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COFFMAN ENGINEERS



VACA DIXON POWER CENTER - ARGES BESS

Hazard Mitigation Analysis

COFFMAN PROJECT NO. 251796

IFP SUBMITTAL

October 28, 2026

Prepared for: Arges BESS LLC

HAZARD MITIGATION ANALYSIS

FOR

ARGES BESS

Vacaville, California

Project Number: 251796

Revision	Date	Description
0	12/30/2025	Issued for Permit
1	10/9/2026	Change in BESS Technology

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ABBREVIATIONS

AHJ	Authorities Having Jurisdiction
AESC	Automotive Energy Supply Corporation
BMS	Battery Management System
BOL	Beginning of Life
CFC	California Fire Code
DC	Direct Current
EMS	Energy Management System
EOL	End of Life
ESS	Energy Storage System
FACP	Fire Alarm Control Panel
FCC	Fire Command Center
IFC	International Fire Code
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
PG&E	Pacific Gas and Electric Company
SCADA	Supervisory Control and Data Acquisition
UPS	Uninterruptible Power Supply

1 PROJECT BACKGROUND

1.1 Introduction

Coffman Engineers, Inc. provides this Hazard Mitigation Analysis (HMA) in accordance with the 2025 California Fire Code (CFC), as amended and adopted by the City of Vacaville, for the Arges Battery Energy Storage System (BESS) facility located in Vacaville, California. The site utilizes AESC Model #HE-L5030A BESS enclosures containing Prismatic Lithium Iron Phosphate (LFP) batteries, totaling 100 Megawatts (MW), 4-hour duration of battery energy storage.

This HMA for the Arges BESS facility has been prepared for Arges BESS LLC and is being submitted to the California Energy Commission (CEC) for review and approval. The CEC is the entity responsible for licensing the Arges BESS facility including review (in consultation with the Vacaville Fire Department) and approval of fire-related plans and design related to the BESS facility. The Vacaville Fire Department is the Fire Marshal and is considered the AHJ for the purposes of Fire and Life Safety matters (e.g., emergency response planning and incident response). The life safety of personnel shall be the highest priority during any event.

1.2 Site Location

The Arges BESS facility, with a capacity of 100MW/400MWh, is located on a 5.75-acre portion of a 10-acre parcel (APN 0133-060-060). The separate Vaca Dixon BESS facility, with a capacity of 57MW/57MWh, is located to the south on a 4.25-acre portion of the same parcel. The project is located within Solano County, Kilkenny Rd, Vacaville, CA 95377 with coordinates 38°23'46.4"N 121°55'17.3"W. See Figure 1.2.1 and figure 1.2.2 for site location and layout.

Project Summary	
Owner	Arges BESS LLC
Utility	Pacific Gas and Electric Company (PG&E)
ESS Enclosure Type	Enclosure Type IP-55 AESC HE-L5030A
Number of ESS Enclosures	100 BOL (108 EOL)
Total Site Footprint	5.75 acres
Capacity	100 MW / 400 MWh

The project will utilize AESC HE-L5030A outdoor-rated energy storage system (ESS) enclosures and associated on-site support facilities including inverters, collection lines, fencing, access roads, SCADA, switchgear, and other ancillary equipment. The Arges switchgear is located on-site to the west of the Arges BESS.

The typical equipment arrangement is a block of four AESC ESS enclosures connected to a single power conversion system (PCS) which is then connected to the site switchgear via buried

medium voltage (MV) circuits.

The project includes a separate BESS yard (Vaca Dixon BESS) that is located to the south of the Arges BESS yard and is outside the scope of work and will not be addressed within this HMA. A separate HMA has been prepared for the Vaca Dixon BESS facility.

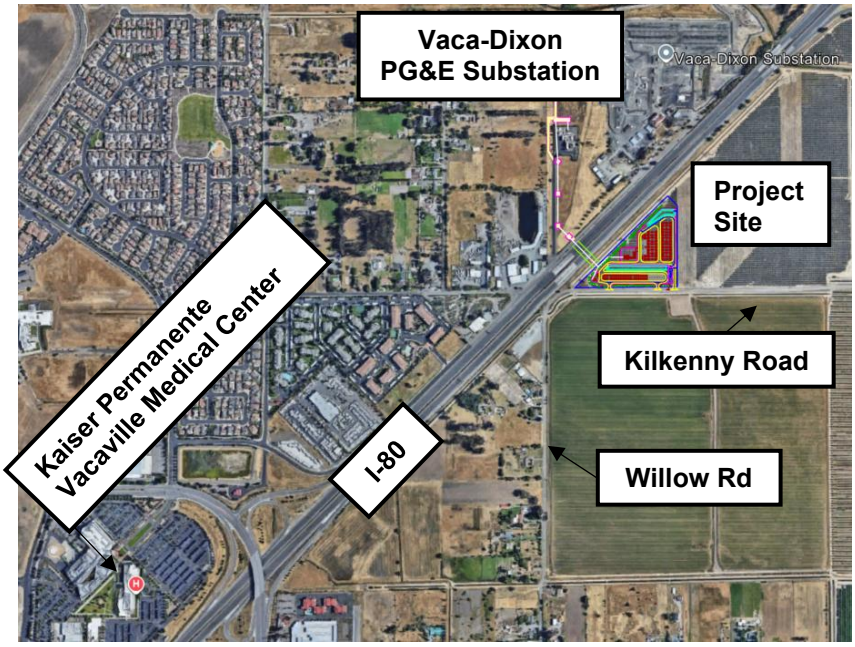

Figure 1.2.1 – Arges BESS Vicinity Map (North ↑)

