venting occurred at 156°C (312.8°F) and thermal runaway occurred at 232°C (449.6°F).
- Gas composition was analyzed showing the primary flammable gas constituents as hydrogen, methane and ethylene. The primary toxic gas was carbon monoxide.

5.1.2 Module Level Test

The module level test document that was referenced for this report was published by SGS-CEC New Energy Technology (Chongqing) Co., Ltd., Dated 07/30/2024, Report No. CQES240700055301.

The module test was conducted with 2 cells being forced into thermal runaway by inducing heat via 1 film heater between the 2 initiating cells.

- The report doesn't confirm the number of cells that went into thermal runaway, but the results look similar to what was observed during the unit level test.
- Gas composition was analyzed showing the primary flammable gas constituents as hydrogen, methane and ethylene. The primary toxic gas was carbon monoxide.
- No flying debris, explosive discharge of gas, sparks or electrical arcs were observed during the test.

5.1.3 Unit Level Test

The unit level test document that was referenced for this report was published by SGS-CEC New Energy Technology (Chongqing) Co., Ltd., Dated 08/29/2024, Report No. CQES240800069201.

- The unit test was conducted with a single module being forced into thermal runaway with 1 film heater used to simultaneously heat 2 cells within the module. No fire suppression system was installed for any test.
- Thermal runaway of a single module occurred approximately 1 hour and 15 minutes after heater activation. At approximately 2 hours and 24 minutes temperature readings

inside the initiating module showed it had cooled to approximately the same temperature as when thermal runaway initiated. Cooling continued for the duration of the test.

- Thermal runaway propagated to 1 non-induced cell within the initiating module, resulting in a total of 3 cells in thermal runaway.
- The unit test results demonstrate that the thermal runaway event was limited to a single module within the initiating rack unit and there was no propagation to other modules within the initiating rack unit or any of the target rack units. There were no observations of a deflagration or explosive discharge of gases.
- The maximum external heat flux detected was 1.2 kW/m^2. This level of heat flux is below the level that can ignite combustibles.
    - For perspective on the effects of thermal radiation at various radiant heat flux values are provided below.
        - 1 kW/m^2 – Solar radiation (sunny day)
        - 10 kW/m^2 – Pain after 2 seconds of skin exposure (SFPE Handbook, 4th ed. Table 2-6.19, Perkins)
        - 29 kW/m^2 – Wood ignites spontaneously after prolonged exposure (Drysdale, 2005)
- The UL 9540A unit test demonstrates that the ESS enclosure design will limit a thermal runaway event from propagating outside of a single enclosure with a clearance distance of 100mm (0.4 inches) to adjacent units. This testing supports the proposed layout and spacing of rack units at the site.
- Additional thermal runaway prevention will be provided via a Battery Management System (BMS) that monitors battery voltage, temperature, etc. to detect irregularities and disconnect power if needed.

6 FIRE PROTECTION FEATURES

6.1 Fire Suppression / Thermal Runaway Mitigation System

The failure of a battery module could lead to a thermal runaway event. UL 9540A testing has demonstrated that the failure and thermal runaway of one module is likely to be contained within the ESS enclosure. A clean agent suppression system is provided inside the enclosure, however UL9540A testing was conducted without this suppression system and a thermal runaway event will likely be contained to one module. If thermal runaway and cell venting occurs, the enclosure's exhaust ventilation system is expected to activate if LFL concentration above 10% is detected.

Three (3) fire hydrants are provided within the site for fire department use and exterior fire protection. In addition, each enclosure is equipped with smoke, heat, and combustible gas detectors to trigger a fire alarm in the event of fire or thermal runaway. The features are discussed in the Hazard Mitigation Analysis (HMA) for the project.

6.2 Smoke, Heat, and Gas Detection

Each SYL SU3794U3794KC ESS enclosure will contain smoke detectors, heat detectors, and combustible gas detectors. If respective detection criteria are reached within the enclosure, these detectors will send either level 1 (single smoke/heat detector) or level 2 (multiple smoke/heat detectors) or Gas Concentration (gas detector) alarm signals to the enclosure's internal fire alarm panel. These signals will activate the alarm bell, horn/strobe, or exhaust ventilation of the ESS enclosure and individual alarm signals will also be sent to the site FCC and relayed via a cellular communicator to a central station and then to the responding fire department. For additional information on the fire alarm system, reference the fire alarm drawings, HMA, & ERP.

6.3 Explosion Protection

The explosion control system within the SYL SU3794U3794KC ESS enclosures employs an automatic approach that integrates gas detection devices, ventilation system, and operational safeguards:

- Gas Detection: Each enclosure houses two gas detectors specifically designed to detect flammable gases (e.g., H2, hydrocarbons) typically released during lithium-ion battery thermal runaway. The detectors are calibrated to activate at a threshold of 10% LFL.
- Exhaust Ventilation (NFPA 69): Upon gas detection, one exhaust fan (697 cfm) activates to remove flammable gases from the enclosure.
- Operational Controls: Detection triggers several actions: alarms are sent, charging/discharging processes halt, off-gassing valves open, and exhaust ventilation activates.

6.4 Fire Alarm System/Fire Command Center

A networked site fire alarm panel and a Fire Command Center (FCC) is provided at the site entrance and connected to each remote fire alarm panel located throughout the site. The fire alarm panels monitor fire alarm devices within the ESS enclosures and interface with the FCC. These systems provide current information on active alarms and system telemetry to the responding fire department without approaching the battery enclosure.

The fire alarm system is monitored through a cellular connection and transmits supervisory, trouble and alarm signals to a constantly attended central station contracted by the project owner.

6.5 Battery Management System

A Battery Management System (BMS) is provided for each SYL SU3794U3794KC enclosure. The total BMS system is comprised of three (3) components known as the Module Battery Management Unit (BMU), Battery Cluster Unit (BCU), and Battery Array Unit (BAU). Each BMU monitors one (1) module, which supplies enclosure level information to the BCU, and finally that information is processed within the BAU. Together, these components act as the BMS which monitors state of charge (SOC), temperature, and voltage to identify modules and cells that are not operating within acceptable ranges. The BMS can disconnect module clusters by switching the DC contactor from the BCU to cease charging/discharging. The BMS communicates with the Energy Management System (EMS) which may shut down the affected SYL SU3794U3794KC if needed and alert the Network Operator and SCADA monitors. The actions of the BMS system are not functionally tested in UL 9540A testing.

6.6 Signage

Approved signage shall indicate the type of lithium batteries in the enclosure, identify that the enclosure contains energized battery systems, and that the enclosure contains energized electrical circuits in accordance with CFC Section 1207.4.8.

7 POTENTIALLY HAZARDOUS EMISSIONS

7.1 Characterization of Potential Hazards

The UL 9540A cell level test report identifies thirteen (13) hazardous substances captured during the thermal runaway that may have an impact on nearby receptors described earlier. The hazardous substances include carbon monoxide, carbon dioxide, hydrogen, methane, ethylene, ethane, propene, propane, butane, butene, pentane, isopentane and cyclopentane.

The following describes the potential air toxics, and potential effects from acute inhalation exposure: Acute Exposure Guideline Levels (AEGLs), Emergency Response Planning Guidelines (ERPGs), Temporary Emergency Exposure Limits (TEELs), Immediately Dangerous to Life and Health (IDLH), and Protective Action Criteria for Chemicals (PACs). Descriptions of health effects are summarized from the National Institute of Health PubChem database. ERPGs are developed by the Emergency Response Planning committee of the American Industrial Hygiene Association (AIHA).

AEGLs are developed by the National Academy of Sciences. TEELs are derived by the U.S. Department of Energy Subcommittee on Consequence Assessment and Protective Actions (SCAPA) according to a specific, standard methodology. IDLH limits are derived by the National Institute of Occupational Safety and Health (NIOSH). The public exposure guideline systems use a three-tier system to differentiate severity levels except for IDLH which has one level per substance. The tier levels for each system are described below as published by the EPA:

The AEGL values are defined as:

- AEGL-1 is the airborne concentration (expressed as parts per million [ppm] or milligrams per cubic meter [mg/m^3]) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- AEGL-3 is the airborne concentration, (expressed as ppm or mg/m^3), of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

The ERPG values are defined as follows:

- ERPG-1 is the maximum airborne concentration below which nearly all individuals could be exposed to for up to one hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.
- ERPG-2 is the maximum airborne concentration below which nearly all individuals could be exposed to for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

- ERPG-3 is the maximum airborne concentration below which nearly all individuals could be exposed to for up to one hour without experiencing or developing life-threatening health effects.

The TEEL values are defined as:

- TEEL-1 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, when exposed for more than one hour, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure.
- TEEL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, when exposed for more than one hour, could experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape.
- TEEL -3 is the airborne concentration (expressed as ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, when exposed for more than one hour, could experience life-threatening adverse health effects or death.

The PACs dataset is a hierarchy-based system composed of the public exposure guideline systems. The PACs dataset prioritizes AEGLs (final or interim), followed by ERPGs, and lastly TEELs when determining values for levels of concern. The distance of toxic endpoints uses the PAC-2 values per EPA guidance to evaluate potential risk to nearby receptors or first responders.

The IDLH level is defined as:

- The airborne concentration (expressed as ppm or mg/m^3) from which a worker could escape without injury or irreversible health effects from an exposure in the event of the failure of respiratory protection equipment. The IDLH considered a maximum concentration above which only a highly reliable breathing apparatus providing maximum worker protection should be permitted.

The table below summarizes the individual values for each gas species measured in the UL 9540A cell level test.

Table 7.1 – Summary of Hazardous Thresholds

			EPA[1] (1 hour)			Cameo Chemicals[2] (NOAA)			U.S. Dept. of Energy[3]				NIOSH[4]
Gas Species	**Formula**	**CAS #**	**AEGL-1**	**AEGL-2**	**AEGL-3**	**ERPG**	**ERPG**	**ERPG**	**PAC-1**	**PAC-2**	**PAC-3**	**LFL %**	**IDLH**
Carbon Monoxide	CO_2	630-08-0	-	**83**	**330**	200	350	500	75	83	330	12.5	**1,200**
Carbon Dioxide	CO_2	124-38-9	-	-	-	-	-	-	30,000	40,000	50,000	-	40,000
Hydrogen	H_2	1333-74-0	-	-	-	-	-	-	65,000	230,000	400,000	**4**	-
Methane	CH_4	74-82-8	-	-	-	-	-	-	65,000	230,000	400,000	**5**	-
Ethylene (Ethene)	C_2H_4	74-85-1	-	-	-	-	-	-	600	6,600	40,000	**2.7**	-
Acetylene	C_2H_2	74-86-2	-	-	-	-	-	-	65,000	230,000	400,000	**2.5**	-
Ethane	C_2H_6	74-84-0	-	-	-	-	-	-	65,000	230,000	400,000	**3**	-
Propane	C_3H_8	74-98-6	5,500	17,000	33,000	-	-	-	5,500	17,000	33,000	**2.3**	2,100
Propylene (Propene)	C_3H_6	115-07-1	-	-	-	-	-	-	1,500	2,800	17,000	**2**	-
Isobutane	C_4H_{10}	75-28-5	-	-	-	-	-	-	5,500	17,000	53,000	**1.8**	-
Butane	C_4H_{10}	106-97-8	5,500	17,000	33,000	-	-	-	5,500	17,000	53,000	**1.9**	1,600
Isobutylene	C_4H_8	115-11-7	-	-	-	-	-	-	750	2,500	11,000	**1.8**	-
1-Butene	C_4H_8	106-98-9	-	-	-	-	-	-	750	2,900	17,000	**1.6**	-
trans-2-Butene	C_4H_8	624-64-6	-	-	-	-	-	-	750	2,400	14,000	**1.8**	-
cis-2-Butene	C_4H_8	590-18-1	-	-	-	-	-	-	750	2,200	13,000	**1.7**	-
Pentane	C_5H_{12}	109-66-0	-	-	-	-	-	-	3,000	33,000	200,000	**1.5**	1,500

1 https://www.epa.gov/aegl/access-acute-exposure-guideline-levels-aegls-values
2 https://cameochemicals.noaa.gov/search/simple
3 https://emhub1.energy.gov/pacteel
4 https://www.cdc.gov/niosh/idlh/intridl4.html

Gas Species	Formula	CAS #	AEGL-1	AEGL-2	AEGL-3	ERPG	ERPG	ERPG	PAC-1	PAC-2	PAC-3	LFL %	IDLH
trans-2-Pentene	C_5H_{10}	646-04-8	-	-	-	-	-	-	-	-	-	-	-
cis-2-Pentene	C_5H_{10}	627-20-3	-	-	-	-	-	-	-	-	-	-	-
1,4-Pentadiene	C_5H_8	591-93-5	-	-	-	-	-	-	-	-	-	-	-
Hexane	C_6H_{14}	110-54-3	-	2,900	8,600	-	-	-	400	2,900	8,600	**1.1**	1,100
1-Hexene	C_6H_{12}	592-41-6	-	-	-	-	500	5,000	150	500	5,000	**1.2**	-
Benzene	C_6H_6	71-43-2	52	800	4,000	50	150	1,000	52	800	4,000	**1.4**	500
1-Heptene	C_7H_{14}	592-76-7	-	-	-	-	-	-	130	1,400	8,700	**1**	-
Toluene	C_7H_8	108-88-3	67	560	3,700	50	300	1,000	67	560	3,700	**1.4**	500
Styrene	C_8H_8	100-42-5	20	130	1,100	50	250	1,000	20	130	1,100	**0.9**	700
Dimethyl Carbonate	$C_3H_60_3$	616-38-6	-	-	-	-	-	-	11	120	710	-	-
Ethyl Methyl Carbonate	$C_4H_8O_3$	623-53-0	-	-	-	-	-	-	-	-	-	-	-
Mixture Total	-	-	-	-	-	-	-	-	-	-	-	**7.45**	-

8 ESTIMATED THERMAL RUNAWAY EMISSIONS

A UL 9540A cell-level test was conducted by a cell being forced into thermal runaway by inducing heat via a film heater. The UL 9540A cell-level test captured the total volume of gas, in liters (L), vented during the thermal runaway event over a collection time which was analyzed to be approximately 15 minutes. The assumed release duration for a single cell was based on the UL 9540A cell-level test report by averaging the difference between cell venting time and thermal runaway time based upon the values within Attachment C of the UL 9540A cell-level test. This vent time is considered more conservative than the gas emission duration time within the NFPA 69 Analysis Report, which is 1128 seconds (18.8 minutes).

Although this estimation is based on the initiating time of thermal runaway and may not include its total duration, a shorter emissions duration of 15 minutes in the PHAST™ model is a more conservative approach than a longer duration. The gases recorded during the cell-level UL 9540A test are used in this report. These gases were collected in a fixed-volume vessel and include all pre-flaming gases released from a battery cell. The vented gases measured in the cell-level test do not indicate volume, only concentration in percentage.

During the UL 9540A module-level test, thermal runaway was initiated in 2 cells and propagated to 1 additional cell within the module, resulting in a total of 3 cells in thermal runaway. This result was repeated in the UL 9540A unit-level test which involved thermal runaway in 2 initiating cells and propagation to 1 additional cell, resulting again in a total of 3 cells in thermal runaway.

Based on the UL 9540A module and unit level tests, the off-gas plume resulting from the thermal runaway of 3 cells may be described as a “credible event”. A safety factor of 2 would then be applied, resulting in a plume analysis “credible event” based upon 6 cells in thermal runaway.

Emissions from all 6 cells were modeled simultaneously rather than sequentially, which gives a more conservative result.

Table 8: Emission Release Rate	
Hazardous Gas Component	UL 9540A Gas Analysis (%)
Carbon Monoxide	13.453
Carbon Dioxide	27.205
Hydrogen	41.313
Methane	7.403
Ethene (Ethylene)	4.408
Ethane	1.235
Propene (Propylene)	1.297
Propane	0.734
Butene	1.085
Butane	0.193
Pentane	0.335
Hexane	0.147
Heptane	0.997
Toluene	0.013
Styrene	0.013
Total Cell Off-gas Volume	**211.7 L**
Credible Event Vent Volume	**1,270.2 L**
Credible Event Vent Mass	**1.272 kg**
Credible Event Mass Flow Rate*	**0.0848 kg/min**

*Note: * The emission rate was calculated for 6 cells with a conservative venting time of 15 minutes as described in Section 8.*

L = liters; min = minutes; kg = kilograms.

9 OFFSITE CONSEQUENCE ANALYSIS

An offsite consequence analysis was performed using emission rate estimates as described in Section 8 and the PHAST™ model as described in the sections below.

9.1 Methodology

The EPA's "Risk Management Program Guidance for Offsite Consequence Analysis" recommends conducting an offsite consequence analysis to represent release scenarios that are possible (although unlikely) to occur under a variety of weather and wind conditions to determine the distance to a toxic or flammable endpoint. Modeling assumptions and meteorological conditions that were used for conducting this offsite consequence analysis are described below. The offsite consequences analysis was conducted based on the following assumed conditions:

- Specific conditions –
  - Wind speed of 3.4 miles per hour (mph), 3.9 mph, 5.8 mph, 7.8 mph, and 19.9 mph were modeled based upon nearby ASHRAE weather station data.
  - Atmospheric stability class F (Stable – night with moderate clouds and light/moderate wind) and class B (Unstable – as with A/B only less sunny and more windy).
  - Release temperature of 312.8 degrees Fahrenheit (°F) for toxic and flammable gas releases.
  - Relative humidity of 53%, 66%, and 83%.
  - Height of release – 8 feet (approximate center of exhaust vent).
  - Surface roughness – PHAST™ default of "user defined" between "low crops" and "high crops"; as determined based on the density and height of obstructions.
  - No perimeter fence, barrier, or wall.

The first of the 10 weather scenarios within the model was based upon average weather conditions, with subsequent weather models changing one variable at a time. The subsequent 9 weather scenarios evaluated the effects of altering atmospheric stability class, temperature, wind speed, and humidity.

The PHAST™ model was set up to specify three toxic levels of concern, three flammable levels of concern, one heat flux level of concern, and three overpressure levels of concern. Modeling was conducted to identify maximum estimated distances to AEGL-2/PAC-2 at 1 hour, AEGL-3/PAC-3 at 1 hour, IDLH, LFL, 50% LFL, 25% LFL, 2.5 kW/m^2, 4.7 kW/m^2, 5 kW/m^2, 1.45 psi, 3 psi, and 4.35 psi. The gas cloud levels of concern were recorded from an elevation of 20 feet and below. This elevation was chosen as a worst-case gas cloud in the event of any unforeseen down drafts and includes the gases found up to approximately twice the height of the enclosure. This was chosen as the hazards of flammable gases extend beyond exposure to the gases themselves, but the hazard of heat flux and overpressure in the event of ignition of the flammable gases.