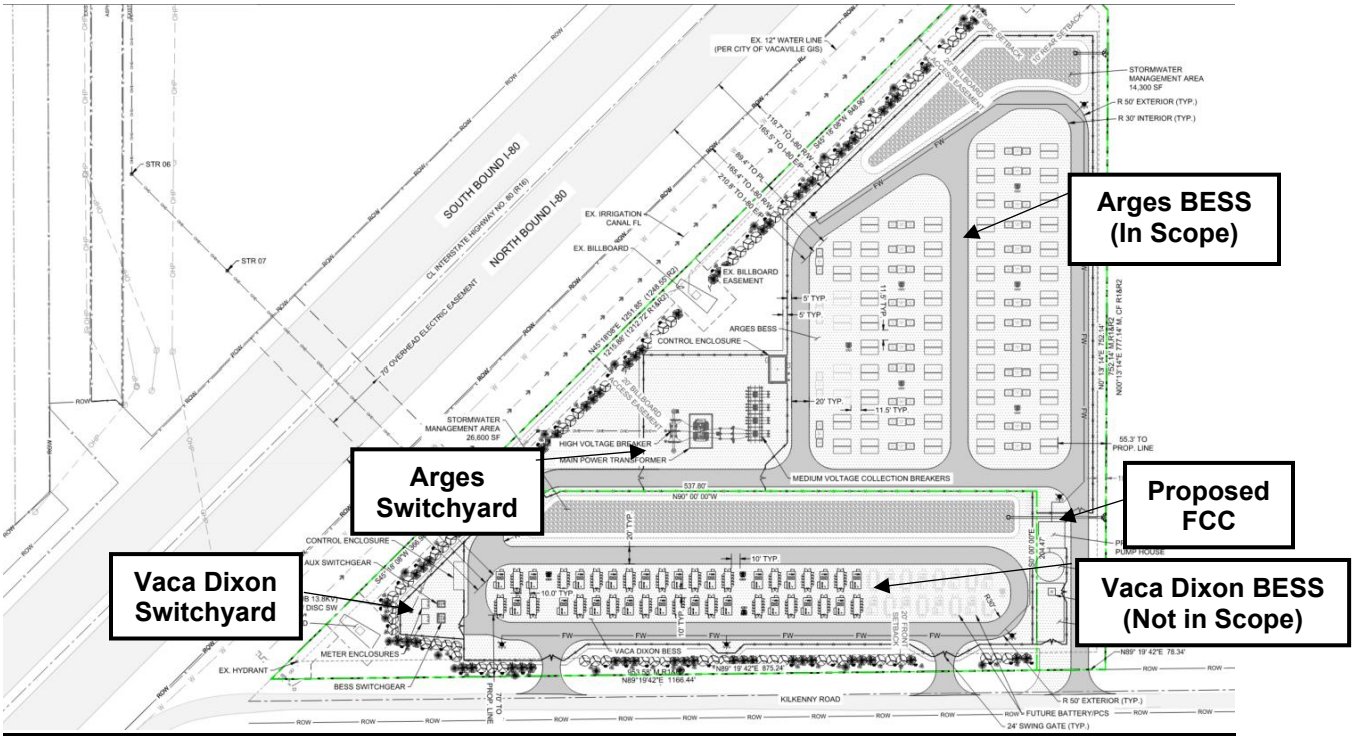

Fig 1.2.2 – Arges BESS (North ↑)

1.3 Project and Code Summary

1.3.1 Enclosure and Battery Requirements

ESS REQUIREMENTS		
Code	Requirement	Compliance Status
Equipment Listing: *CFC §1207.3.2*	ESS shall be listed in accordance with UL 9540.	**Compliant.** AESC HE-L5030A ESS Enclosure, certified to ANSI/CAN/UL 9540, 2023 by TÜV Rheinland under test report no. CN251VG2 001. Certificate #: CU 72503210 0001 *Additional details: HMA Appendix A*
ESS Type: *CFC §202 CFC 2025 Edition Definition)*	An Energy Storage System Cabinet is defined as a system where personnel cannot enter the enclosure other than reaching in to access components for maintenance purposes.	**Compliant.** Classification: Energy Storage System Cabinet Note: "ESS enclosure", and "non-walk-in" are used synonymously with "Energy Storage System Cabinet" in this report. All terms refer to the AESC enclosure. *Additional details: HMA Section 1.6*
Technology: *CFC §1207.6*	Requires lithium-ion ESS to comply with provisions relating to thermal runaway and explosion control.	**Compliant.** ESS Enclosures are provided with an Energy Management System and explosion prevention system.
Size and Separation: *CFC §1207.5.1, 1207.5.2*	Allows groups to exceed 50 kWh with less than 3 ft spacing based upon large-scale testing. The ESS's Maximum allowable stored energy (600 kWh) to be exceeded where an HMA and large-scale testing justify an increase.	**Compliant.** 5,030 kWh total per enclosure. Large-scale testing (UL 9540A) has been conducted to justify reduced spacing. The distance between the instrument wall and the initiating BESS is 10ft, the maximum wall surface temperature was 211°F . *Additional details: HMA section 2.4 and Appendix H.*
Hazard mitigation analysis: *CFC §1207.1.6*	The ESS's Maximum allowable stored energy (600 kWh) to be exceeded where an HMA and large-scale testing justify an increase.	**Compliant.** Hazard Mitigation Analysis will be submitted to the AHJ for final Approval.
Thermal Runaway: *CFC §1207.6.5*	Listed device or approved method required to preclude, detect, and minimize the impact of thermal runaway.	**Compliant.** Thermal runaway mitigation provided via UL9540A tested design and UL1973 listed Battery Management System (BMS) which actively monitors the voltage and temperature of all cells. *Additional details: HMA Section 3.3*
Explosion Control: *CFC 1207.6.3*	Explosion prevention or deflagration venting measures required.	**Compliant.** NFPA 69 Explosion Prevention system with mechanical ventilation activated by gas sensor to keep below 25% LFL. Includes 4 supplemental deflagration venting panels (NFPA 68) as a secondary system. *Additional details: HMA Section 3.4*
Fire Detection: *CFC §1207.5.4*	Requires a smoke fire detection system be installed in all rooms containing ESS	**Compliant.** The AESC enclosure is equipped with an automatic fire detection system (smoke and heat detectors) and a gas detection system. *Additional details: HMA Section 3.1*