Air toxics levels of concern were determined as described in section 7. Flammable levels of concern were based upon the lower flammable limit of the combined gas mixture or an individual gas. The gases analyzed were the collective gas mixture results from the UL 9540A cell-level test, carbon monoxide and hydrogen as these were determined to be the most concerning toxic and flammable gas mixture constituents. The heat flux level was based upon the NFPA 59A Table 19.8.4.2.1 threshold for “irreversible harm to persons outdoors without PPE”. Overpressure levels of concern were based on values from *Guidelines for Quantitative Risk Assessment*, “Purple Book”, 2005 that describe probabilities of fatalities from overpressure exposure indoors and outdoors to a vapor cloud explosion.

Table 9.1: Pressure Effects for a Vapor Cloud Explosion

Explosion Overpressure PSI (BARG)	Probability of Death	
	Indoor	Outdoor
> 4.35 (0.3)	100%	100%
> 3 (0.2)	-	50%
> 1.45 (0.1)	2.5%	0%

The offsite consequence analysis was conducted according to EPA’s “Risk Management Program Guidance for Offsite Consequence Analysis”. Plume analysis and exposure impacts were conducted using DNV®’s PHAST™ hazards modeling program. Based on the information from a chemical release, PHAST™ estimates how quickly the chemicals will escape from containment forming a hazardous gas cloud, and how that release rate may change over time. PHAST™ can then model how that hazardous gas cloud will travel downwind, including both neutrally buoyant and heavy gas dispersion.

Additionally, if the chemical release is flammable, PHAST™ can simulate multiple scenarios including pool fires, boiling liquid expanding vapor explosions, vapor cloud explosions, jet fires, and flammable gas clouds (where flash fires might occur). PHAST™ evaluates different types of hazards (depending on the release scenario) including toxicity, flammability, thermal radiation, and overpressure. PHAST™ produces a threat zone estimate, which shows the area where a particular hazard (such as toxicity, flammability, or thermal radiation) is predicted to exceed a specified level of concern at some time after the release begins. PHAST™ is able to determine a threat zone under different weather and wind scenarios.

10 OFFSITE CONSEQUENCE ANALYSIS

The release scenario was modeled using ASHRAE weather data from the Vacaville Nut Tree weather station located approximately 2 miles away from the Vaca Dixon Energy Storage site. The weather data represents average temperature and wind speed over an 18-year period from 2001-2019.

A toxic release from 6 battery cells was the basis for the model runs with the potential for release of Carbon Monoxide, Carbon Dioxide, Hydrogen, Methane, Acetylene, Ethane, Ethene (Ethylene), Propane, Propene (Propylene), Butane, Pentane, Hexane, Heptene, Dimethyl carbonate, and Ethyl methyl carbonate. Note that Heptene, Dimethyl carbonate, and Ethyl methyl carbonate are not material options within PHAST™. Together, these gases comprise 0.128% of the UL 9540A cell-level test gas composition and were substituted within PHAST™ for Heptane. Heptane's chemical formula is C_7H_{16}, compared to Heptene's C_7H_{14}. Heptane has a molecular mass of 100.21 grams/mol and is more similar to Heptene, Dimethyl carbonate, and Ethyl methyl carbonate compared to the other UL 9540A constituent gas species on a mass basis. Therefore, Heptane was chosen to replace the missing 0.128% gas volume that was comprised of Heptene, Dimethyl carbonate, and Ethyl methyl carbonate on the UL 9540A cell-level test. Graphical diagrams and data generated in PHAST™ are shown in the sections below.

All measurements along the X-axis in the following graphs start at 0, the modeled gas release point.

10.1 Hydrogen

The modeled percentage LFL due to the emission of hydrogen during thermal runaway is shown in the diagrams and figures below. The categories are displayed in PPM based on the following colors in the legend:

- All contours show 25% LFL (10,000 ppm)

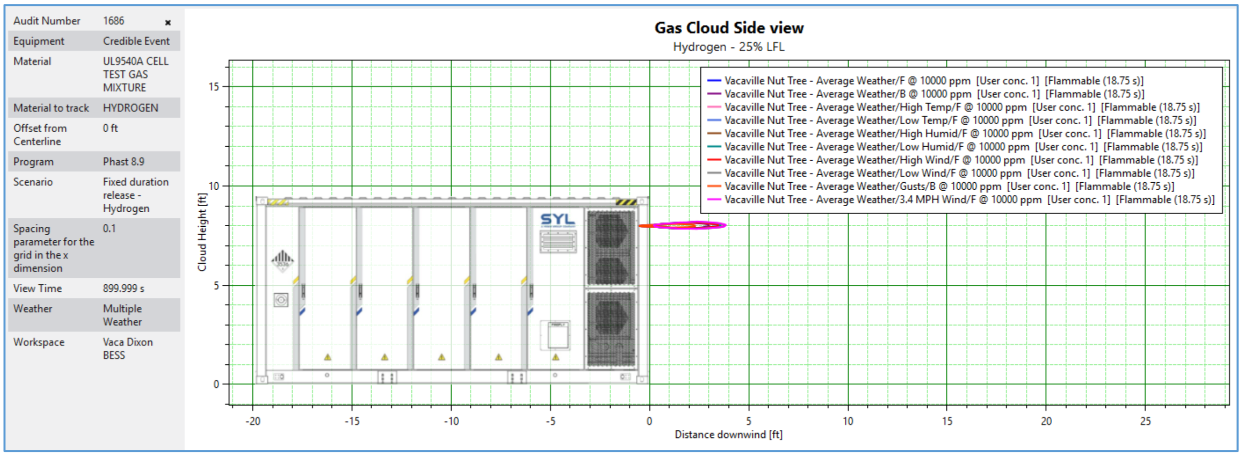


Figure 10.1(a) - Hydrogen - Gas Cloud Side View – LFL by percent at 15 minutes

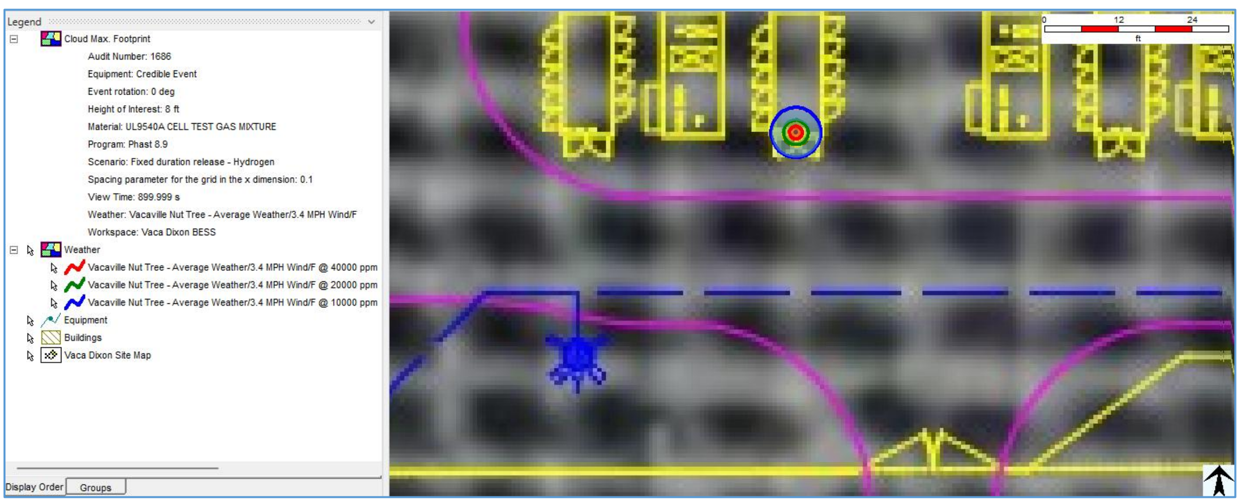


Figure 10.1(b) - Hydrogen - Gas Cloud Cross Section at 8-foot Elevation (Maximum cloud diameter below 20-feet) - LFL Concentration in PPM

10.2 Carbon Monoxide

The modeled carbon monoxide emissions due to emissions during thermal runaway is shown in the diagrams and figures below. The categories are displayed in PPM based on the following colors in the legend:

- All contours show AEGL-2 (1 hour) / PAC-2 levels of 83 ppm

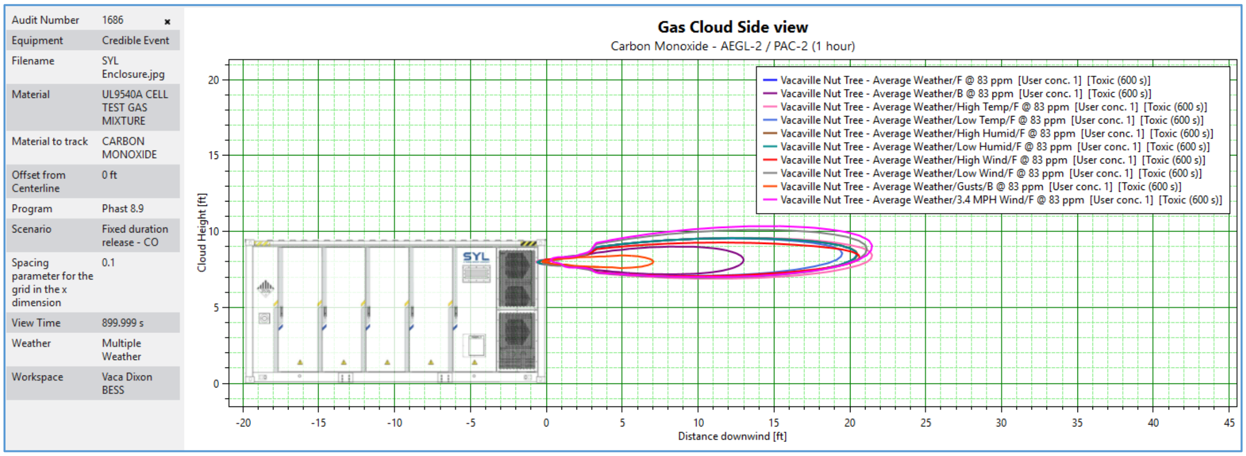


Figure 10.2(a) - Carbon Monoxide - Gas Cloud Side View – Concentration by PPM

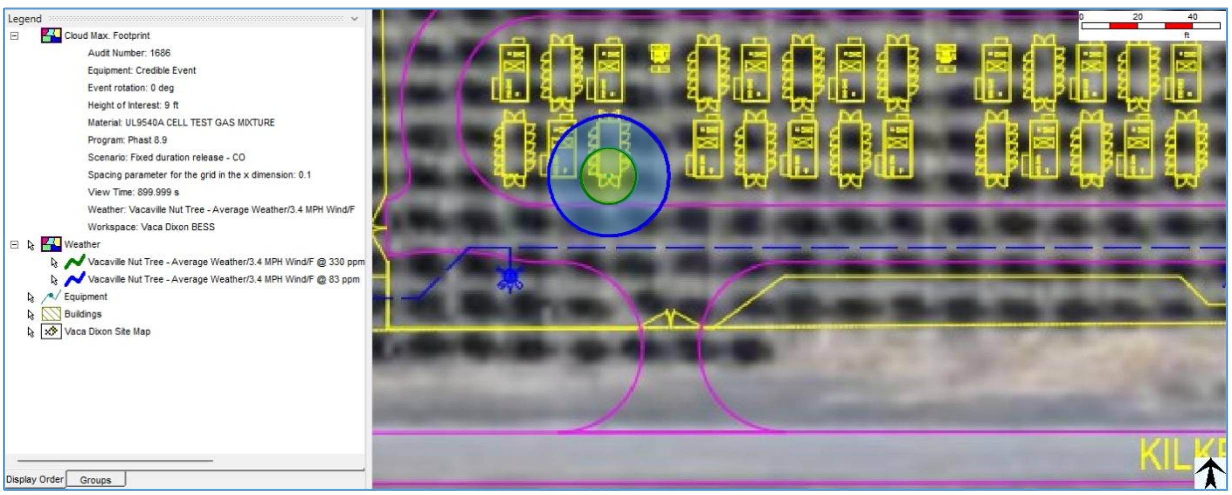


Figure 10.2(b) – Carbon Monoxide - Gas Cloud Cross Section at 10-foot Elevation - Concentration in PPM

10.3 Hydrocarbons

The modeled hydrocarbons based in the UL 9540A testing due to emissions during thermal runaway is shown in the diagrams and figures below. The categories are displayed in PPM based on the following colors in the legend:

- All contours show 25% LFL (16,362.5 ppm)

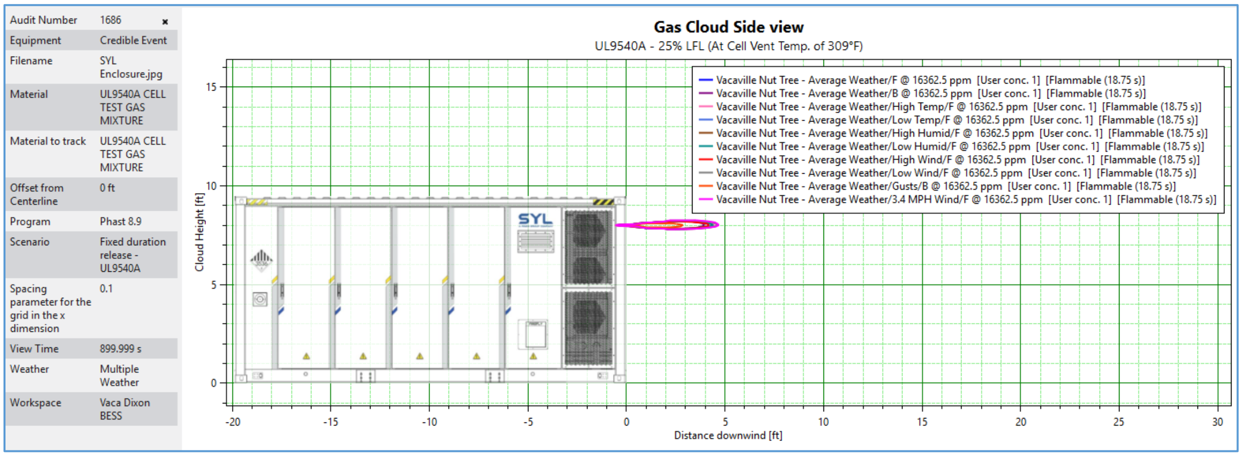


Figure 10.3(a) – UL 9540A Cell-level Hydrocarbon - Gas Cloud Side View Concentration by PPM

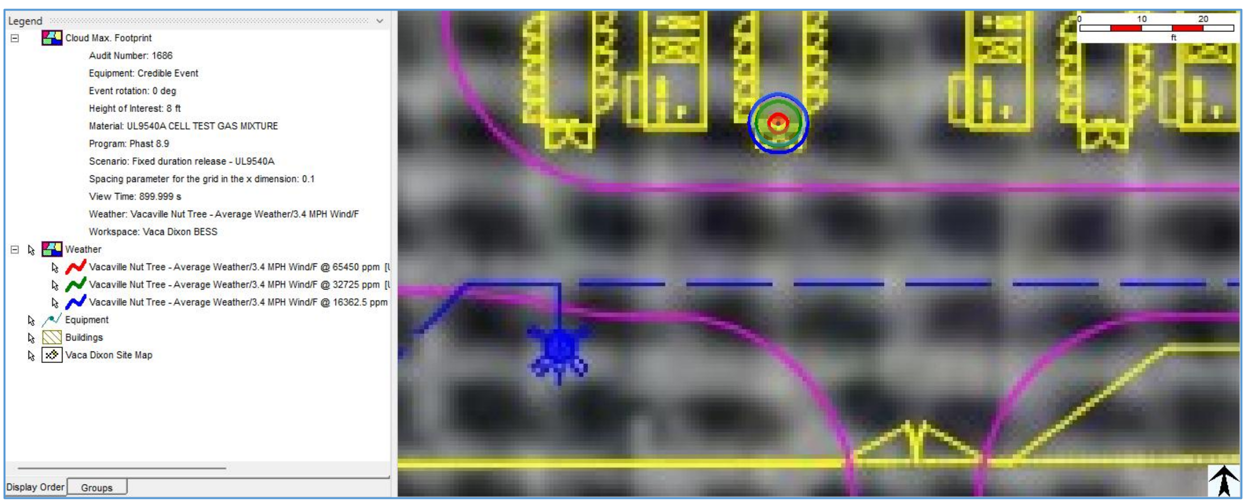


Figure 10.3(b) – UL 9540A Cell-level test Hydrocarbons - Gas Cloud Cross Section at 8-foot Elevation (Maximum cloud diameter below 20-feet) - Concentration in PPM

10.4 Radiation and Heat Flux

The modeled heat flux is based on the UL 9540A cell level testing emissions during thermal runaway and is shown in the diagrams and figures below.

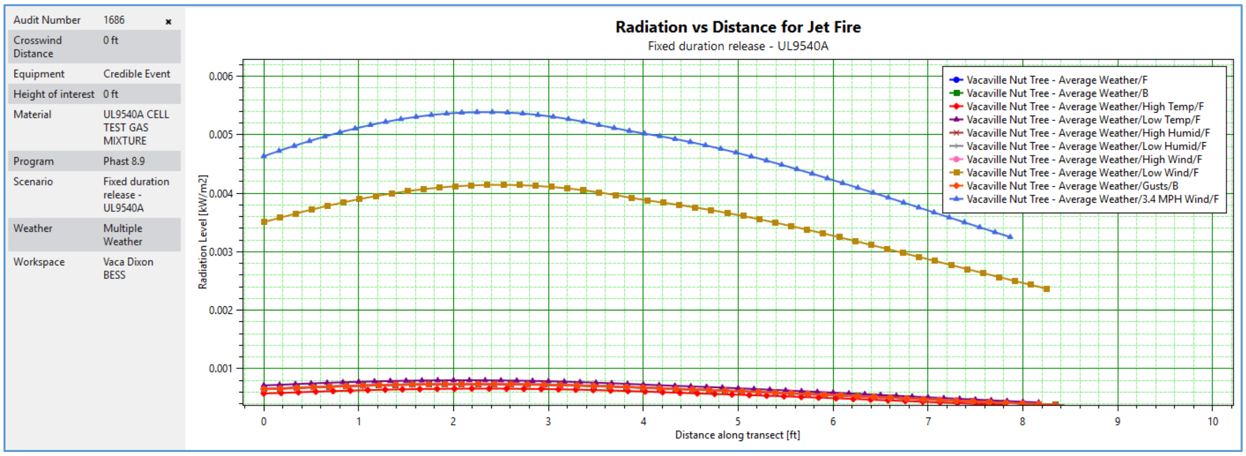


Figure 10.4(a) – UL 9540A Cell-level Test Gas Mixture - Jet Fire Heat Flux by Distance

Note that the model did not produce any contours that reached the 2.5 kW/m^2 threshold.

10.5 Explosion Effects

The modeled pressure effects are based on the UL 9540A cell level testing emissions during thermal runaway (multiplied by 6 for the number of cells in a SYL SU3794U3794KC credible thermal runaway event) and is shown in the diagrams and figures below. The categories are displayed in pounds per square inch (psi) based on the following colors in the legend:

- Blue is 1.45 psi
- Green is 3.00 psi
- Red is 4.35 psi

The model produced an overpressure event when a late ignition point was manually provided away from the gas release point. The late ignition point was input at 1-ft intervals, producing equivalent overpressure events at the 1-ft, 2-ft, and 3-ft ignition points. At 4-ft, the model failed to produce an overpressure event. The 3-ft ignition point is displayed in the following figures as it is the event that occurs furthest from the gas release point.

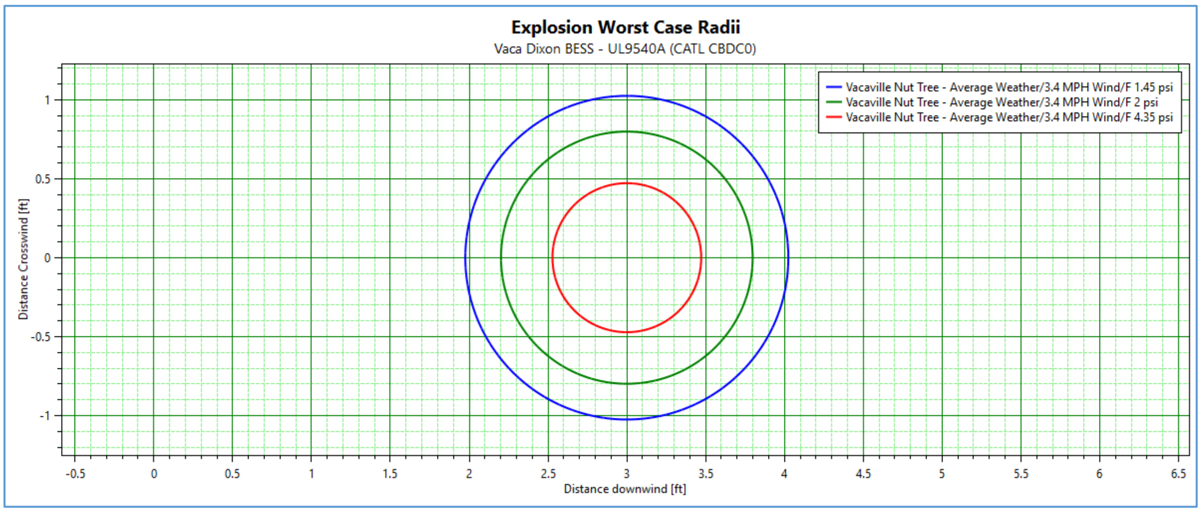


Figure 10.5(a) – UL 9540A Cell-level Test Gas Explosion - Pressure Effects

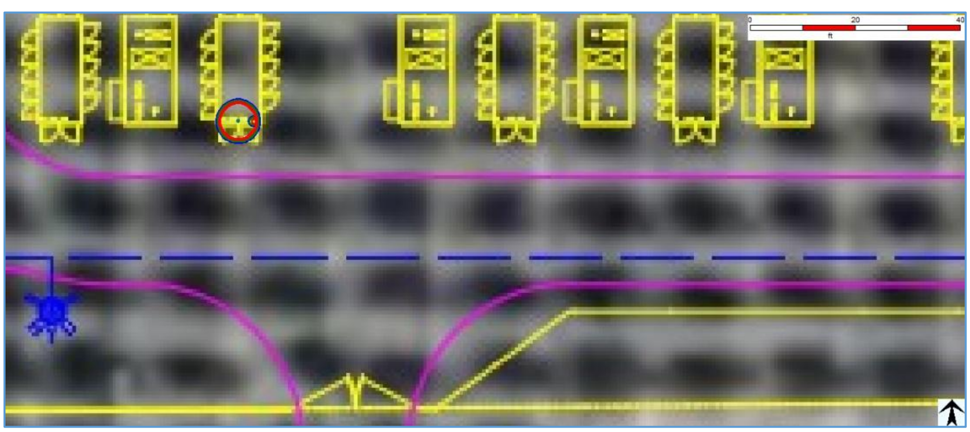


Figure 10.5(b) – UL 9540A Cell-level Test Gas Explosion – Pressure Effects (Large circles show 1.45 psi, 3 psi, 4.35 psi effect zone contours. Small circles show overpressure event 3-ft offset from gas release point)

10.6 PHAST™ Analysis Effects Summary Table

Table 10.6: PHAST™ Analysis Results Table

#	Scenario	Gas Type	Release Type	Endpoint - Extent of Hazard at 20 ft Above Grade (ft)							
				100% LFL	50% LFL	25% LFL	IDLH	AEGL-3	AEGL-2	Heat Flux (2.5 kW/m^2)	Overpressure (1.45 psi)
1	Failure of 6 cells within SYL SU3794U3794KC (15 Minutes)	UL 9540A Cell Test Gas Composition	Flammable	**2 ft**	**4 ft**	**5 ft**	N/A	N/A	N/A	**N/A**	**5 ft**
2		Hydrogen (H_2)	Flammable	**2 ft**	**2 ft**	**4 ft**	N/A	N/A	N/A	N/A	**5 ft**
3		Carbon Monoxide (CO)	Toxic	N/A	N/A	N/A	**7 ft**	**12 ft**	**22 ft**	N/A	N/A

The modeling analysis results are as follows:

- The maximum toxic endpoint distance of Carbon Monoxide's AEGL-2 / PAC-2 value would be 22 feet.
- The maximum distance to the flammable endpoint at 25% LFL would be 5 feet, based on the UL 9540A gas mixture.
- There is no heat flux endpoint distance as a heat flux of 2.5 kW/m^2 is never reached.
- An overpressure event did not develop within the model and a distance to the overpressure endpoint of 1.45 psi was never reached.

The results of the consequence analysis show that the maximum distance of these levels of concern is 22 feet based on Carbon Monoxide. The nearest receptor (ESS enclosure to site fence) is located approximately 35 feet away.

Below is an image with a hazard extent distance of 22 feet overlaid onto the site layout.

Figure 10.6 – Hazards Extent Overlay in blue (North ↑)

11 SUMMARY

Coffman has provided this HCA for the Vaca Dixon Energy Storage site. The report was conducted for the batteries planned to be implemented at the site, as well as the correct number of modules and potential toxins during a credible event. Modeling was accomplished with PHAST™ software, based on the information provided in the UL 9540A test reports, to identify and describe safety measures and fire risk mitigation measures, identify distance from the project site to the nearest sensitive receptors, and identify and characterize the quantities and locations of hazardous chemicals that could be released during a thermal runaway and/or fire event.

12 MAIN STUDY ASSUMPTIONS/REFERENCE MATERIAL

1. UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, December 9, 2019.
2. DNV GL, Considerations for ESS Fire Safety, February 9, 2017, https://www.nyserda.ny.gov/-/media/Project/Nyserda/files/Publications/Research/Energy-Storage/20170118-ConEd-NYSERDA-Battery-Testing-Report.pdf
3. National Fire Protection Association, Hazard Assessment of Lithium Ion Battery Energy Storage Systems, February 26, 2016, https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Hazardous-materials/RFFireHazardAssessmentLithiumIonBattery.ashx
4. Office of Response and Restoration, Public Exposure Guidelines, July 25, 2016, https://response.restoration.noaa.gov/oil-and-chemical-spills/chemical-spills/resources/public-exposure-guidelines.html
5. EPA, Risk Management Guidance for Offsite Consequence Analysis, March 2009, https://www.epa.gov/rmp/rmp-guidance-offsite-consequence-analysis
6. Guidelines for Quantitative Risk Assessment, “Purple Book”, 2005, International Atomic Energy Agency.

APPENDICES

Appendix A

SYL SU3794U3794KC UL 9540A CELL LEVEL TEST RESULT

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

Project Number................................:	**4790838636.1**
Date of issue ....:	**2023.09.07 Amendment No.1: 2023.12.11**
Total number of pages...................:	**51**
UL Report Office ....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name............................:	**Contemporary Amperex Technology Co., Limited**
Address ....:	No 2 Xingang Road Zhangwan Town Jiaocheng District NingdeFujian 352100 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, 7.6.1, 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).

The issuance of this report in no way implies Listing, Classification or Recognition by UL and does not authorize the use of UL Listing, Classification or Recognition Marks or any other reference to UL on the product or system. UL LLC authorizes the above named company to reproduce this Report provided it is reproduced in its entirety. UL's name or marks cannot be used in any packaging, advertising, promotion or marketing relating to the data in this Report, without UL's prior written permission.

UL LLC, its employees, and its agents shall not be responsible to anyone for the use or non-use of the information contained in this Report, and shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use of, or inability to use, the information contained in this Report.

Cell level information	
Model No ....:	CBDC0
Ratings (Vdc, Ah) ....:	3.2V, 285Ah
Chemistry of test item………………:	Lithium Iron Phosphate
Original Equipment Manufacturer (OEM):	Contemporary Amperex Technology Co., Limited
Branding Manufacturer (if not OEM):	N/A
Was the cell certified? ………………………….:	Yes
Standard test item certified to …………..:	UL 1973
Organization that certified test item …….:	MH62898
Average cell surface temperature at gas venting, °C:	156
Average surface temperature at thermal runaway, °C:	232
Gas Volume-:	211.7L
Lower flammability limit (LFL), % volume in air at the ambient temperature	7.45
Lower flammability limit (LFL), % volume in air at the venting temperature	6.545
Burning velocity (S_u) cm/s:	62.44
Maximum pressure (P_{max}) psig:	96.79

Cell Gas composition

Gas		Measured %
Carbon Monoxide	CO	13.453
Carbon Dioxide	CO_2	27.205
Hydrogen	H_2	41.313
Methane	CH_4	7.403
Acetylene	C_2H_2	0.101
Ethylene	C_2H_4	4.408
Ethane	C_2H_6	1.235
Propylene	C_3H_6	1.297
Propane	C_3H_8	0.734
-	C4 (Total)	1.296
-	C5 (Total)	0.335
-	C6 (Total)	0.147
1-Heptene	C7H14	0.025
Styrene	C8H8	0.013
Benzene	C_6H_6	0.049
Toluene	C_7H_8	0.013
Dimethyl Carbonate	$C_3H_6O_3$	0.917
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.055
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

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 module 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)........................ :	Zhang Wei /Vic Zhang	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) .... :	N/A	N/A
Project Handler (name, signature).............. :	Arui Zhou	Arui Zhou
Reviewer (name, signature) …………….:	Benjamin Liu	Benjamin Liu
Amendment 1 Project Handler (name, signature) .... :	Arui Zhou	Arui Zhou
Amendment 1 Reviewer (name, signature) …………….:	Benjamin Liu	Benjamin Liu

Gas Analysis 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
Project Handler (name, signature).............. :	Arui Zhou
Reviewer (name, signature) …………….:	Albert He

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

Attachment A: Cell Conditioning (Charge/discharge) Profiles - (*Pages **18** through **20***)

Attachment B: Cell Instrumentation Photos - (*Pages **21** through **21***)

Attachment C: Cell Temperature Profiles during testing - (*Pages **22** through **24***)

Attachment D: Cell Testing Photos - (*Pages **25** through **34***)

Attachment E: Cell vent gas test chamber photo and profile of chamber gas analysis (O_2 and Pressure) – (*Pages **35** through **35***)

Attachment F: Cell Gas Analysis Report - (*Pages **36** through **36***)

Attachment G-1~G4 for Amendment 1 report

Attachment G-1: Cell Conditioning (Charge/discharge) Profiles - (*Pages **39** through **40***)

Attachment G-2: Cell Instrumentation Photos - (*Pages **41** through **41***)

Attachment G-3: Cell Temperature Profiles during testing - (*Pages **42** through **43***)

Attachment G-4: Cell Testing Photos - (*Pages **44** through **51***)

Photo of cell/Stack:	
	
Figure 0-1	**Figure 0-2**
Test Item Charge/Discharge Specifications:	
• **Charge current, A:**	285
• **Charge Power, W**	912
• **Standard full charge voltage, Vdc:**	3.65
• **Charge temperature range, °C:**	0~60
• **End of charge voltage, V:**	3.65
• **Discharge current, A:**	285
• **Discharge Power, W**	912
• **End of discharge voltage, Vdc:**	2.5
• **Discharge temperature range, °C:**	-20~60

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)
Testing..:	CBDC0
Date of receipt of test item ....:	2023-04-28, 2023-10-10
Date (s) of performance of tests ....:	2023-05-10~2023-05-13, 2023-10-20~2023-10-29

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: Guangdong Ruiqing Contemporary Amperex Technology Limited Factory_1 address: No.1 Shidai Street,High-tech Industrial Development Zone, Zhaoqing City，Guangdong Province Factory_2: Jiangxi Yichun Contemporary Amperex Technology Limited Factory_2 address: No. 1, Chunfeng Road, Yichun Economic and Technological Development Zone, Jiangxi Province Factory_3: Fuding Contemporary Amperex Technology Limited Factory_3 address: No. 1, Shidai Road, Xueqiao Village, Qianqi Town, Fuding City, 355200 Ningde City, Fujian Province, PEOPLE'S REPUBLIC OF CHINA

General product information and other remarks:

The tested cell is a Lithium-ion battery cell, Model CBDC0. Each cell has a capacity of 285 Ah and nominal voltage 3.2 Vdc.

The weight of cell is 5400g±300g.

The test samples were produced in Factory 1.

The test samples are figure 0-1 and figure 0-2.

Amendment 1 report:

The overall dimensions of cell were corrected from 71.6±0.8mm(Width) by 174.7±0.8mm(Length) by 207.3±0.8mm(Height) to the 71.55±0.8mm (depth) by 174.3±0.8 mm(width) by 207.3±0.8 mm(height).

The customer has changed the design of the top cover of the cell, figures 0-1 and 0-2 are the original design of the cell, 0-3 and 0-4 are the new designs.

Attachment G-1~G-4 is the supplementary test after the design change of the cell.

According to customer analysis, the above differences do not affect the test results.

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:	Lithium iron phosphate	—
	Electrolyte Chemistry:	LiPF6 with additives	—
	Flow Battery Electrolyte No. 1 Chemistry:	Not flow battery	—
	Max volume of system electrolyte No. 1, L:	Not flow battery	—
	Flow Battery Electrolyte No. 2 Chemistry:	Not flow battery	—
	Max volume of system electrolyte No. 2, L:	Not flow battery	—
	Separator Melt Temperature, °C:	Not used during test	—
	Format: Cylindrical /Prismatic /Pouch Flow Battery Stack	Prismatic	—
	Overall Dimensions, mm	174.3±0.8mm (depth) by 71.55±0.8mm (width) by 207.3±0.8mm (height)	—
	Cell Weight, g	5400±300g	—
5.1.2	Cell Certification:	Yes	—
	Standard Used for Cell Certification:	UL 1973	—
	Organization that Certified Cell:	MH62898	—
5.1.1, 5.4.1	Cell/Stack Ratings: • Nominal Voltage, Vdc •Nominal Capacity, Ah	3.2 285	— —
5.4.1	Flow Battery: No. of Cells per Stack:	Not flow battery	—
	Flow battery system manufacturer:	Not flow battery	—
	Flow battery system model:	Not flow battery	—
	Flow battery system ratings, Vdc, Ah:	Not flow battery	—
5.4.2	Flow battery system certified to UL 1973:	Not flow battery	—
	Organization that certified flow battery system:	Not flow battery	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		C
7.2	**Samples**		C

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

7.2.1	Samples conditioned through charge discharge cycling a minimum of 2 cycles.	See Attachment A and Attachment G1 for profiles See Table 1 and Table G0-1 for specifications See also Table 2 and Table G0-2	C
7.2.2	100% SOC and stabilize from 1h to 8 h before testing		
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 Attachment C and Attachment G3 See Table 3 and Table G0-3	C
7.3.1.2	Heat the cell to thermal runaway by externally applied flexible film heaters	See Attachment B and Attachment G2	C
	Heater Dimension	Two heaters 152.4mm by 203.2 mm in size for each sample. Each side of the cells was instrumented with the heater	
	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, D, G1, G4 See Table 4 and Table G0-4	C
	Maximum surface end point temperature, °C	Not used, the cells are heated until the thermal runaway achieved According to the Certification Requirement Decision: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery. Holding temperature was not utilized during the test and the cell was continuously heated until thermal runaway occurred	

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

	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	See Attachment E	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.	Not used, the cells are heated until the thermal runaway achieved According to the Certification Requirement Decision: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery. Holding temperature was not utilized during the test and the cell was continuously heated until thermal runaway occurred	N/A
7.3.1.6	The cell was heated until thermal runaway has occurred.	Refer to Attachment C and Attachment G3	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 and Attachment G2	C
7.3.1.8	The temperature at which the cell case vents due to internal pressure rise was documented.	See Table 4 and Table G0-4 See Attachment C, D, G3,G4	C
7.3.1.9	The temperature at the onset of thermal runaway was documented.	See Table 4 and Table G0-4 See Attachment C, D, G3, G4	C
	If cell venting occurs first, the cell was heated continuously until thermal runaway occurs.	See Attachment C and Attachment G3	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 5, G0-3, G0-4 and G0-5 See Attachment C, D, G3, G4	C
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: 100L 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):0.17	C
		Oxygen concentration measured (% volume):0.17	
		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.	Refer to Table 3 Refer to attachment C and F	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 and 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 and 10	C
7.4.5	P_{max} of the synthetically replicated cell vent gas was determined in accordance with EN 15967.	Refer to Table 9 and 10	C
7.6	**Cell Level Test Report Information**		C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
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 with external heater during the test	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

Note: Table G0-1~G0-5 and Attachment G-1~G4 for amendment 1, Table 1~5 and Attachment A~F for original report.

Table 1 – Specified conditioning parameters			
Charging:		Discharging	
Current, A	285	Current, A	285
Power (CP), W	912	Power (CP), W	912
Standard full charge voltage, Vdc	3.65	Voltage at start of discharge, Vdc	3.65
End of charge voltage, Vdc	3.65	End of discharge voltage, Vdc	2.5
Charging Test Ambient, °C	0~60	Discharging Test Ambient, °C	-20~60
Refer to Attachment A for charge/discharge profiles for each cell.			

Note: The charge and discharge cycle of the cell is carried out in accordance with 912W constant power.