1.3.2 ESS Site Requirements

SITE REQUIREMENTS		
Code	Requirement	Compliance Status
Outdoor ESS Installation Type: *CFC §1207.8*	Outdoor ESS installations less than 100 ft from adjacent to site exposures, buildings, lot lines, or public ways shall be classified as "Near Exposures." Installations greater than 100 feet are "Remote locations.	**Compliant.** Classification: Outdoor ESS installations, location near exposures.
Clearance to Exposures: *CFC §1207.8.3*	A 10 ft clearance from ESS to lot lines, public ways, buildings, combustible materials, and other potential exposure hazards is required to prevent fire spread. Clearances to exposures other than buildings may be reduced to 3 ft where approved and supported by large-scale fire testing of the ESS	**Compliant.** The installation complies with the clearance to exposure requirement based on the results from UL 9540A Test. A minimum of 10 feet is provided in all directions within the BESS Yard to the nearest lot line. *Additional details: HMA Figure 1.6.1*
Site Fire Water Source: *CFC §507.1 (inferred)*	Requires adequate on-site fire water source.	**Compliant**. UL 9540A testing was completed without water suppression. Water availability for site non-ESS fire events will be provided via three on-site hydrants, which are supplied by an on-site 120,000 gal water storage tank. *Additional details: HMA Section 3.2*
Vegetation Control: *CFC §1207.5.7*	Areas within 10 ft on each side of outdoor ESS shall be cleared of combustible vegetation and other combustible growth.	**Compliant.** Decomposed granite or paved areas are provided at least 10 ft on all sides of the ESS enclosures.
Fire Department Access: *CFC Chapter 5*	Ensures adequate site access for emergency events and would require proper features including road widths, turnarounds, grade/surface and signage/markings.	**Compliant.** The site will incorporate all requirements within these access provisions established by CFC Chapter 5 subject to AHJ requirements and approval. The Arges facility will be provided with two access points, one off of Kilkenny Rd and one via the Vaca Dixon facility.
Impact Protection: *CFC §1207.4.5*	ESS shall be located or protected to prevent physical damage from impact where such risks are identified.	**Compliant.** There is limited risk to vehicle impact without individual bollards based upon the following: 1) Completely fenced off area with no public access. 2) Only technicians familiar with the site will access the site. 3) Enclosures are located at least 5 ft from the edge of the access roads 4) Vehicle traffic speeds will be limited to 10 mph. At a minimum there will be bollards placed at the corners of the road for turning protection.
Security of installation *CFC §1207.4.9*	ESS shall be secured against unauthorized entry and safeguarded in an approved manner.	**Compliant.** A 7 ft fence is provided around the entire site with no public access. The entrance gates are manually opened, and pad locked closed.

1.3.3 ESS Provisions not Applicable to this Project

REQUIREMENTS NOT APPLICABLE TO THIS PROJECT		
Code	Requirement	Compliance Status
Fire Area Separation: *CFC §1207.7.4*	Rooms or spaces containing ESS shall be separated from other areas of the building by 2-hour fire barriers.	**Not Applicable.** Enclosures have no fire rating requirement as they are not installed in a building.
Exhaust Ventilation: *CFC §1207.6.1*	N/A for Lithium-Ion technology	**Not Applicable.** Not required/applicable as it does not off gas during normal charging operations.
Fire Suppression Systems: *CFC §1207.5.5*	Requires rooms containing ESS systems shall be equipped with an automatic sprinkler system installed.	**Not Applicable.** No suppression is required per the UL 9540 listing of the enclosure. (9540A testing shows limited propagation with no suppression). Enclosures are also non-walk type. Additional details: HMA Section 3.2
Spill Control: *CFC §1207.6.2*	N/A for lithium-ion technology	**Not Applicable.** Not required/applicable as the electrolyte is sealed.
Safety Caps: *CFC §1207.6.4*	N/A for Lithium-Ion technology	**Not Applicable.** Not required/applicable.
Means of Egress Separation: *CFC §1207.5.8*	A 10 ft separation between ESS enclosures and egress paths is required to ensure safe escape routes in case of fire.	**Not Applicable.** The ESS enclosures are not installed in a building, occupied areas, or adjacent to an egress path. No egress path separation provisions apply.

Code Requirements

1.3.4 Applicable Codes and Standards

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 69, Standard on Explosion Prevention Systems (2024 Edition)
- NFPA 855, Standard for the Installation of Stationary Energy Storage Systems (2023 Edition)
- UL 9540, Standard for Energy Storage Systems and Equipment (2020 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:

- NFPA 855, Standard for the Installation of Stationary Energy Storage Systems (2026 Edition)
- Pre-incident planning per NFPA 1620, Standard for Pre-incident Planning (2020 Edition)

The referenced editions exceed the requirements of the existing guides and standards referenced in the 2025 CFC.

1.4 Hazard Mitigation Analysis

1.4.1 Purpose

This HMA report is required by CFC § 1207.1.6 to support the approval of maximum energy storage quantities greater than 600 kWh for lithium-ion battery installations.

1.4.2 Basis of Analysis

This HMA report is a technical assessment conducted by a qualified professional fire protection engineer (compliant with CFC § 104.2.2) to evaluate the consequences of single failure modes as required by CFC § 1207.1.6.1.

The fire protection and life safety strategies incorporated into the HMA are informed by manufacturer documentation, results of full-scale fire testing (UL 9540A), and site planning for the Arges BESS. Manufacturer documentation is included in the appendix.

The HMA should be kept in a safe location and reviewed annually by the site operator and owner. As part of the management of change process, any modifications or changes to equipment type could trigger a permit by the AHJ. As the Engineer of Record for this project, revisions to this document must be completed by Coffman Engineers.

1.4.3 AHJ Evaluation Criteria

The AHJ may approve increased maximum energy storage quantities. An approved HMA must support this approval. The HMA should evaluate the consequences of the following hazard and incorporate large-scale fire testing evidence and analysis.

CFC	Hazard Consequences Evaluated	Compliance Assessment
§ 1207.1.6.2 (1)	Fires will be contained within unoccupied ESS rooms or areas for the minimum duration of the fire-resistance-rated walls identified in Section 1207.7.4.	This minimum duration of the fire-resistance-rated walls provision is not applicable to this project as the ESS is an outdoor installation and is not a room within a building. There is no requirement for fire-resistance-rated separations.
§ 1207.1.6.2 (2)	Fires involving the ESS will allow occupants or the general public to evacuate to a safe location.	This project is classified as an outdoor unoccupied ESS installation and is not open to the public.
		While toxic gases will be released in the event that a fire occurs involving an ESS, there are no buildings on site and the site is considered to be unoccupied, and the toxic gases released will not reach a concentration level in excess of the IDLH where occupants or the general public will be located.
		The batteries are hermetically sealed and do not vent under normal charging or discharging operating conditions. Flammable gases are not released during normal operations.
		There is potential that the battery cells will vent flammable gases in the event of an internal short within a battery cell, overcharging, in the event of a BMS or EMS failure, or other abnormal conditions. Fires or explosion hazards will be mitigated with an explosion prevention system designed to maintain flammable gas concentrations below 25% of the lower flammability limit (LFL), to prevent development of an explosion hazard with the potential to injure service personnel and emergency responders.

Table 1.5.3 - AHJ Evaluation Criteria

1.5 System Overview

The AESC HE-L5030A ESS enclosure is designed as an outdoor installation complying with CFC Section 1207. The site layout allows for potential expansion, and any future installations will necessitate an updated HMA to maintain code compliance. See Appendix for additional information.

1.5.1 ESS System Description

The AESC enclosures are non-walk-in outdoor steel ESS Cabinets. They are not intended for occupancy and will be accessed externally for maintenance only. See the configuration in the table below for a high level of each component.

				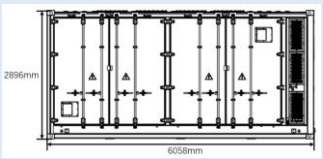
Component	**Cell**	**Module**	**Rack/Unit**	**AESC Enclosure**
Manufacturer	AESC Jiangsu Co., Ltd Co., Ltd.	AESC	AESC	AESC
Model	HC-L315A	HP-L630B	HR-L630B	HE-L5030A
Nominal Voltage (V)	3.2	166.4	1331.2	1331.2
Nominal Capacity (kWh)	1.008	104.83	838	5,030
Weight (lbs.)	2.56	375	1,477	94,799
Dimensions (in)	6.88 x 8.15 x 2.82	13.86 × 42.13 × 8.58 in	31.26 × 85.83 × 9.65 in	19.9 ft x 8 ft x 9.5 ft
Configuration / Chemistry	Lithium Iron Phosphate (LiFePO4)	104 Cells (2P52S)	8 Modules 2P52S	6 Racks ((2P52S)8S)6P
Thermal Management	n/a	Liquid Cooling System	Liquid Cooling System	Liquid Cooling System
Listing / Certification	UL 1973	UL 1973	UL 1973	UL 9540

Table 1.6.1 - AESC Configuration

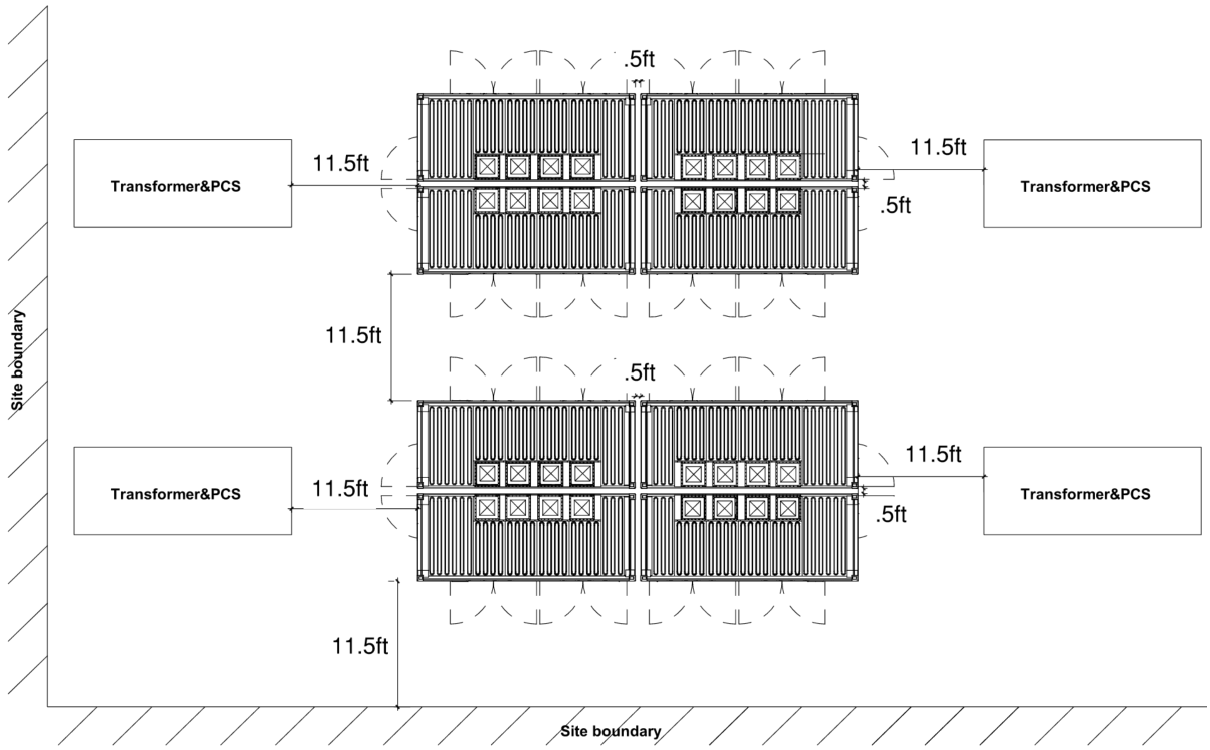

Figure 1.6.2 – ESS Separation Requirements per AESC (Manufacturer)

2 FIRE TEST ANALYSIS

Test Standard: UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 4th Edition, November 12, 2019.

2.1 Cell Test

2.1.1 Setup and Conditions

A lithium iron phosphate (LiFePO4, LFP) battery cell (Model HC-L315A), certified to UL 1973, was tested according to UL 9540A. Thermal runaway was induced using an external heater. Vent gas was captured in a 160.4L pressure vessel for analysis. Gas flammability was assessed using the ASTM E918 method at both ambient and cell vent temperatures.

The cell level test document that was references for this report was published by UL (Changzhou) Quality Technical Co., Ltd. Dated 06/21/2024, test report no. 4791271040. The UL9540A Cell Level Test can be found in Appendix B.

2.1.2 Cell Test Results

The cell's average venting temperature was 159 °C (318.2 °F), with an average thermal runaway temperature of 246 °C (474.8 °F). Vent gas analysis confirmed flammability when mixed with air. The LFL was 7.75% (vol in air) at 25°C, decreasing to 7.45% at vent temperature. The vent gas contained significant amounts of hydrogen, carbon dioxide, carbon monoxide, and various hydrocarbons.