Table 2 – Charge completion and cell test initiation times		
Cell Test Number	**Charge Completion Date and Time**	**Cell test Date and Time**
1	2023-05-18 08:43	2023-05-18 11:10
2	2023-05-18 12:14	2023-05-18 19:35
3	2023-05-19 06:04	2023-05-19 10:39
4	2023-05-20 12:00	2023-05-20 16:02
5	2023-05-25 10:38	2023-05-25 18:08

Table 3 - Test Initiation Details					
	Cell Test 1	**Cell Test 2**	**Cell Test 3**	**Cell Test 4**	**Cell Test 5**
Test Date	2023-05-18	2023-05-18	2023-05-19	2023-05-20	2023-05-25
Test Start Time	11:10	19:35	10:39	16:02	18:08
Initial Lab Temperature	25.9°C	25.9°C	24.4°C	25.0°C	24.6°C
Initial Relative Humidity	70.9%RH	70.9%RH	71.5%RH	61.9%RH	56.3%RH

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	3.355	3.349	3.351	3.340	3.340
Average Heating Rate, °C/min	4.5	4.5	4.6	4.5	4.5
Venting Time after the test start (hh:mm:ss)	0:34:44	0:35:14	0:35:00	0:35:46	0:35:54
Venting Temperature, °C	157	156	154	158	163
Thermal Runaway Time after the test start (hh:mm:ss)	0:54:20	0:54:06	0:54:22	0:55:04	0:53:11
Thermal Runaway Temperature, °C	231	227	233	237	229
Refer to Attachment C for surface temperature profiles during testing					

Table 5 – Average Vent and Thermal Runaway Temperatures	
Average of Cell Vent Temperatures, °C	156
Average of Cell Thermal Runaway Temperatures, °C	232
#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	13.453	10.9
Carbon Dioxide	CO_2	27.205	N/A
Hydrogen	H_2	41.313	4.0
Methane	CH_4	7.403	4.4
Acetylene	C_2H_2	0.101	2.3
Ethylene	C_2H_4	4.408	2.4
Ethane	C_2H_6	1.235	2.4
Propylene	C_3H_6	1.297	1.8
Propane	C_3H_8	0.734	1.7
-	C4 (Total)	1.296	N/A
-	C5 (Total)	0.335	N/A
-	C6 (Total)	0.147	N/A
1-Heptene	C7H14	0.025	N/A
Styrene	C8H8	0.013	1.1
Benzene	C_6H_6	0.049	1.2
Toluene	C_7H_8	0.013	1.0
Dimethyl Carbonate	$C_3H_6O_3$	0.917	N/A
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.055	N/A
Total	-	100	-

[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	13.619	10.9
Carbon Dioxide	CO_2	27.541	N/A
Hydrogen	H_2	41.823	4.0
Methane	CH_4	7.494	4.4
Acetylene	C_2H_2	0.102	2.3
Ethylene	C_2H_4	4.463	2.4
Ethane	C_2H_6	1.251	2.4
Propylene	C_3H_6	1.313	1.8
Propane	C_3H_8	0.743	1.7
Propadiene	C_3H_4	0.000	1.9
-	C_4 (Total)	1.312	N/A
-	C_5 (Total)	0.339	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)	7.45
Lower Flammability limit at Vent Temperature, [156°C] (% vol in air)	6.545
Burning Velocity Measurement, S_u cm/sec	62.44
Maximum Pressure P_{max}, psig	96.79

	TABLE: Critical components information				
Object / part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cell Model	Contemporary Amperex Technology Co.,Limited	CBDC0	Nominal voltage：3.2V Rated capacity：285Ah	UL 1973	MH62898
Separator	Contemporary Amperex Technology Co.,Limited	SBM	Material: PE Size: LxWxT;(30542-36690mm) * (176-214mm) * (0.008-0.018mm) Separator melting temperature: 140±5°C	—	—
Electrolyte	Contemporary Amperex Technology Co.,Limited	ESN	Composition: LiPF6, DMC, EMC, EC, PC, DEC;	—	—
Case	Contemporary Amperex Technology Co.,Limited	PPA	Material: Al 3003 Minimum thickness: 0.6-0.7mm	—	—
Insulators/ location in cell	Contemporary Amperex Technology Co.,Limited	PTA PAP	Up-Plate Material: PP Down-Plate Material: PP	—	—
Vent	Contemporary Amperex Technology Co.,Limited	PTA	Size: (25.3-30.3) mm *(13.7-16.7) mm Pressure: 0.4Mpa~1.2Mpa	—	—

Attachment A: Cell Conditioning (Charge/discharge) Profiles - (*Pages **18** through **19***)

Note: The charge and discharge cycle of the cell is carried out in accordance with 912W constant power.

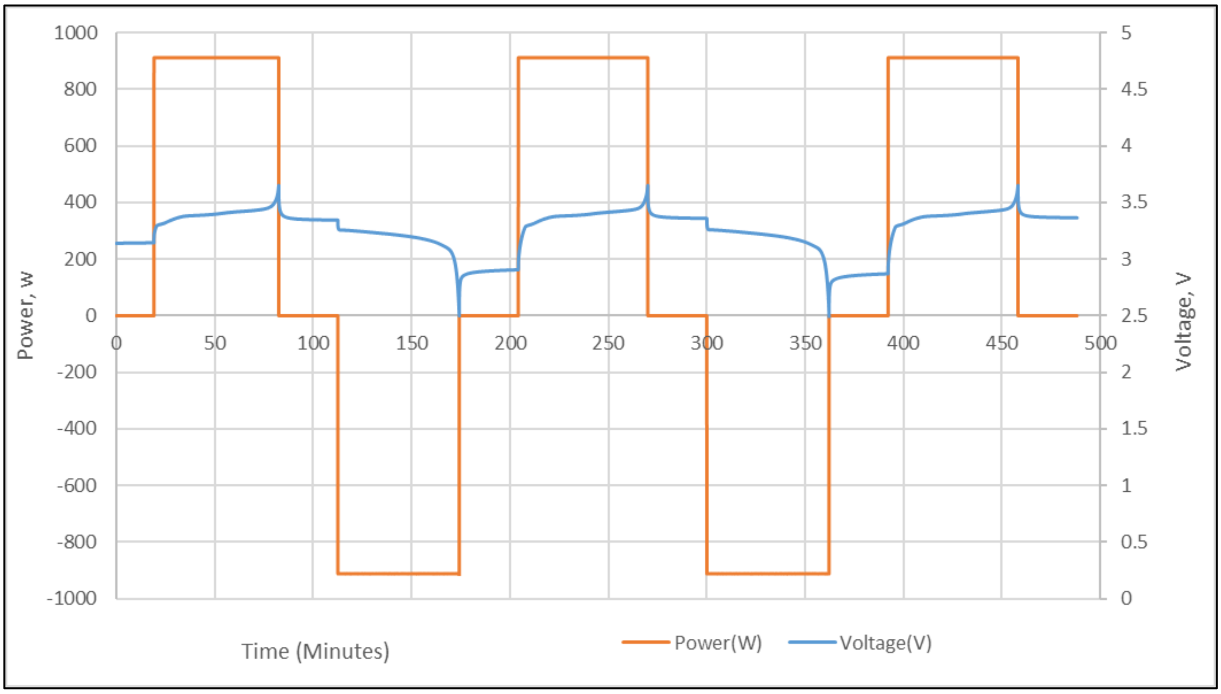


Figure 1: Cell 1 Conditioning (Charge/discharge) Profiles

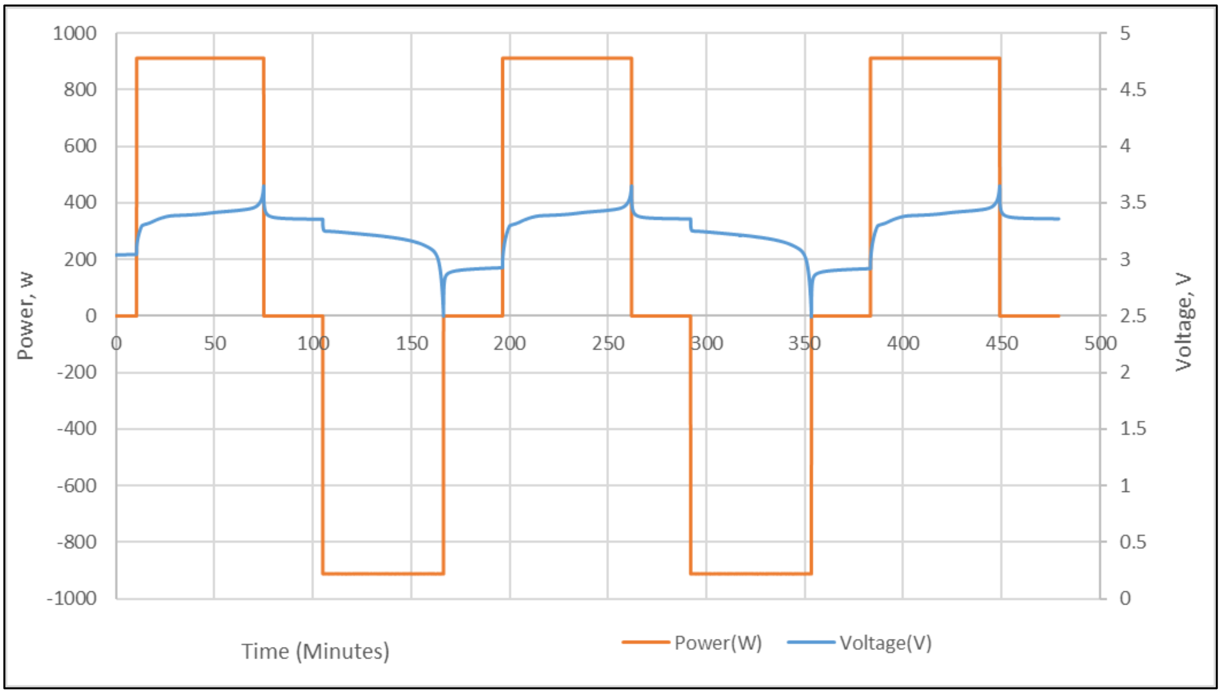


Figure 2: Cell 2 Conditioning (Charge/discharge) Profiles

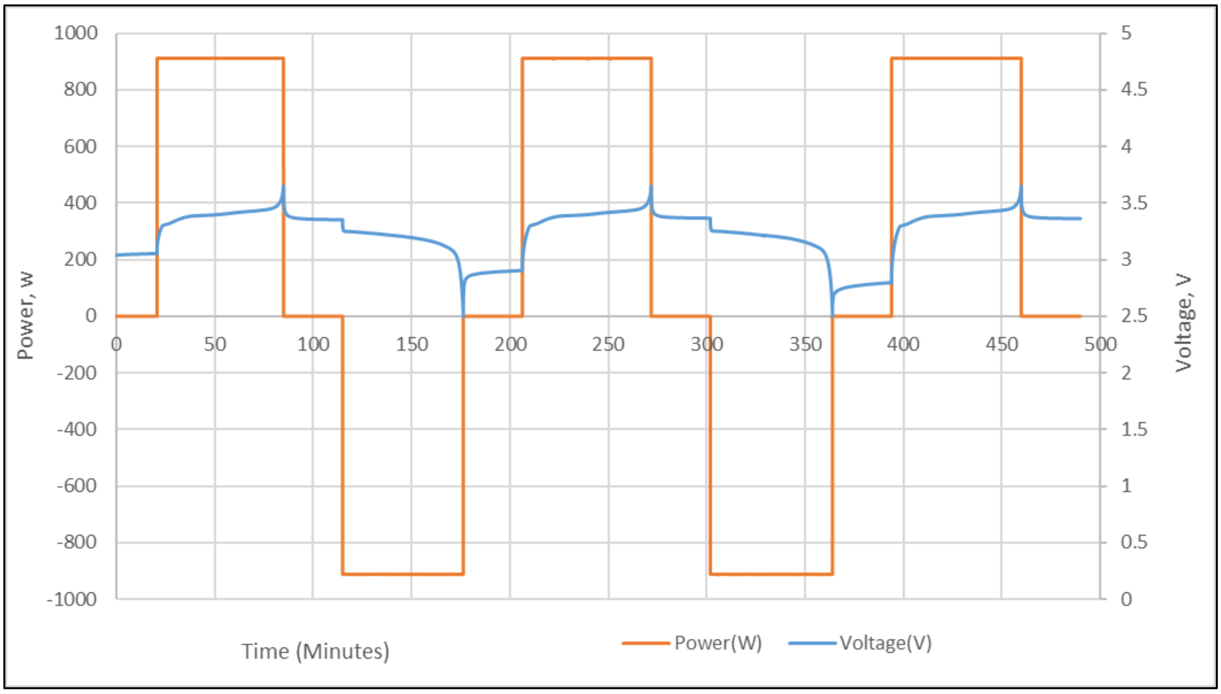


Figure 3: Cell 3 Conditioning (Charge/discharge) Profiles

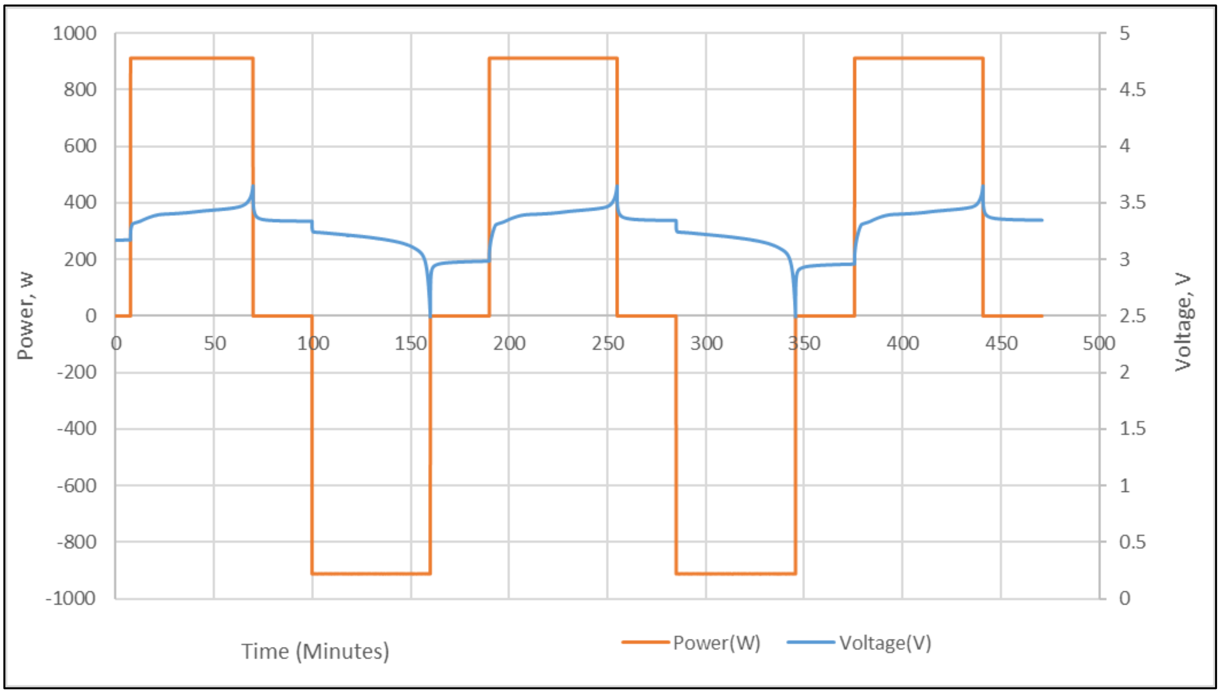


Figure 4: Cell 4 Conditioning (Charge/discharge) Profiles

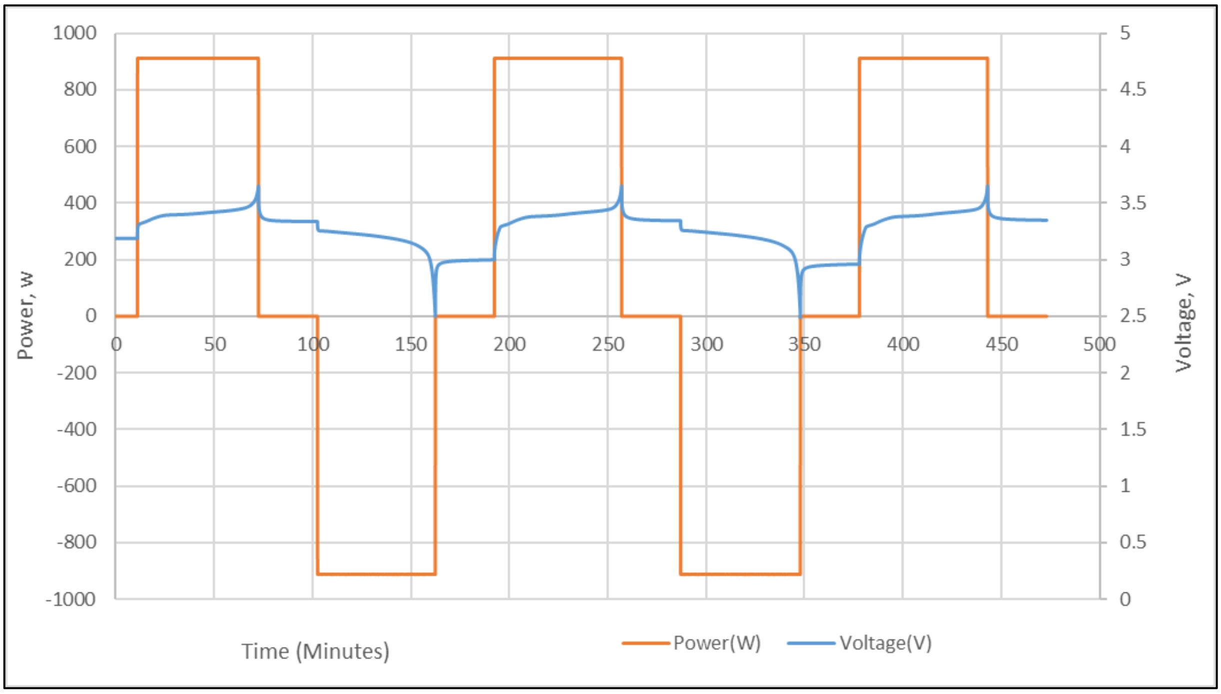


Figure 5: Cell 5 Conditioning (Charge/discharge) Profiles

Attachment B: Cell Instrumentation Photos - (*Pages **21** through **21***)

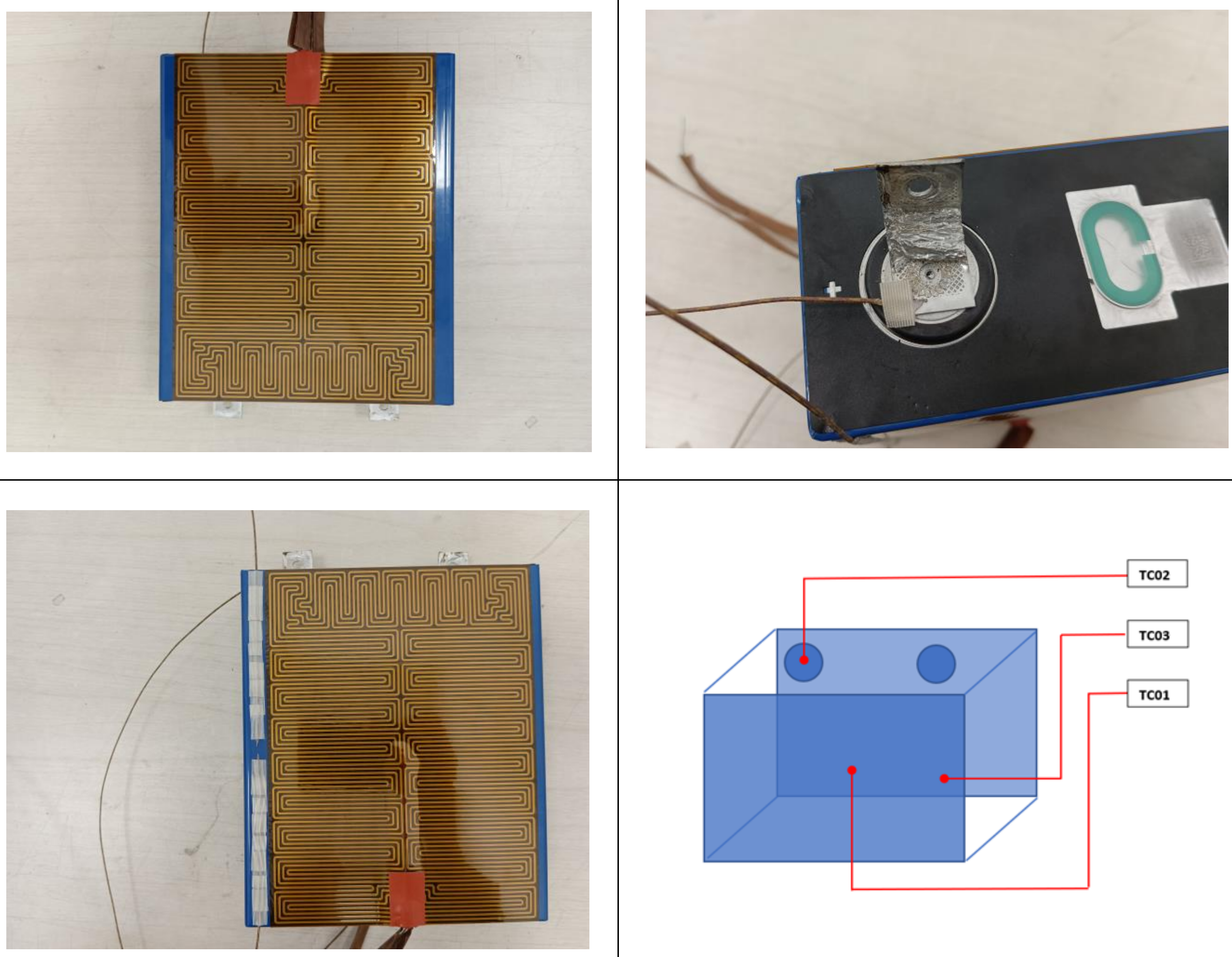


Figure 6: Sample Instrumentation Prior to Test

Note: heaters were placed on two sides of the cell after thermocouples were instrumented.