2.2 Module Test

2.2.1 Setup and Conditions

This test evaluates fire hazards within a battery module as part of an ESS installation. Measurements include chemical heat release rate, maximum temperature, vent gas composition, enclosure integrity, and the presence of explosions, hazardous ejections, and external flaming. Thermal runaway was induced using external heaters at a rate of 4-7°C per minute.

The module level test document that was references for this report was published by UL (Changzhou) Quality Technical Co., Ltd. Dated 07/25/2025, test report no. 4791603240. The UL9540A Module Level Test can be found in Appendix B.

2.2.2 Module Test Results

The module level test was performed by heating one cell using film heaters. Each module contains 104 cells. A total of four cells within the module went into thermal runaway. Gas and smoke venting were observed. No external flaming or sparking and no explosion or flying debris was observed.

2.3 Unit Test

2.3.1 Setup and Conditions

This test evaluated fire behavior and propagation within an AESC ESS unit with a focus on containment and preventing flying debris or explosive gas discharge. Thermal runaway was induced using external heaters at a rate of 4-7°C per minute. No BMS or fire suppression systems were active.

The unit level test document that was references for this report was published by TUV Rheinland (Shanghai) Co., Ltd. Dated 08/04/2026, test report no. CN25EW8J 001. The UL9540A Unit Level Test can be found in Appendix B.

2.3.2 Unit Test Results

The unit level test was performed by heating one cell using film heaters. The enclosure level test results demonstrate that thermal runaway propagation was limited to 1 cells. Module-to-module propagation of thermal runway was observed. Explosion hazards were not observed, including deflagration or detonation. Gas and smoke venting were observed. External flaming, sparking, and explosion or flying debris were not observed.

2.4 Large Scale Test

2.4.1 Setup and Conditions

This test was designed to evaluate a worst-case battery failure event within an AESC HE-L5030A ESS enclosure, with a focus on multiple cells being driven into thermal runaway by film heaters within a single module while introducing a propane burner to ignite the flammable vent gases. The intent is to show that a fully developed fire in one ESS enclosure will not propagate to a neighboring enclosure. This large-scale fire test was conducted in accordance with CSA/ANSI C800:25 and meets the intent of both NFPA 855 and the IFC for large-scale fire testing. Active fire protection and thermal runaway mitigation measures were disabled for this test, and the BMS was active with its outputs disabled. The Large-Scale Test can be found in Appendix B.

2.4.2 Large Scale Test Results

Observations during the test included flaming that was induced by a propane burner approximately 1 hour and 15 minutes into the test, a partial volume deflagration approximately 2 hours and 45 minutes later which deformed the deflagration vent panels on adjacent Enclosures B and C, and visible exterior flaming that stopped approximately 33 hours and 40 minutes into the test. Thermocouple temperatures were recorded at more than 400 locations across all enclosures throughout the test and all temperatures remained below the cell vent temperature of 159 °C (318.2 °F). No fire or thermal runaway propagation was observed to the adjacent enclosures.

3 ESS SAFETY SYSTEMS

Battery storage ESS enclosures at the Arges BESS site will incorporate the following safety features:

3.1 Fire Detection and Alarm

Each ESS enclosure is provided with an internal fire detection and alarm system, consisting of an internal Fire Alarm Control Panel (iFACP) with two smoke detectors, two heat detectors, and two gas detectors (hydrogen detector and carbon monoxide detector) within the main ESS container, as well as one smoke detector within the enclosure's integration cabinet. All internal Fire Alarm Control Panel (iFACP) are connected to a site Fire Alarm Control Panel (FACP), which monitors all fire alarm signals from each ESS enclosure. The site Fire Alarm Control Panel (FACP) reports to the Fire Command Center (FCC), which is in an approved location. ESS Status indicators will be visible at the FCC and the ESS container's associated FACP.

3.1.1 Code Requirements

While CFC §1207.5.4 does not mandate fire detection in outdoor, non-walk-in energy storage systems, the AESC HE-L5030 ESS enclosures will exceed minimum requirements with an NFPA 72-compliant fire alarm system.

3.1.2 System Description

The fire alarm system incorporates multiple detection technologies, integrated actions, and redundant monitoring:

- Detection: Each AESC ESS container will contain smoke detectors, heat detectors, and combustible gas detectors. These detectors, compliant with NFPA 72 standards, were not active during the UL 9540A unit level test.
- Integration: Detection systems also transmit signals to the BMS system. Upon gas detection, the system automatically shuts down the HVAC, halts charge/discharge processes and activates off-gas ventilation.
- Monitoring: Each stand-alone site level fire alarm panel is monitored at the Fire Command Center (FCC) featuring an annunciator display. All alarms, supervisory, and trouble signals are transmitted to the FCCs and off-site monitoring service. FACPs include an uninterruptible power supply (UPS) for 24 hours of standby plus 2 hours of alarm.

3.1.3 Safety Assessment

The fire alarm system's design aligns with relevant sections of CFC and NFPA 72 standards to provide the following benefits:

- Fire Detection: Detection enables reliable identification of thermal runaway hazards with overlapping coverage.
- Redundancy: Networked FACPs and off-site monitoring ensure continuous oversight and minimize response delays.
- Proactive Mitigation: Automatic ventilation triggered by gas detection reduces the risk of flammable gas buildup.

3.2 Fire Suppression System

3.2.1 Code Requirements

The AESC ESS enclosures are classified as outdoor, non-occupiable installations. CFC § 1207.5.5 requires “rooms” containing stationary storage battery systems to be equipped with an automatic sprinkler system and designed in accordance with NFPA 13. As they are not considered "rooms" within buildings, CFC § 1207.5.5 does not require in-unit fire suppression systems.

3.2.2 System Description

While the AESC ESS enclosures have the infrastructure to support a water spray system, they were tested without an automatic water supply in accordance with UL 9540A unit (unit) testing procedures. It should also be noted that the ESS containers will come preinstalled with a manual dry sprinkler system with a fire department connection but will not be connected or used.

3.2.3 Safety Assessment

UL 9540A tests demonstrated that the AESC ESS design successfully prevents thermal runaway propagation between modules without an internal suppression system. This indicates that the ESS enclosure design effectively contains fire hazards. The decision to rely on the fire department for water supply aligns with CFC provisions for outdoor, non-occupiable installations while still offering a level of fire protection.

Fire water will be accessed from the three on-site fire hydrants located around the perimeter of the Arges BESS facility along the fire department access road. The on-site fire hydrants will be served by an on-site 120,000 gal fire water storage tank connected to a fire pump. The fire pump is located in a prefabricated fire pump house and the fire pump and water storage tank are located on the south side of the Arges site. The Emergency Response Plan (ERP) should be further referenced for recommendations.

3.3 Thermal Runaway Protection

3.3.1 Code Requirements

The design of the AESC ESS system aligns with the fire safety provisions outlined in the CFC regarding thermal runaway prevention in lithium-ion ESS:

- CFC § 1207.6.5: This paragraph mandates the use of listed devices or other approved methods to prevent, detect, and minimize the impact of thermal runaway events.
- CFC § Table 1207.6: Table emphasizes the necessity of specific protection against potential fire and explosion hazards associated with thermal runaway in lithium-ion batteries.
    - Footnote E, Table 1207.6: This footnote clarifies that thermal runaway mitigation strategies can be incorporated into the BMS, provided the BMS has been evaluated in conjunction with the battery using UL 1973 standards.

3.3.2 System Description

The AESC ESS module employs a thermal runaway design prevention based on thermal management and is comprised of the following elements:

- Battery Management System (BMS): The BMS plays a central role in monitoring and safeguarding the health of the batteries. It continuously tracks critical parameters, including voltage, temperature, and state of charge. See Appendix D for additional information. Essential BMS functions include:
    - Fault Detection: The BMS monitors for over-temperature, over-charge, over-discharge, over-current conditions, and overall system health. Upon detection of faults or parameters exceeding safe tolerances, the BMS will isolate affected battery strings and transmit alarm signals to the Emergency Management System (EMS).
    - Thermal Management: The BMS actively oversees temperature monitoring and control, ensuring optimal operating conditions to prevent thermal events.
- Liquid Cooling System: Cooling liquid powered by an internal pump will circulate inside battery modules and take the heat from the batteries and will circle back to a heat exchanging tank. This design feature actively cooling the batteries to reduce the potential of thermal runaway, reducing the risk of cascading failures.
- LFP Chemistry: Lithium Iron Phosphate (LFP) batteries are inherently more stable and resistant to thermal runaway when compared to other lithium-ion chemistries, offering a foundational layer of fire safety.

3.3.3 Safety Assessment

The effectiveness of the ASCE ESS design in containing and mitigating thermal runaway events has been validated through UL 9540A unit (rack) level testing. Key findings from these tests include:

- Containment: In tests initiating thermal runaway, the event was successfully confined to a small number of cells resulting in no sparks, flaming, electrical arcs, or other electrical events during test.
- Minimal Hazards: The tests observed no deflagration, external flaming, projectiles, explosive events, or other hazards that could pose a risk to personnel or surrounding property.

3.4 Explosion Control Systems

3.4.1 Code Requirements

The AESC ESS installation incorporates an explosion control system to mitigate the risks associated with flammable gas release during potential fire events. This system aligns with the following code requirements (reference Appendix F for NFPA 69 report):

- CFC § 1207.6.3: Mandates explosion control measures for ESS installations.
- CFC § 911: Permits the use of NFPA 69 or NFPA 68 compliant systems.
- NFPA 69 Section 8.3.1: Requires the maintenance of flammable gas concentration below 25% of the Lower Flammability Limit (LFL).

3.4.2 System Description

The explosion control system within the AESC ESS enclosure employs a proactive approach that integrates gas detection devices, ventilation system, and operational safeguards:

- Gas Detection: Each ESS container houses two gas detectors specifically designed to detect Hydrogen (factory calibrated) typically released during lithium-ion battery thermal runaway.
- Exhaust Ventilation (NFPA 69): Upon gas detection, Exhaust fans activate to remove flammable gases from the ESS container. Reference Appendix F for the full report.
- Deflagration Venting Panels (NFPA 68): Four panels located on the enclosure roof will activate based on pressure, relieving pressure in the event of an explosion. Should the exhaust ventilation system fail.
- Operational Controls: Detection triggers several actions: alarms are sent, charging/discharging processes halt, off-gassing valves open, and exhaust ventilation activates.

3.4.3 Safety Assessment

An analysis of UL 9540A Testing supports the design and effectiveness of the explosion control system. Gas release data obtained during these tests provides a reliable prediction of the expected gas concentration, composition, and LFL release from a thermal runaway event to validate the ventilation system design.

Even with the explosion control system in place, strict safety protocols are essential. During fire or thermal runaway events, personnel must not approach ESS containers until the ventilation system has effectively cleared flammable gases and all alarm conditions have been reset.

The explosion control system implemented in the AESC ESS design is based on testing and validated analysis and aligns with relevant fire codes. These proactive measures, in conjunction with safety procedures, significantly reduce the risk of explosion hazards.