Note: TC01 between cell body and heater; TC02 on the cell positive; TC03 on the cell body not covered by heater; TC04 Ambient temperature; V1 cell voltage.

Attachment C: Cell Temperature Profiles during testing - (*Pages **22** through **24***)

Note: TC01 between cell body and 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.

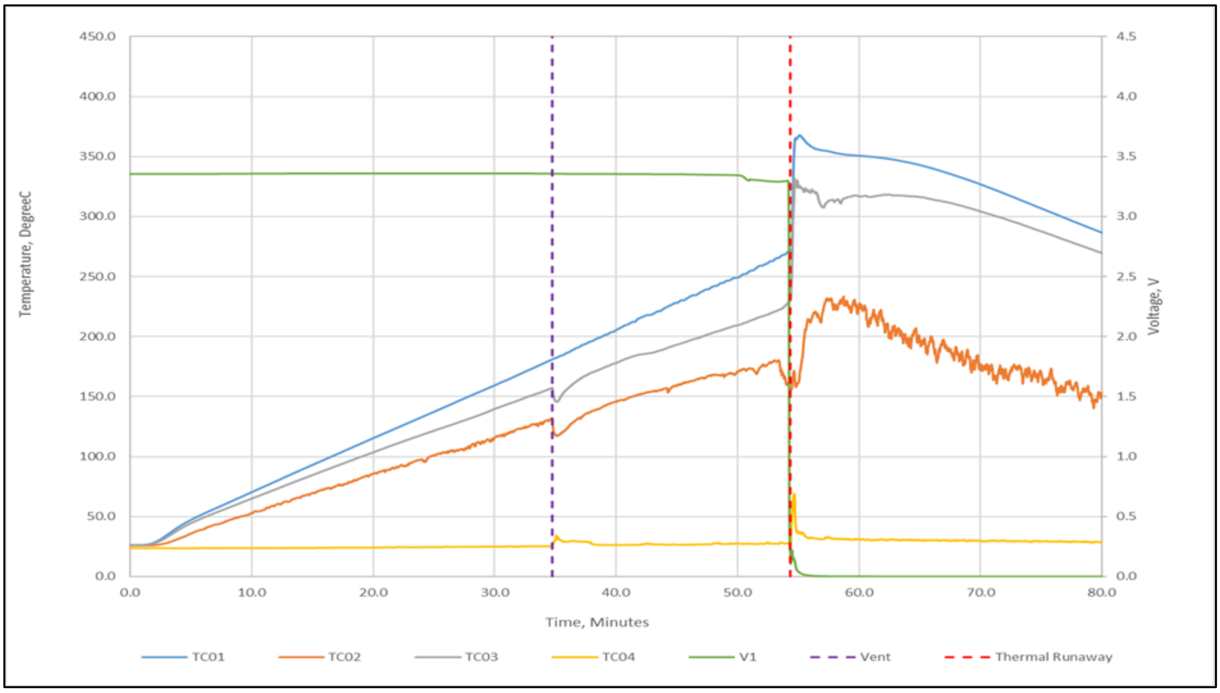


Figure 7: Cell 1 – External Heating 4.5°C per minute

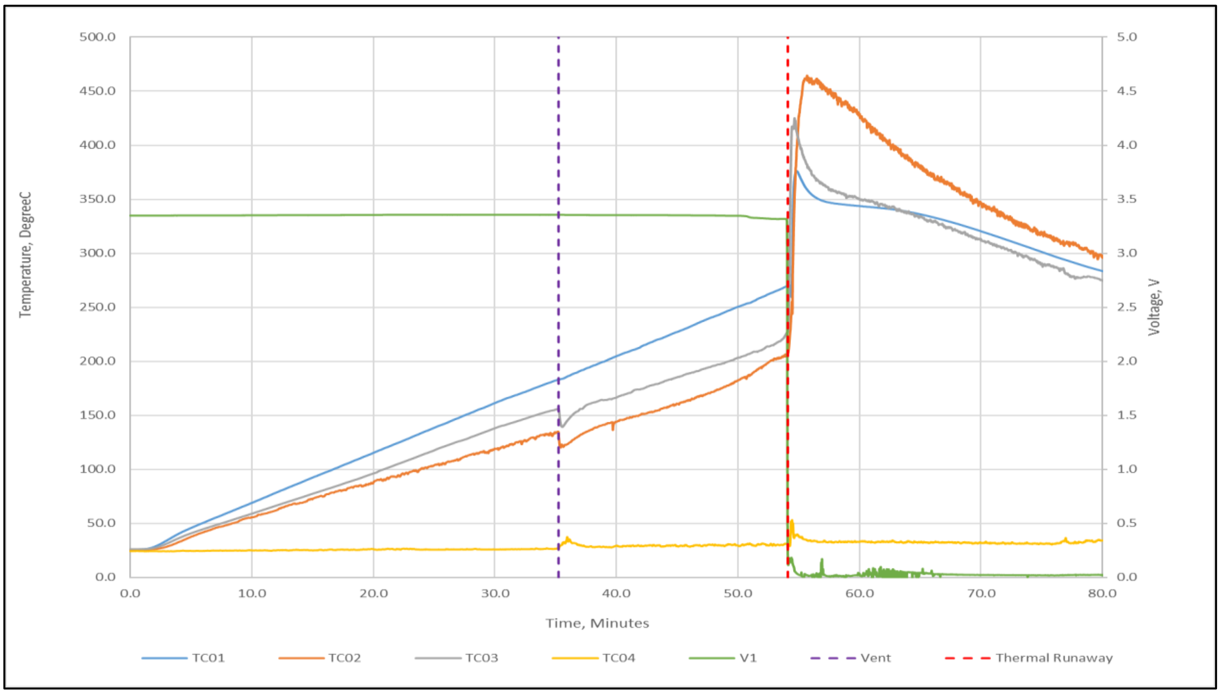


Figure 8: Cell 2 – External Heating 4.5°C per minute

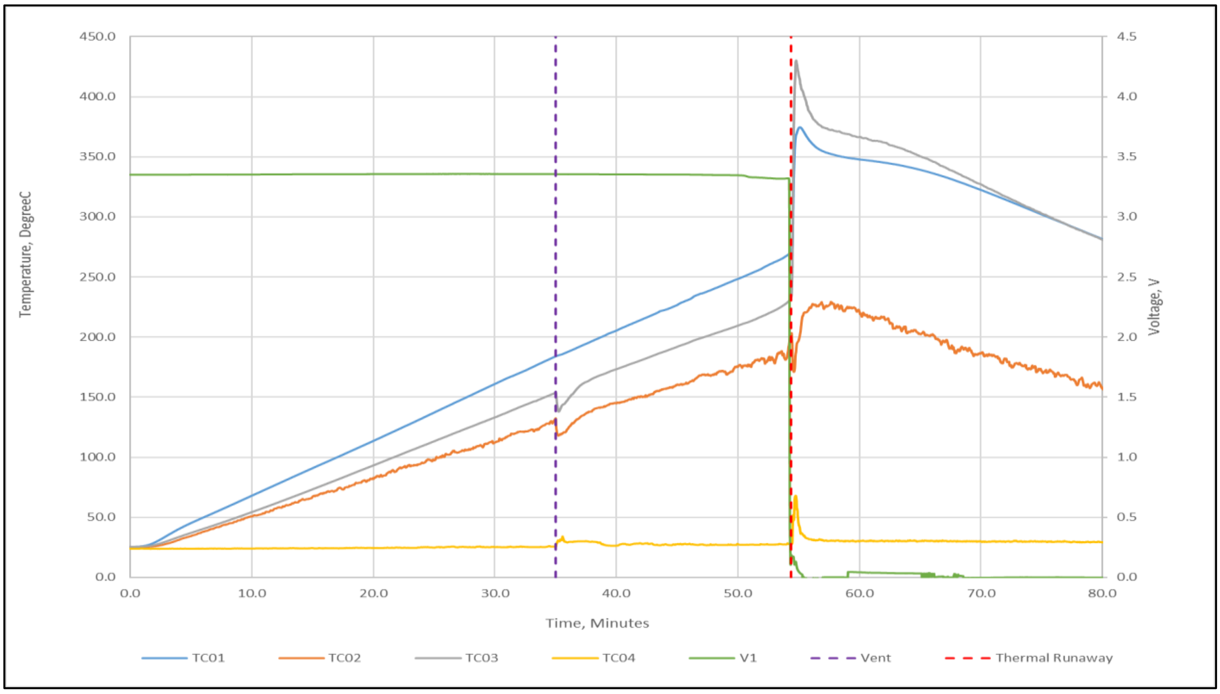


Figure 9: Cell 3 – External Heating 4.5°C per minute

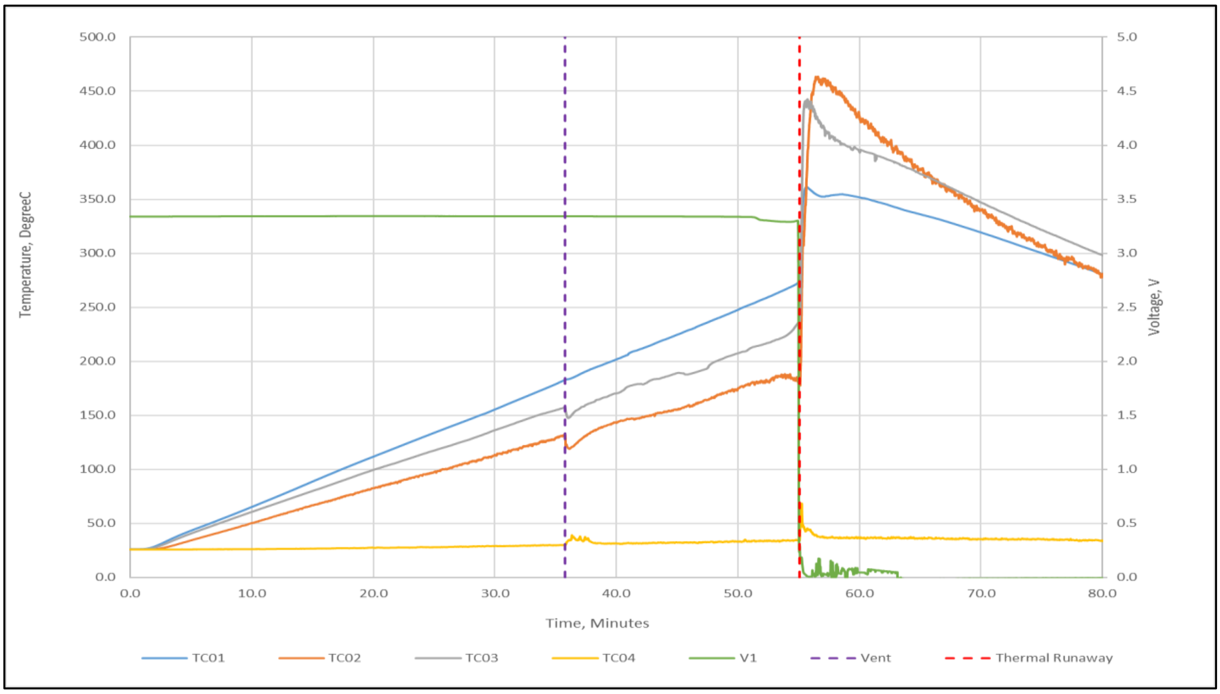


Figure 10: Cell 4 – External Heating 4.5°C per minute

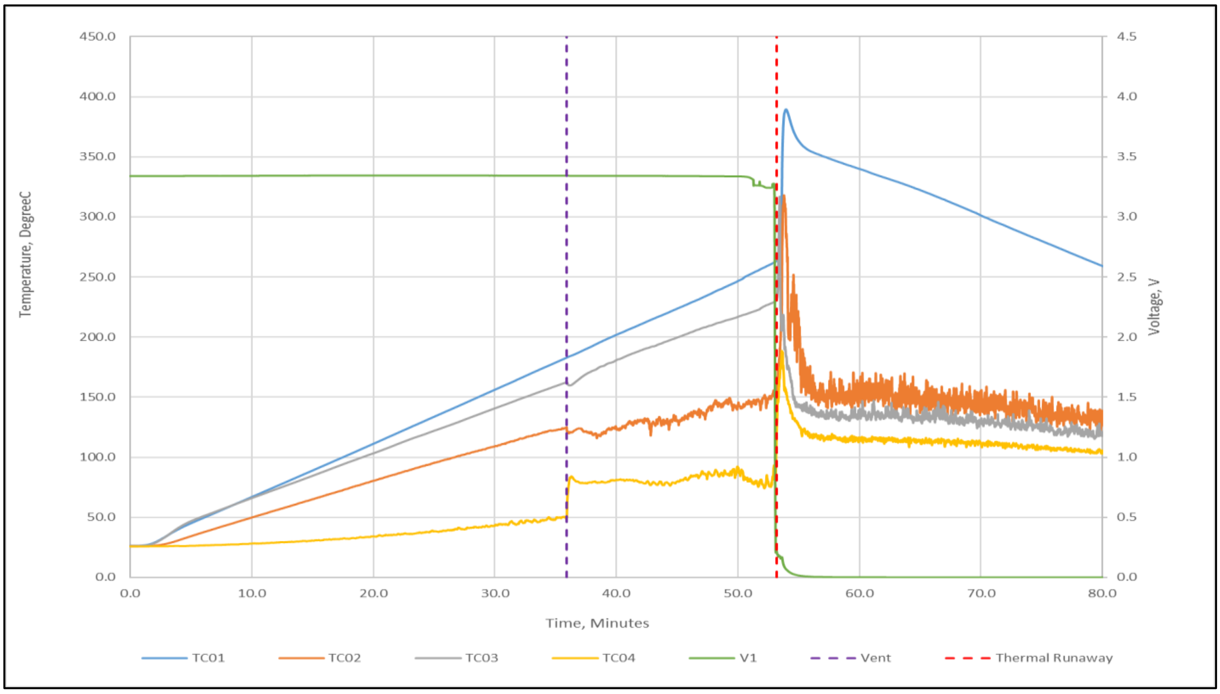


Figure 11: Cell 5 – External Heating 4.5°C per minute

Attachment D: Cell Testing Photos - (*Pages **25** through **34***)

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.

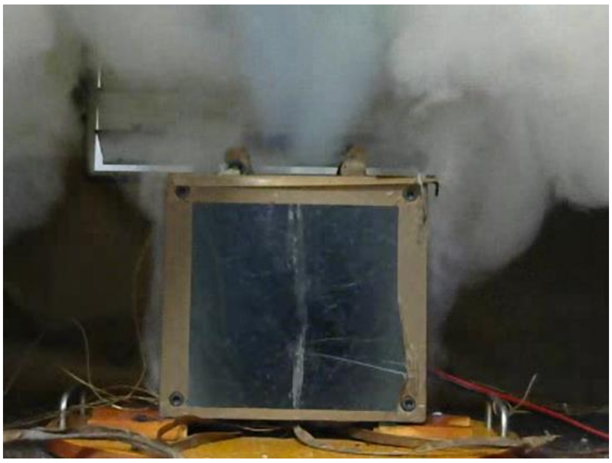
	
(a) Test Start [00:00]	(b) Cell Venting [34:44]
	
(c) Thermal runaway behavior [54:20]	

Figure 12: Highlights of Cell 1 Testing

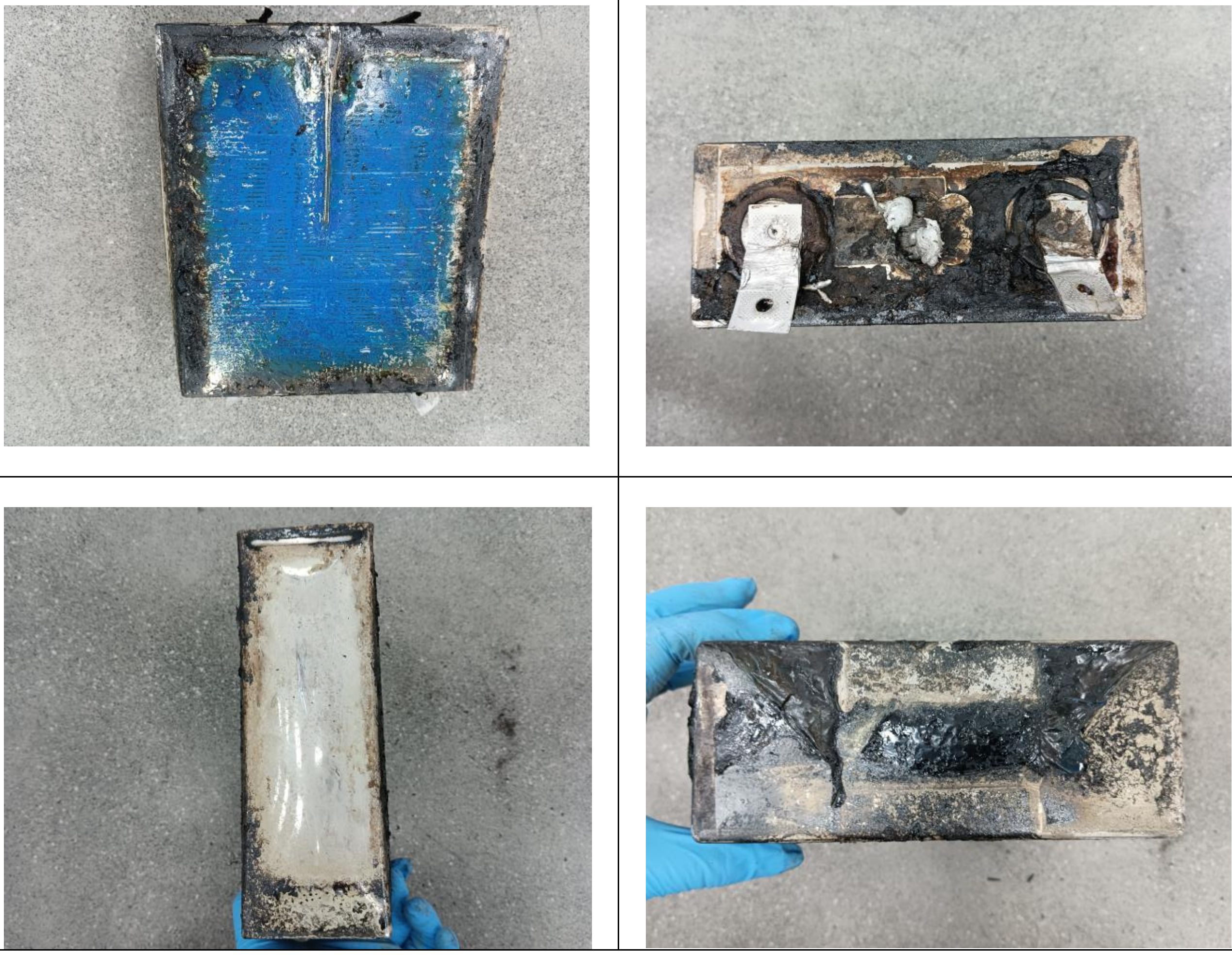


Figure 13: Sample 1 Post Test Photos

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.