FAULT CONSEQUENCE ANALYSIS

Failure	Safety Compliance Level	System Response	Failure Consequence	Severity Risk Analysis
Thermal Runaway §1207.1.6.1 (1)	Containment of fire/gas within the originating module or ESS unit, preventing spread to adjacent units.	Thermal runaway contained to the originating module. Detection of combustible gas, smoke, or heat triggers a fire alarm. The ventilation system activates, purging gases. BMS monitors parameters and disconnects power if necessary.	A thermal runaway event remains confined to the affected module, or unit (rack). Potential smoke/gas release is likely. A fire alarm signal is transmitted.	While a thermal runaway event is disruptive, the demonstrated containment capability limits the potential damage. The fire alarm signal alerts personnel and triggers further mitigation measures.
BMS Failure §1207.1.6.1 (3)	System design and safeguards prevent thermal runaway, even without the BMS.	Affected battery modules cease charging/discharging.	Failure of the BMS (not caused by thermal runaway) results in halted charging/discharging. However, isolated batteries still store electrochemical energy. Other fire and gas detection remains active.	A BMS failure removes an active layer of protection but does not eliminate the inherent energy storage risk of electrochemical batteries. The continued function of other detection systems provides a crucial safety net.
Voltage Surge §1207.1.6.1 (3)	Surge protection prevents widespread equipment damage or immediate fire risks. No unsafe conditions or thermal events were created.	Protective relays/breakers shut down affected ESS portions. Surge arresters divert excess voltage. BMS monitors and shuts down affected segments if anomalies are detected.	Electrical code compliance, surge arresters, and the BMS minimize the potential for severe damage to AESC ESS components from voltage surges.	The system incorporates multiple layers of protection against voltage surges, significantly reducing the likelihood and severity of potential damage.
Short Circuit (Load Side) §1207.1.6.1 (3)	Overcurrent protection prevents widespread damage within the ESS. No unsafe conditions or thermal events were created.	Overcurrent protection devices activate, isolating the fault.	Adherence to electrical codes and the UL 9540 certification of the AESC ESS significantly reduce the likelihood and potential severity of load-side short circuit events.	Code compliance and UL 9540 certification provide a high degree of confidence in the system's ability to withstand and manage short-circuit events safely.
Ventilation or Exhaust System Failure §1207.1.4.1 (3)	A transmitted trouble signal to initiate an investigation or shutdown reduces the risk of thermal runaway. No unsafe conditions or thermal events were created.	Batteries remain in a normal, non-off-gassing state. Combustible gas and smoke detectors trigger a fire alarm signal.	A ventilation system failure in isolation has minimal immediate impact. In a dual-fault scenario with thermal runaway, redundant detection systems, alarms, and procedures alert personnel and prevent unsafe approaches.	While a ventilation failure alone poses minimal risk, its consequences become more severe if coupled with thermal runaway. The presence of redundant safety systems and emergency procedures significantly reduces the likelihood and potential severity of this dual-fault scenario.
Fire Detection Equipment Failure §1207.1.6.1 (3)	Immediate trouble signals provide impairment notification. Detection redundancies ensure monitoring continues. No unsafe conditions or thermal events were created.	Redundant detection (smoke, heat, gas) remains operational. Smoke detector failure transmits a trouble signal. EMS triggers ESS container shutdown upon smoke/heat detector failure. The tiered alarm system activates. NFPA 72 maintenance minimizes failure likelihood.	Delayed detection of smoke or heat is possible. However, redundancy, trouble signaling, automated EMS shutdown, and proactive maintenance significantly reduce the risk and potential severity posed by a single detector failure.	While complete detection system failure is a remote possibility, the multiple safeguards and maintenance protocols in place significantly mitigate the likelihood and adverse consequences of such an event.

FAULT CONSEQUENCE ANALYSIS

Failure	Safety Compliance Level	System Response	Failure Consequence	Severity Risk Analysis
FACP Failure §1207.1.6.1 (4)	Immediate trouble signals provide impairment notification. Redundant FACPs or signaling pathways ensure continued alarm functionality or notification of impairment.	Trouble signals were sent to FCC, EMS, and LPC. EMS initiates shutdown of the affected ESS container group. Redundant fiber-optic pathways ensure signaling for other ESS container groups.	An FACP failure primarily affects only the directly connected ESS container group. Trouble signals, shutdown procedures, and redundant pathways mitigate the potential consequences.	The localized impact, automated response, and redundant signaling design limit the severity of an FACP failure. While disruption to the affected ESS container group is likely, the overall ESS installation maintains a high level of protection.

4 FAULT CONSEQUENCE ANALYSIS

4.1 Thermal Runaway in a Single ESS Module or Rack/Unit

This analysis assesses the potential for a thermal runaway event within a single AESC ESS module, or rack/unit.

4.1.1 Mitigation and System Response

- **Containment:** UL9540A test results confirm that thermal runaway will not propagate to adjacent modules, racks/units. This containment feature significantly reduces the potential impact of the event.
- **Early Detection:** Initial signs of thermal runaway are likely to include the detection of combustible gas released from off-gassing battery cells or the presence of smoke. Detection triggers a fire alarm signal transmitted to the fire alarm panel and a monitored location.
- **Ventilation:** Upon detection, the four ventilation panels activate to purge combustible gases, maintaining concentrations below 25% of the LFL.
- **Battery Management System (BMS):** The BMS continuously monitors battery voltage, temperature, and other operational parameters. In the event of irregularities, the BMS will proactively disconnect power to help prevent the escalation of an abnormal condition into a thermal runaway event.

4.1.2 Consequence and Severity

The UL 9540A testing demonstrates successful containment of a thermal runaway event within the originating module. Additional measures of protection beyond the test configuration include integrated fire detection and gas detection system, exhaust ventilation, and proactive BMS intervention, which significantly reduce the potential severity of a single module thermal runaway event within the AESC ESS system. These integrated safety measures are designed to prevent a localized module failure from cascading into a catastrophic event.

4.2 Failure of Battery or Energy Management System

This analysis assesses the impact of a failure within the AESC ESS battery system or its associated BMS.

4.2.1 Mitigation and System Response

- **BMS Functionality:** The AESC ESS incorporates a BMS designed to protect battery modules from common triggers for off gassing or thermal runaway, including over/under voltage, excessive temperatures, and short circuits.
- **BMS Failure Response:** Upon BMS failure, the affected battery modules immediately cease charging and discharging. This mitigates electrical conditions that could exacerbate a hazardous situation.

4.2.2 Consequence and Severity

While a BMS failure removes active charging and discharging, it does not eliminate the inherent energy storage risk of electrochemical batteries. Even in isolation, batteries can still pose a hazard. Fire safety and emergency response plans, compliant with relevant CFC guidelines, address the potential consequences of this residual risk.

4.3 Failure of the Emergency Ventilation System

This analysis assesses the impact of a ventilation system failure within a AESC ESS installation.

4.3.1 Mitigation and System Response

- **Normal Operation:** Under normal operating conditions, AESC ESS batteries do not off-gas. This minimizes the immediate impact of a ventilation failure.
- **Dual-Fault Scenario:** In the unlikely event of a ventilation failure coinciding with a thermal runaway event, several safeguards remain in place: Combustible gas, smoke, and heat detectors continue to function. Alarms are transmitted to remote fire alarm panels, the ESS yard entrance annunciator, and a constantly monitored location. Emergency procedures mandate that personnel maintain a safe distance until safety checks are complete and alarms are silenced.

4.3.2 Consequence and Severity

A ventilation system failure in isolation carries minimal immediate risk due to the lack of off-gassing during normal battery operation. In the unlikely dual-fault scenario involving thermal runaway, redundant detection systems and emergency procedures alert personnel and prevent unsafe approaches. While a complete ventilation failure coupled with a thermal runaway could have severe consequences, the layered safety measures in place significantly reduce the likelihood and potential severity of such an event.