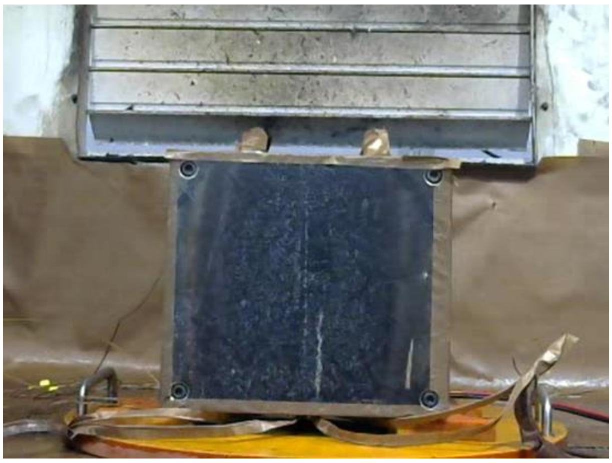
	
(a) Test Start [00:00]	(b) Cell Venting [35:14]
	
(c) Thermal runaway behavior [54:06]	

Figure 14: Highlights of Cell 2 Testing

Figure 15: 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 [35:00]
	
(c) Thermal runaway behavior [54:22]	

Figure 16: Highlights of Cell 3 Testing

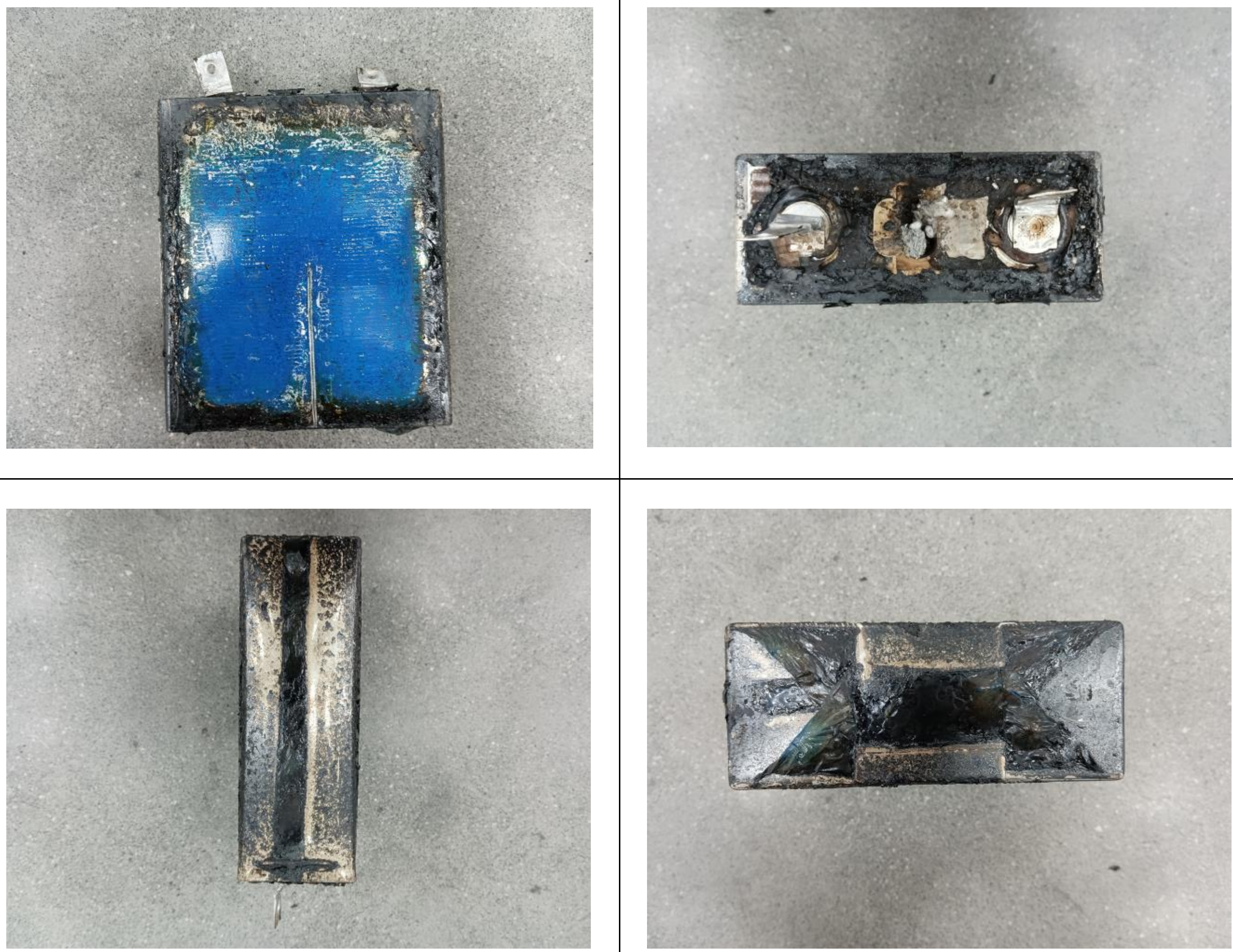


Figure 17: Sample 3 Post Test Photos

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 [35:46]
	
(c) Thermal runaway behavior [55:04]	

Figure 18: Highlights of Cell 4 Testing

Figure 19 Sample 4 Post Test Photos

Cell Sample 5 – 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 [35:54]
	
(c) Thermal runaway behavior [53:11]	
Figure 20: Highlights of Cell 5 Testing	

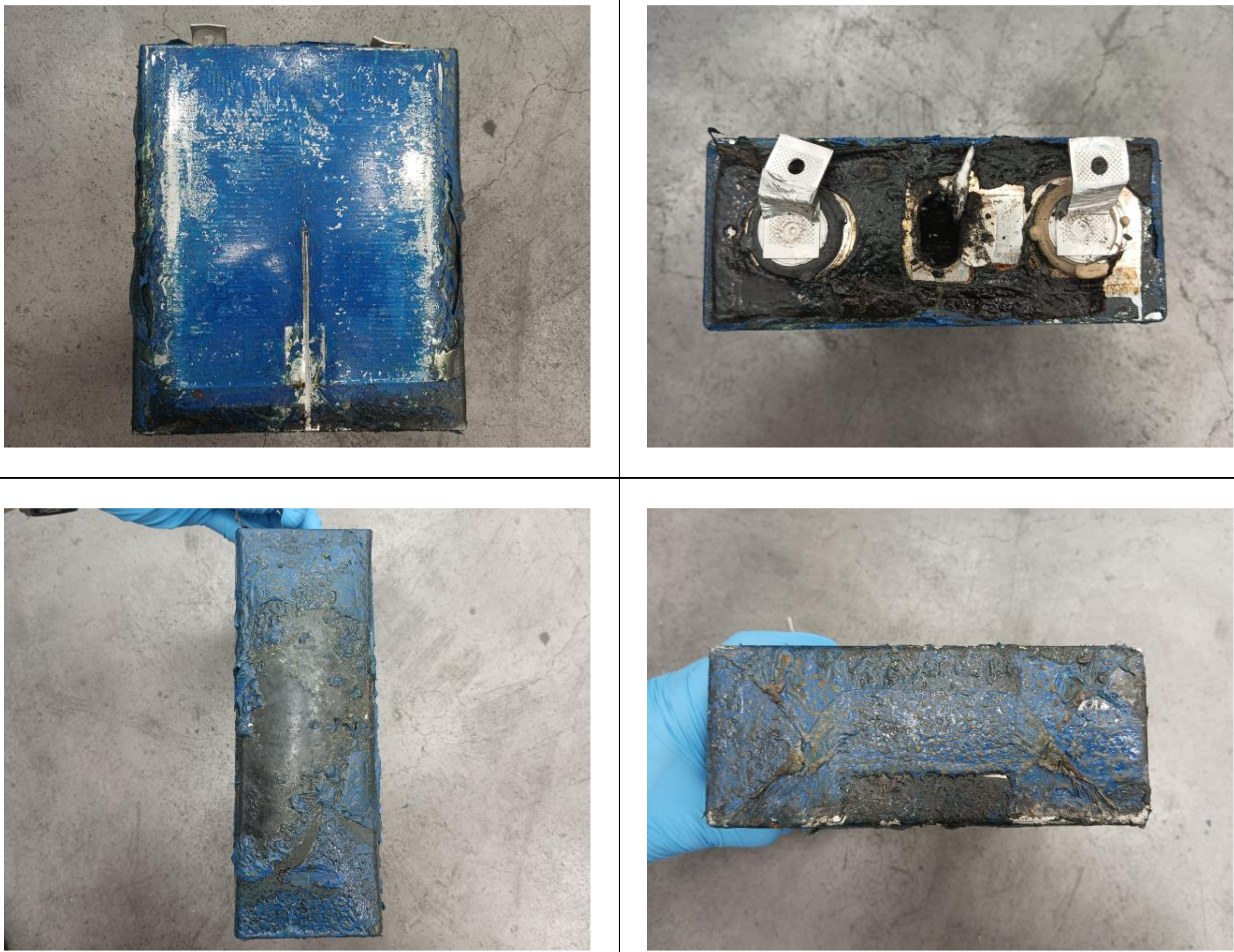


Figure 21: Sample 5 Post Test Photos

Attachment E: Cell vent gas test chamber photo and profile of chamber gas analysis (O2 and Pressure) - (Pages ***35*** through ***35***)

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 0.17%, with initial pressure 0.17psig).

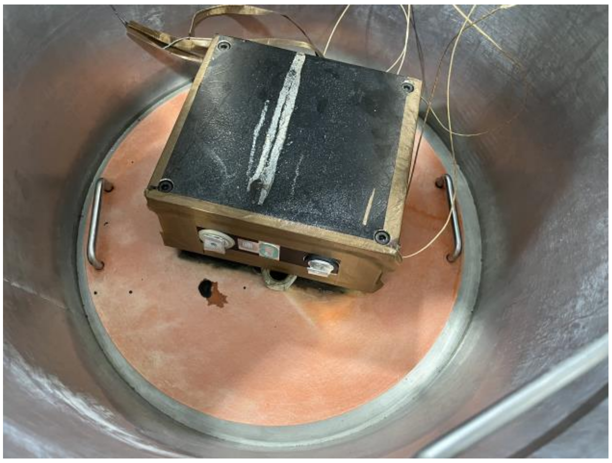


Figure 22: Sample 5 instrumented and inside gas test chamber

$\phi_{O2,\ chamber}$=	0.17	%

Pinitial,chamber=	0.17	psig

Figure 23: Profile of gas test chamber (O2 and Pressure)

Attachment F: Cell Gas Analysis Report - (Pages ***36*** through ***36***)

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

Item	Measure	Chemical formula	Conc.(%)
1	Carbon Monoxide	CO	13.453
2	Carbon Dioxide	CO_2	27.205
3	Hydrogen	H_2	41.313
4	Methane	CH_4	7.403
5	Ethylene	C_2H_4	4.408
6	Acetylene	C_2H_2	0.101
7	Ethane	C_2H_6	1.235
8	Propane	$CH_3CH_2CH_3$	0.734
9	Propylene	C_3H_6	1.297
10	Propadiene (Allene)	C_3H_4	0.000
11	Isobutane	$CH_3CH(CH_3)CH_3$	0.017
12	Butane	C_4H_{10}	0.193
13	Isobutylene	C_4H_8	0.522
14	1-Butene	C_4H_8	0.221
15	trans-2-Butene	C_4H_8	0.143
16	cis-2-Butene	C_4H_8	0.199
17	Pentane	C_5H_{12}	0.198
18	trans-2-Pentene	C_5H_{10}	0.061
19	cis-2-Pentene	C_5H_{10}	0.053
20	1,4-Pentadiene	C_5H_8	0.023
21	Hexane	C_6H_{14}	0.024
22	1-Hexene	C_6H_{12}	0.123
23	Benzene	C_6H_6	0.049
24	1-Heptene	C_7H_{14}	0.025
25	Toluene	C_7H_8	0.013
26	Styrene	C_8H_8	0.013
27	Dimethyl Carbonate	$C_3H_6O_3$	0.917
28	Ethyl Methyl Carbonate	$C_4H_8O_3$	0.055
29	Diethyl Carbonate	$C_5H_{10}O_3$	0.000
	Total	Measurement result	100.000

Amendment 1 report:

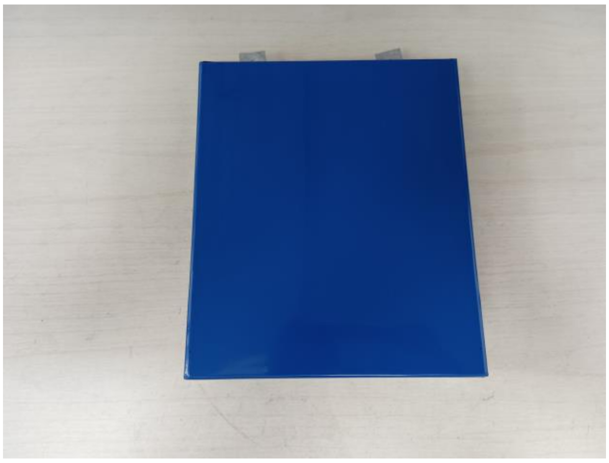
<table>
<tr><td colspan="2">Photo of cell/Stack:</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Figure 0-3</td><td>Figure 0-4</td></tr>
<tr><td>Test Item Charge/Discharge Specifications:</td><td></td></tr>
<tr><td>• Charge Power, W</td><td>912</td></tr>
<tr><td>• Standard full charge voltage, Vdc:</td><td>3.65</td></tr>
<tr><td>• Charge temperature range, °C:</td><td>0~60</td></tr>
<tr><td>• End of charge voltage, V:</td><td>3.65</td></tr>
<tr><td>• Discharge Power, W</td><td>912</td></tr>
<tr><td>• End of discharge voltage, Vdc:</td><td>2.5</td></tr>
<tr><td>• Discharge temperature range, °C:</td><td>-20~60</td></tr>
</table>

Table G0-1 – Specified conditioning parameters			
Charging:		Discharging	
Power (CP), W	912	Power (CP), W	912
Standard full charge voltage, Vdc	3.65	Voltage at start of discharge, Vdc	3.65
End of charge voltage, Vdc	3.65	End of discharge voltage, Vdc	2.5
Charging Test Ambient, °C	0~60	Discharging Test Ambient, °C	-20~60
Refer to Attachment A-1 for charge/discharge profiles for each cell.			

Table G0-2 – Charge completion and cell test initiation times		
Cell Test Number	**Charge Completion Date and Time**	**Cell test Date and Time**
6	2023-10-20 07:49	2023-10-20 10:42
7	2023-10-20 09:49	2023-10-20 14:40
8	2023-10-28 10:23	2023-10-28 15:41
9	2023-10-29 11:30	2023-10-29 15:00

Table G0-3 - Test Initiation Details				
	Cell Test 6	**Cell Test 7**	**Cell Test 8**	**Cell Test 9**
Test Date	2023-10-20	2023-10-20	2023-10-28	2023-10-29
Test Start Time	10:42	14:40	15:41	15:00
Initial Lab Temperature	25.7°C	25.7°C	25.3°C	26.0
Initial Relative Humidity	61.2%RH	61.2%RH	53.4%RH	51.5%RH

Table G0-4 - Thermal Runaway Results				
	Cell Test 6	**Cell Test 7**	**Cell Test 8**	**Cell Test 9**
OCV at start of test, Vdc	3.354	3.338	3.344	3.347
Average Heating Rate, °C/min	4.5	4.5	4.5	4.5
Venting Time after the test start (hh:mm:ss)	0:34:41	0:34:16	0:33:40	0:33:40
Venting Temperature, °C	161	150	156	152
Thermal Runaway Time after the test start (hh:mm:ss)	0:54:48	0:54:51	0:54:22	0:54:53
Thermal Runaway Temperature, °C	240	232	240	237

Table G0-5 – Average Vent and Thermal Runaway Temperatures	
Average of Cell Vent Temperatures, °C	155
Average of Cell Thermal Runaway Temperatures, °C	237
#Averages of cell tests other than the gas analysis test	

Attachment G-1: Cell Conditioning (Charge/discharge) Profiles - (*Pages**39** through **40***)

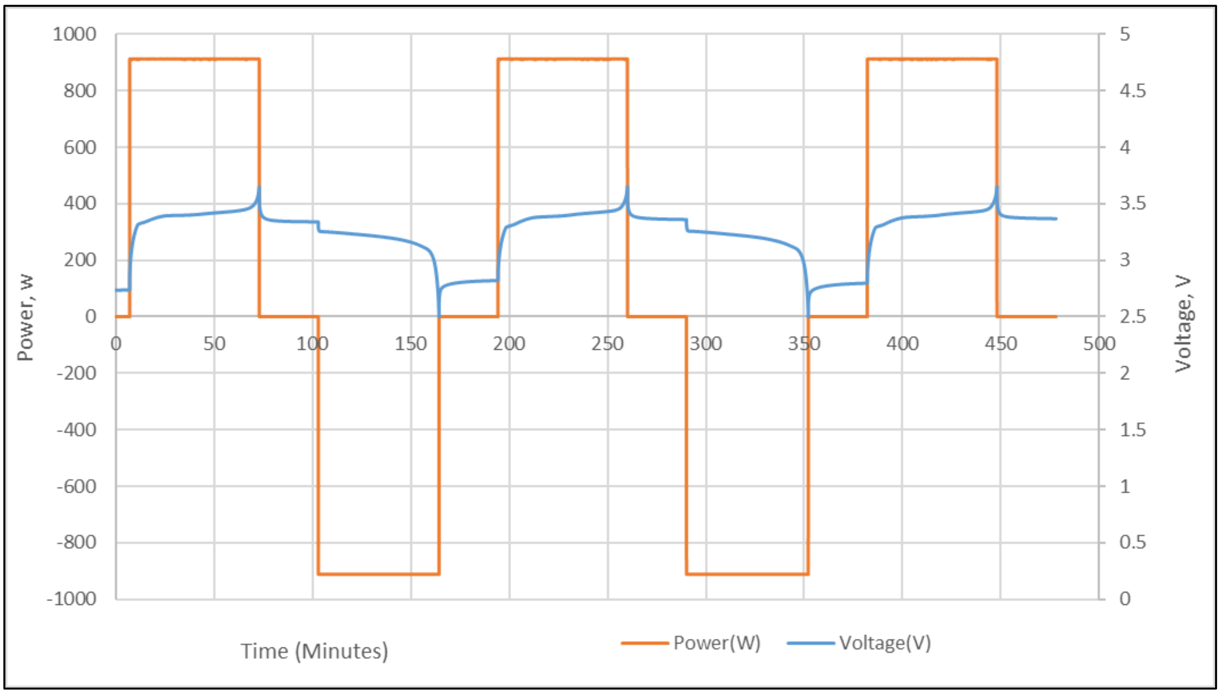


Figure 24: Cell 6 Conditioning (Charge/discharge) Profiles

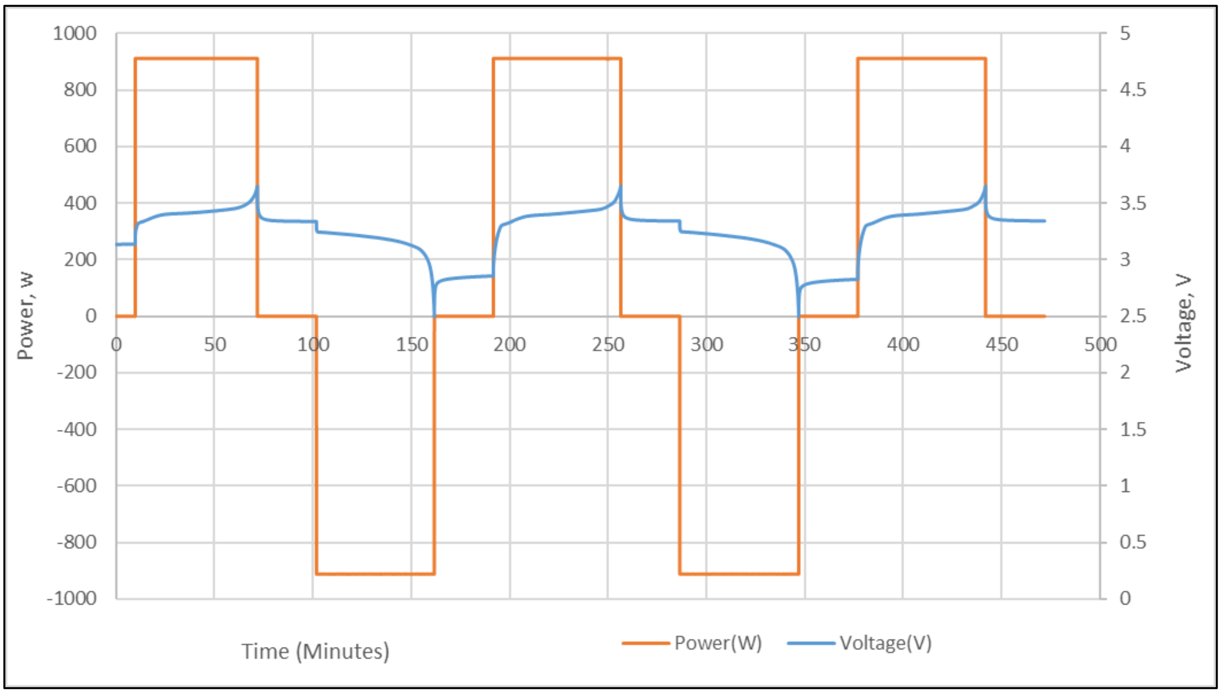


Figure 25: Cell 7 Conditioning (Charge/discharge) Profiles

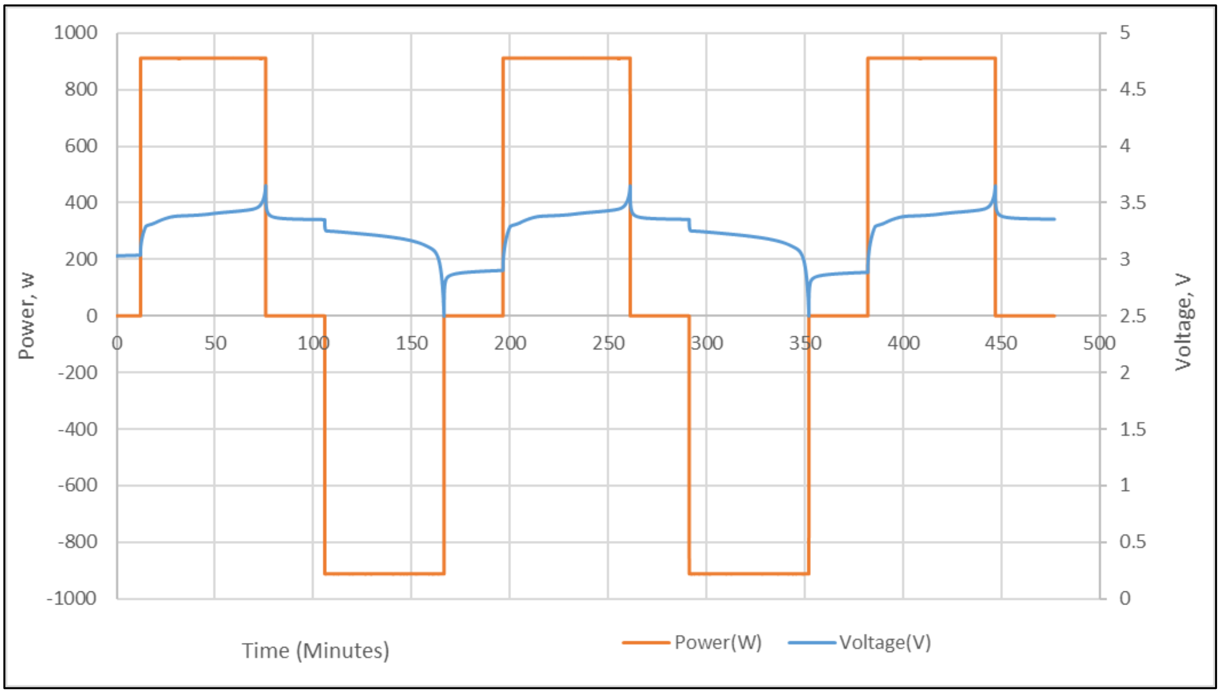


Figure 26: Cell 8 Conditioning (Charge/discharge) Profiles

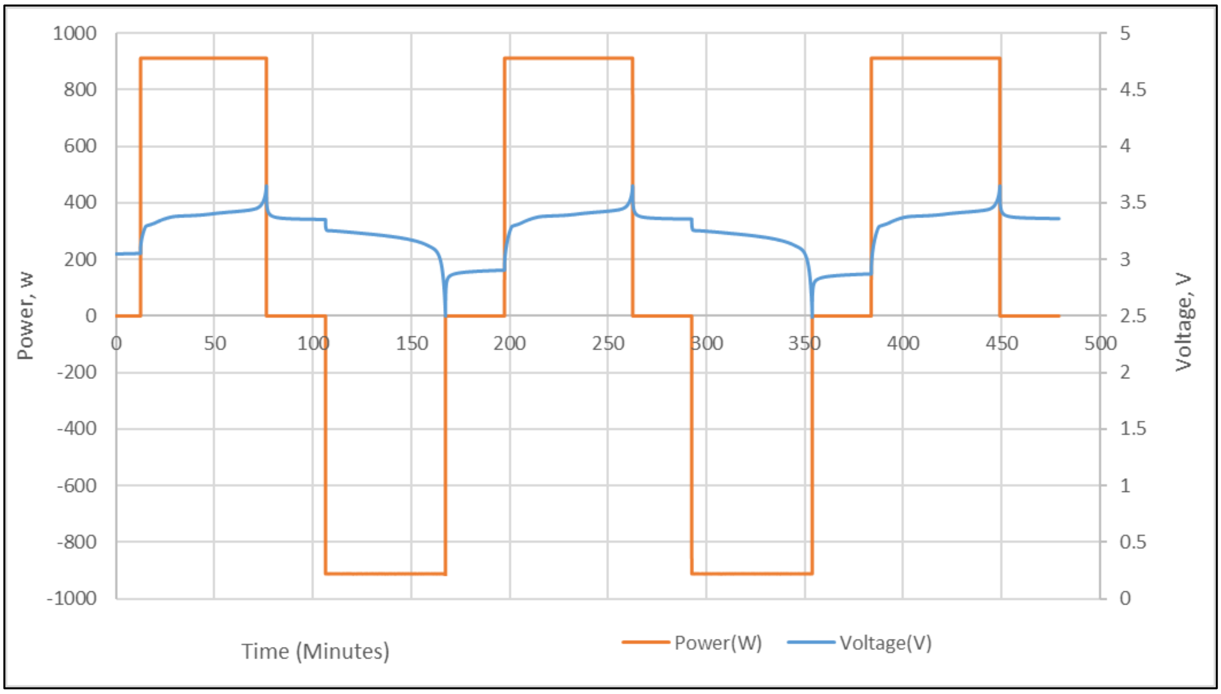


Figure 27: Cell 9 Conditioning (Charge/discharge) Profiles

Attachment G-2: Cell Instrumentation Photos - (*Pages **41** through **41***)

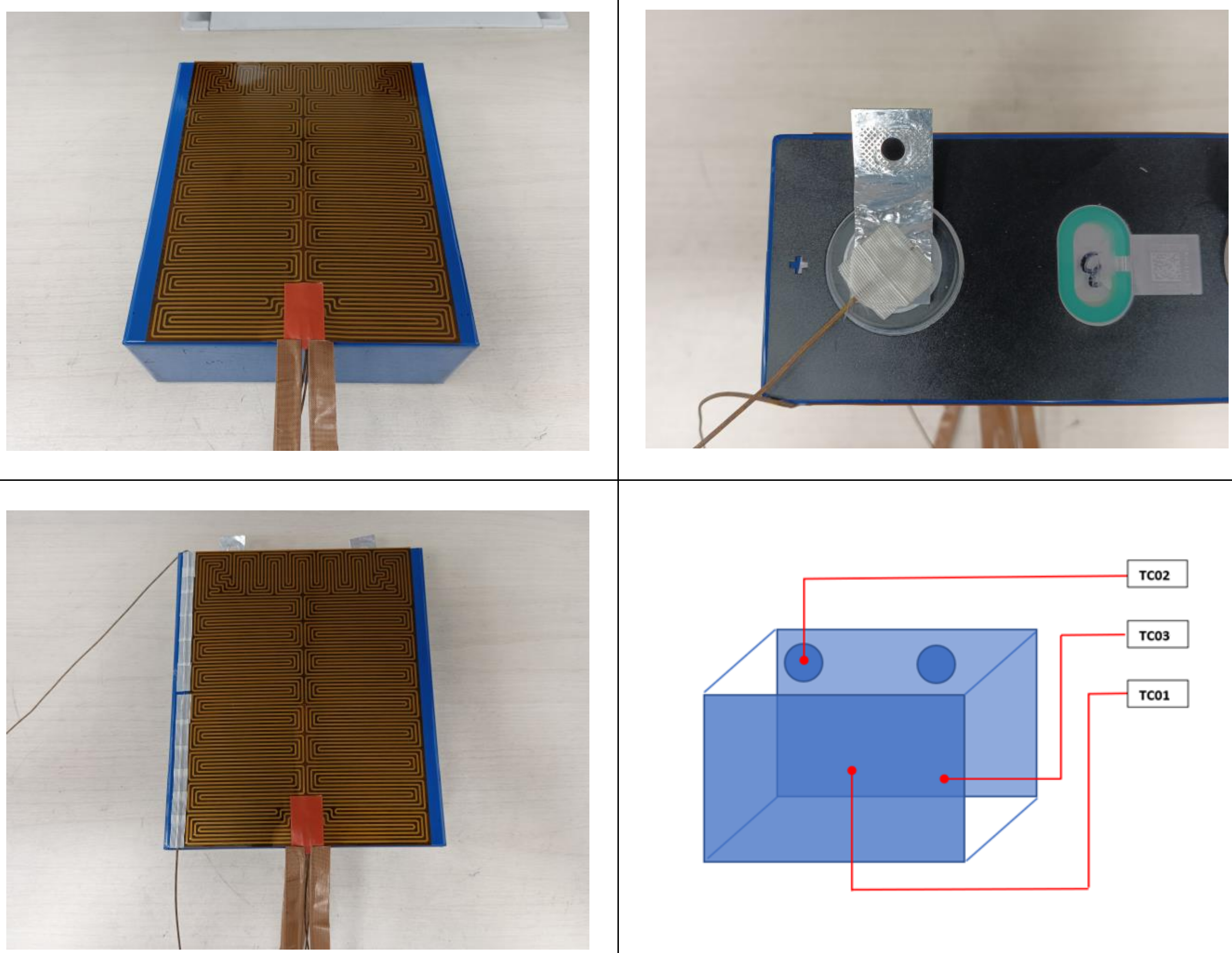


Figure 28: Sample Instrumentation Prior to Test

Note: heaters were placed on two sides of the cell after thermocouples were instrumented.

Note: TC01 between cell body and heater; TC02 on the cell positive; TC03 on the cell body not covered by heater; TC04 Ambient temperature; V1 cell voltage.

Attachment G-3: Cell Temperature Profiles during testing - (*Pages **42** through **43***)

Note: TC01 between cell body and 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.

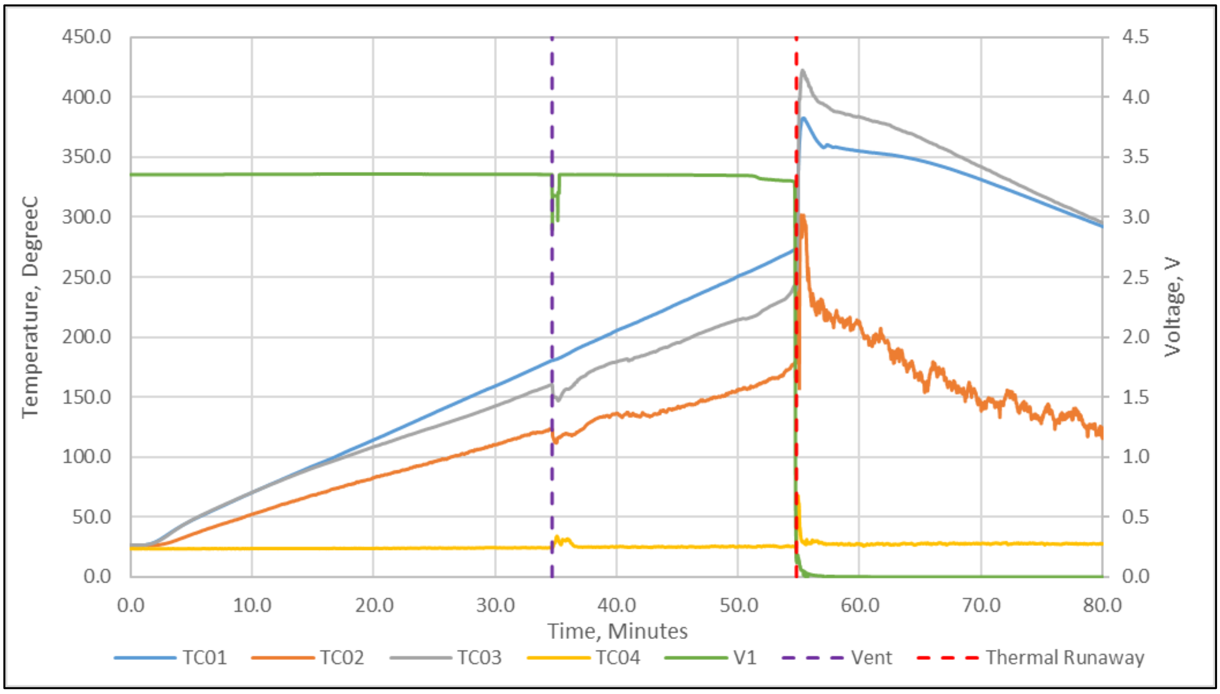


Figure 29: Cell 6 – External Heating 4.5°C per minute

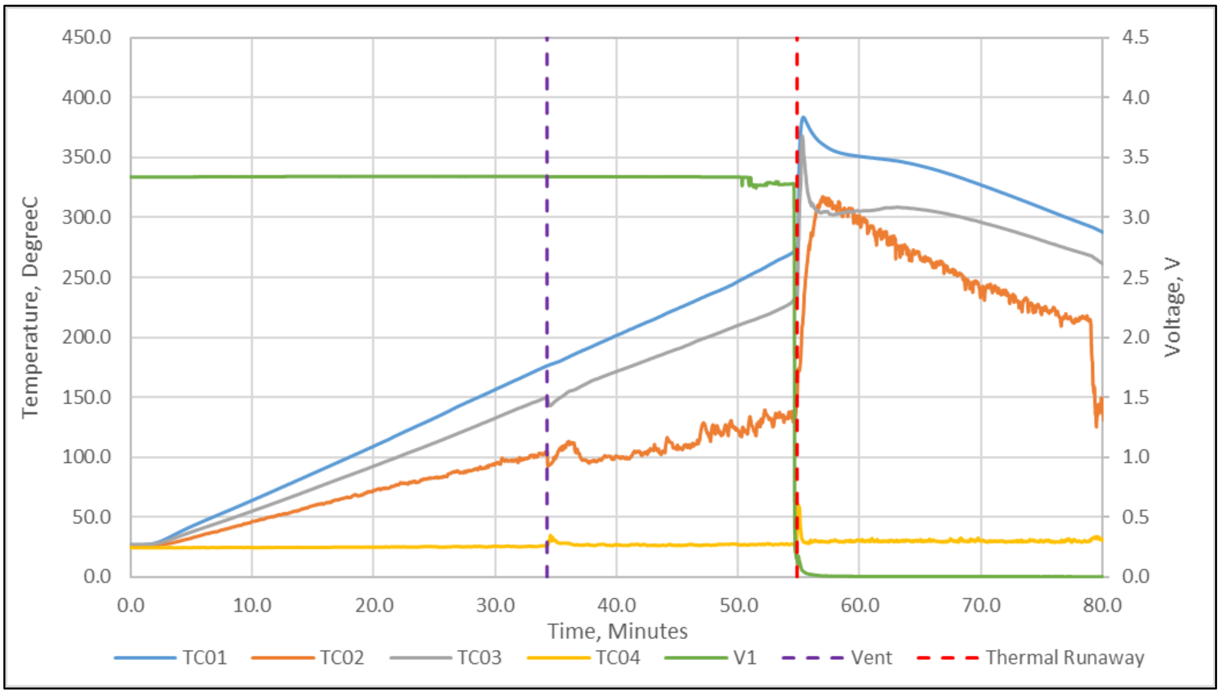


Figure 30: Cell 7 – External Heating 4.5°C per minute

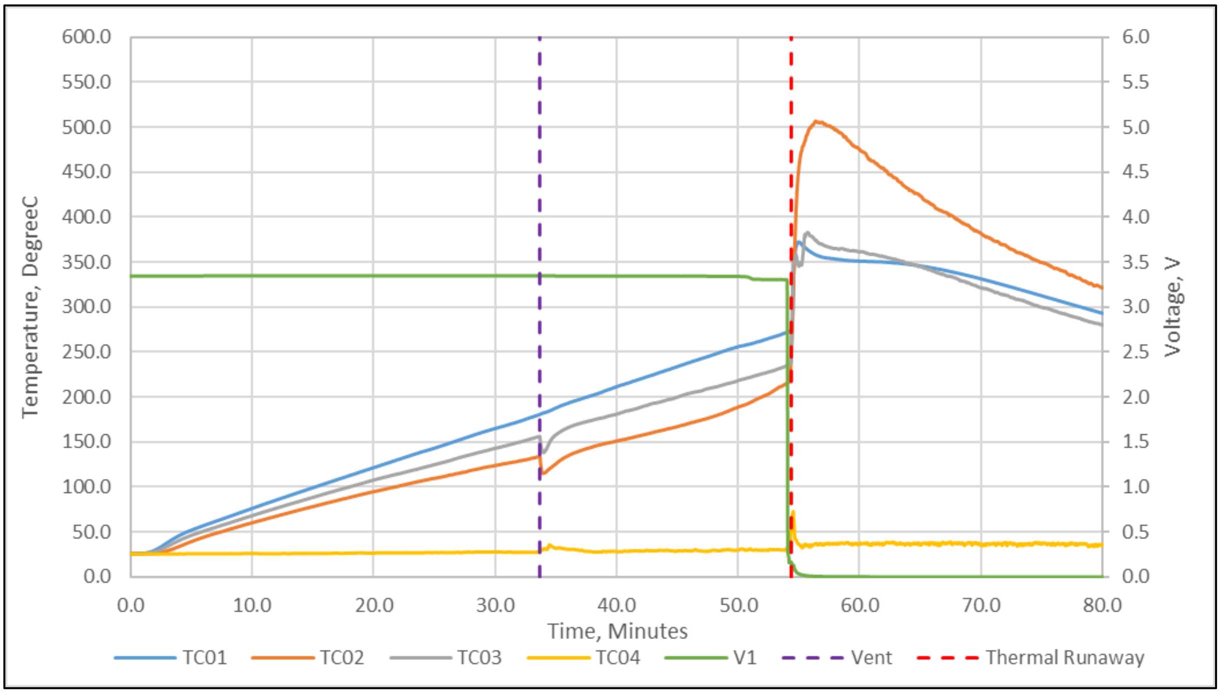


Figure 31: Cell 8 – External Heating 4.5°C per minute

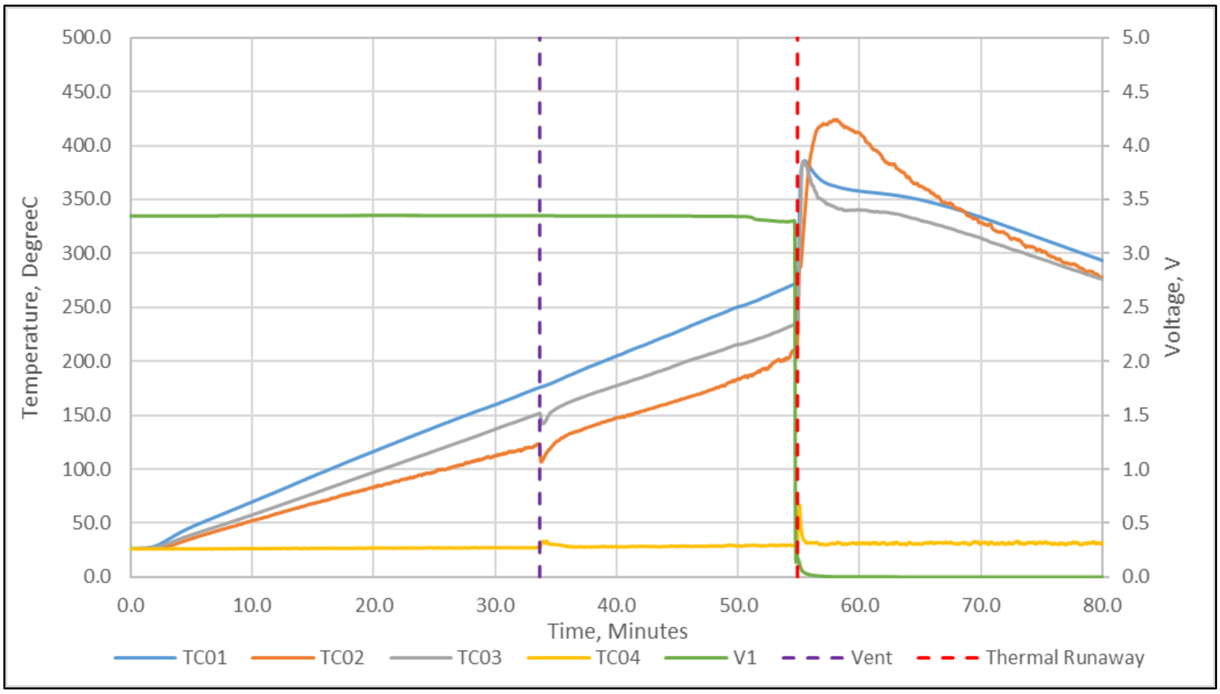
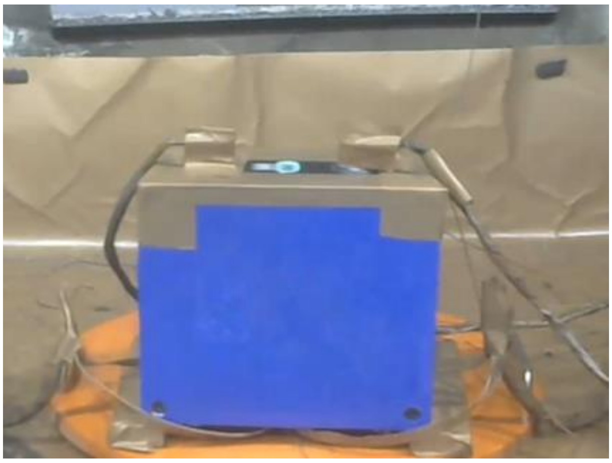


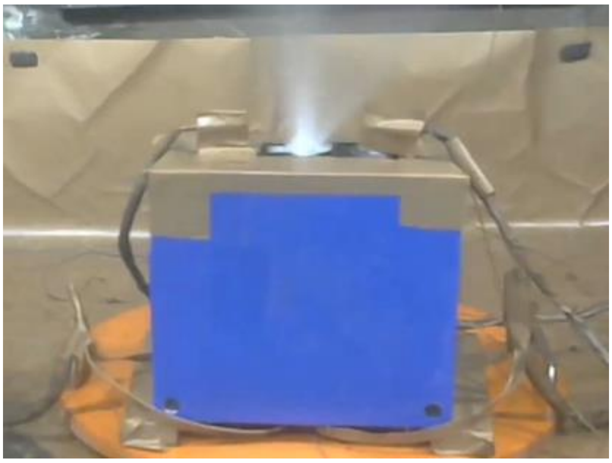
Figure 32: Cell 9 – External Heating 4.5°C per minute

Attachment G-4 Cell Testing Photos - (*Pages **44** through **51***)

Cell Sample 6 – 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
[34:41]

(c) Thermal runaway behavior
[54:48]

Figure 33: Highlights of Cell 6 Testing

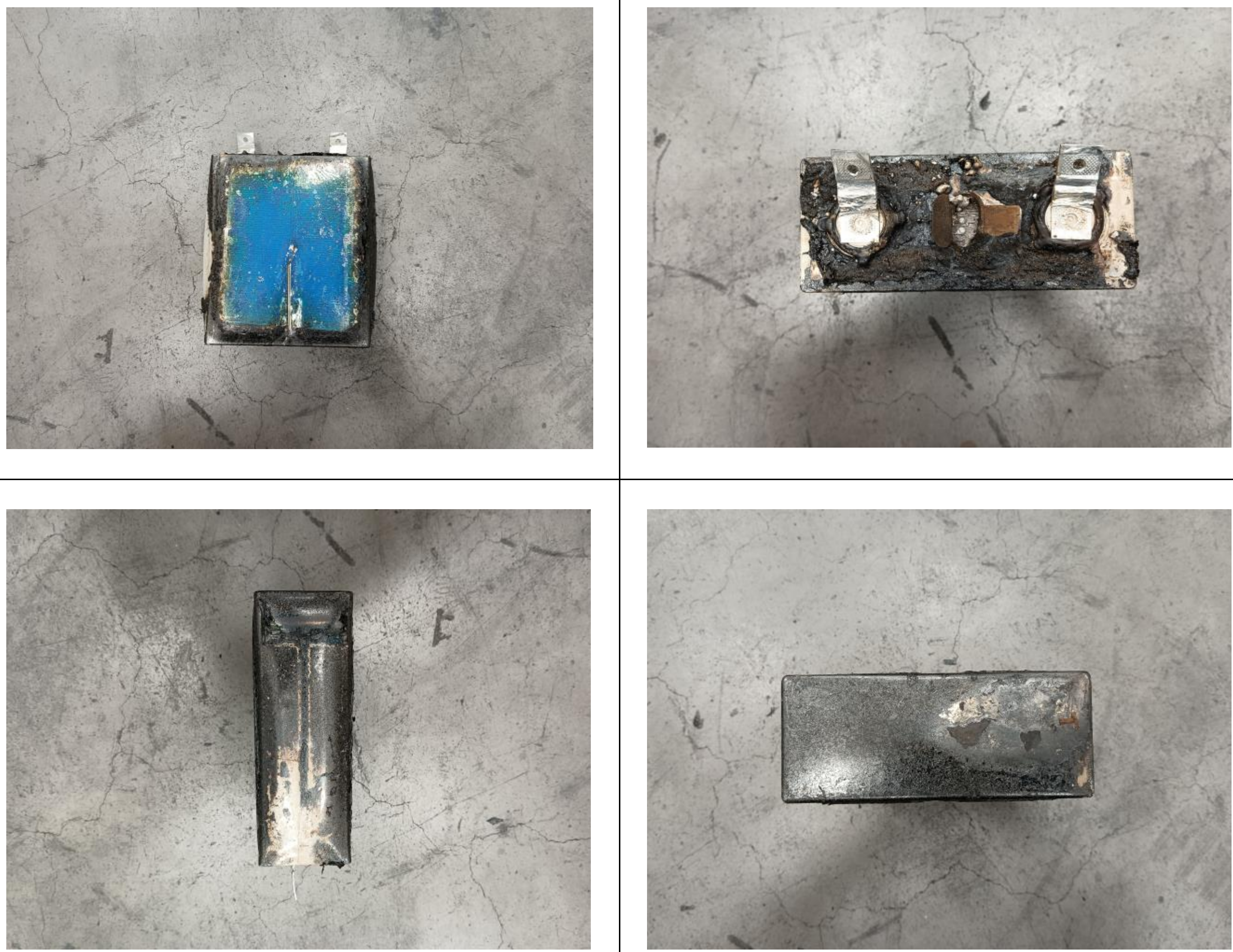


Figure 34: Sample Post Test Photos

Cell Sample 7 – 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.

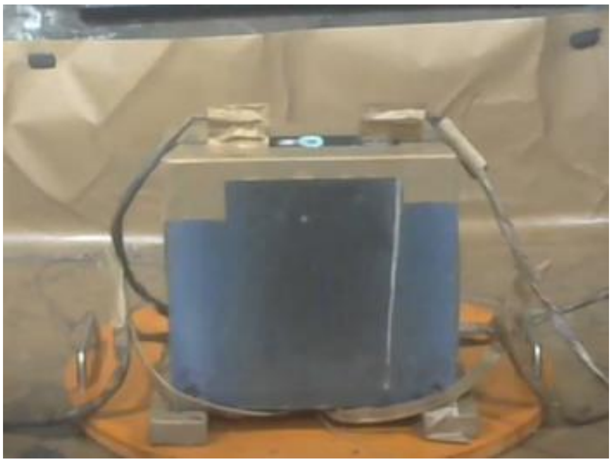
	
(a) Test Start [00:00]	(b) Cell Venting [34:16]
	
(c) Thermal runaway behavior [54:51]	
Figure 35: Highlights of Cell 6 Testing	

Figure 36: Sample Post Test Photos

Cell Sample 8 – 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.

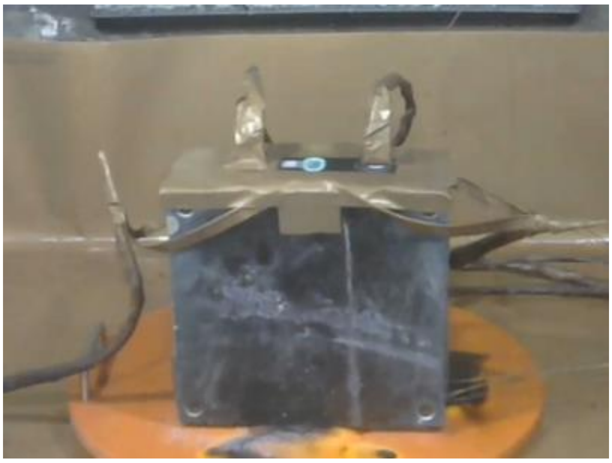
	
(a) Test Start [00:00]	(b) Cell Venting [33:40]
	
(c) Thermal runaway behavior [54:22]	

Figure 37: Highlights of Cell 6 Testing

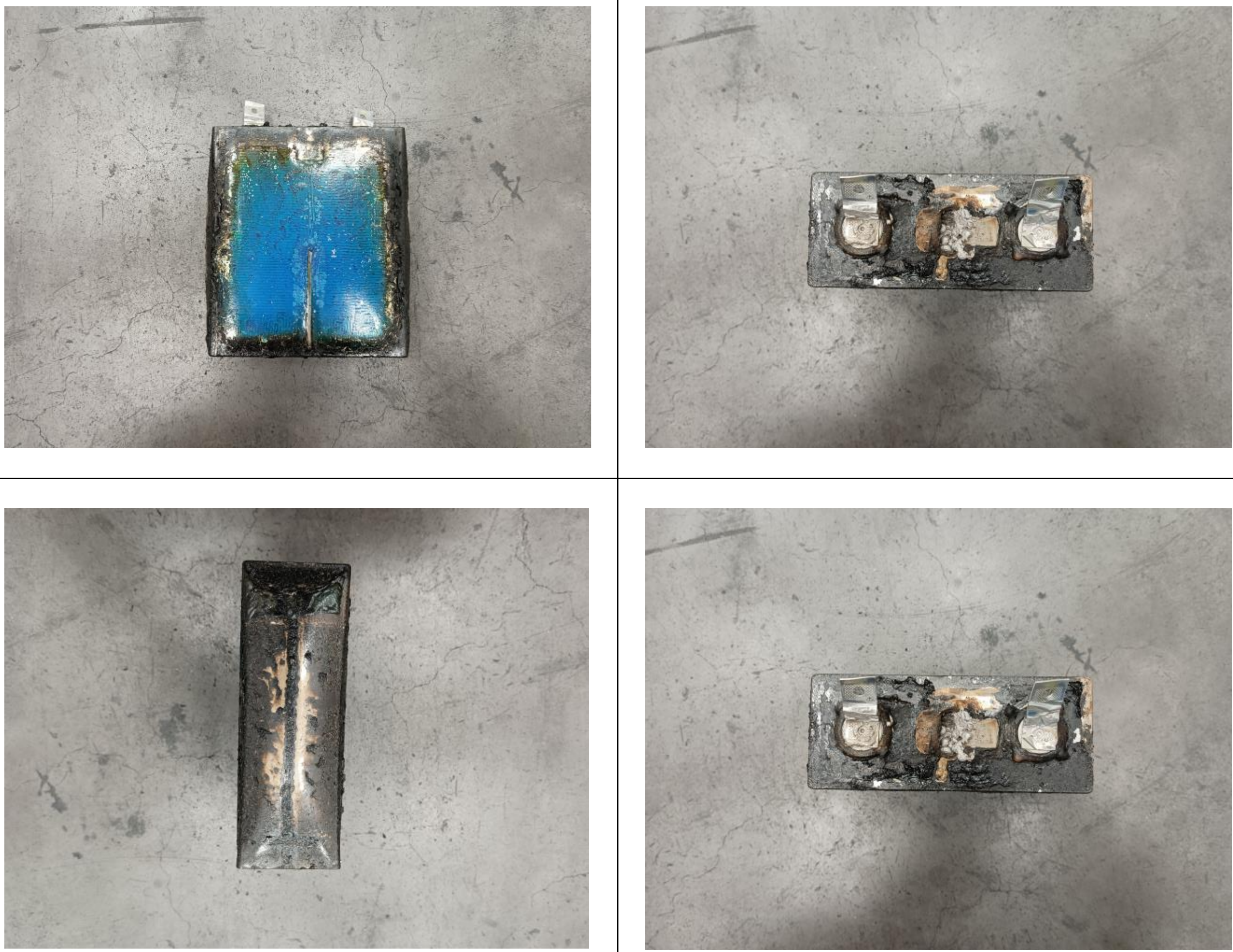


Figure 38: Sample Post Test Photos

Cell Sample 9 – 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 [33:40]
	
(c) Thermal runaway behavior [54:53]	

Figure 39: Highlights of Cell 6 Testing

Figure 40: Sample Post Test Photos