4.4 Voltage Surges on the Primary Electric Supply

This analysis assesses the impact of voltage surges on the primary electrical supply to AESC ESS.

4.4.1 Mitigation and System Response

- **Electrical Code Compliance**: System design adheres to electrical code standards, including protective relays and breakers that trigger ESS shutdown in response to voltage fluctuations outside operational limits.
- **Surge Arresters**: Switchgear switches for each MV feeder are equipped with 35kV surge (lightning) arresters. These limit the severity of surges by diverting excess current to ground.
- **Battery Management System (BMS)**: The BMS continuously monitors battery voltage (individual cells and total). If excessive charge or discharge voltage is detected, the BMS immediately shuts down the affected ESS portion.

4.4.2 Consequence and Severity

The combination of code-compliant design, surge arresters, and the BMS significantly minimizes the potential for damage to the ESS from voltage surges. While surges present an inherent risk, these layered mitigation strategies reduce the likelihood of a severe incident.

4.5 Short Circuits on the Load Side of the ESS

This analysis assesses the potential impact of short circuits occurring on the load side of the AESC ESS installation. Short circuits pose a risk of electrical arcing, which could lead to fires or damage to ESS components.

4.5.1 Mitigation and System Response

The system incorporates several safeguards to address load-side short circuits:

- **Electrical Code Compliance:** The entire system design adheres to all relevant electrical codes, including specific provisions for short circuit protection. This ensures the use of appropriate overcurrent protection devices and system design practices to minimize the risk and severity of short-circuit events.
- **UL 9540 Certification:** The AESC ESS has achieved UL 9540 certification. This assessment includes short circuit studies, verifying the system's ability to withstand and manage potential short circuit faults.

4.5.2 Consequence and Severity

The combined effect of code compliance and UL 9540 certification reduces the likelihood and potential severity of load-side short circuit events in the AESC ESS.

4.6 Failure of the Fire Detection Equipment System

This analysis assesses the impact of a smoke or heat detector failure within a AESC ESS container. While detector failure poses a risk, the system incorporates multiple safeguards to mitigate potential consequences.

4.6.1 Mitigation and System Response

- **Redundancy:** The system employs overlapping detection capabilities with smoke, heat, and combustible gas detectors. Failure of a single detector is unlikely to disable fire detection fully.
- **Trouble Signaling:** Smoke detector failures automatically transmit a trouble signal to the site fire alarm panel and a monitored location, alerting personnel to the need for system maintenance.
- **EMS Response:** Failure of either smoke or heat detection triggers an automatic shutdown of the affected ESS container via the Energy Management System (EMS). This puts the batteries into an idle state, reducing the risk of thermal runaway. The ESS container remains offline pending manual inspection and restoration.
- **Alarm Tiers:** A tiered alarm system (Level 1, Level 2) ensures a graduated response. A single smoke or heat detector activation (Level 1) initiates alarm bell while a second

smoke or heat detector activation (Level 2) initiates HVAC shutdown, EMS alert, external notification, cessation of charge/discharge operations, and clean agent system releasing.

- **Inspection & Maintenance:** A formal documented inspection, testing, and maintenance program compliant with NFPA 72 standards proactively minimizes the likelihood of fire detection system failures.

4.6.2 Consequence and Severity

The combination of redundant detection systems, trouble signaling, automated EMS shutdown, tiered alarms, and strict maintenance protocols significantly reduces the risk and potential severity posed by a single smoke or heat detector failure. While complete system failure remains a remote possibility, these integrated safeguards mitigate the impact of such an event.

4.7 Failure of the Local FACP

This analysis addresses the impact of an FACP failure within a AESC ESS enclosure.

4.7.1 Mitigation and System Response

- **Localized Impact:** An FACP failure primarily affects the AESC ESS enclosure in which the compromised FACP is located in. Other ESS enclosures, served by separate FACPs, maintain operational status.
- **Trouble Signaling:** An FACP failure automatically transmits trouble signals to the monitoring Fire Command Center (FCC), the site Energy Management System (EMS), and the Local Plant Controller (LPC). This alerts personnel and triggers corrective actions.
- **EMS Shutdown:** Upon receiving a trouble signal, the EMS initiates a shutdown of the affected ESS container group. Batteries enter an idle state, significantly reducing the risk of thermal runaway. The ESS container group remains offline until FACP functionality is restored.

4.7.2 Consequence and Severity

The combination of localized impact, proactive trouble signaling, automated EMS shutdown, and redundant signaling pathways significantly minimizes the potential consequences of an FACP failure. At the same time, the affected ESS enclosure will experience temporary disruption.

5 CONCLUSIONS

Coffman Engineers, Inc. has prepared this HMA report to satisfy the requirements of CFC § 1207.1.6 to permit the installation of the ESS with lithium batteries which exceeds the limit of 600 kWh from CFC Table 1207.5. The HMA has summarized the fire protection features of the proposed ESS outdoor installation and addressed the single failure modes addressed by CFC § 1207.1.6.1.

The analysis is supported by UL 9540A full scale fire testing results (Appendix B) and aligns with the Emergency Response Plan, prepared by Coffman Engineers, to aid emergency responders and AHJs with regards to safety surrounding AESC products.

The Emergency Response Plan can be used as guidance to first responders and development of emergency response fire-fighting procedures. Additional supporting documentation for this HMA can be found in the appendices.

Your consideration of the information presented in this report is appreciated. If there are any questions regarding the content of this report, please contact our office.

APPENDICES

Appendix A

UL 9540 CERTIFICATE

TÜVRheinland®

Date: 2025-08-05

AESC Jiangsu Co., LTD
No.66 Shentai Road, Shengang Sub-District,
Jiangyin City, Wuxi
214000 Jiangsu
P.R. China

Ref: CU US + Canada Certificate

Type of Equipment	:	Lithium Ion Battery System
Certificate No.	:	CU 72503210 0001
Report No.	:	CN251VG2 001
Engineer/Contact	:	Depeng Cao
Standards	:	ANSI/CAN/UL 9540:2023

Dear Madame or Sir,

The above referenced technical equipment has been tested and was found to be in compliance with the listed test requirement(s). Enclosed, please find the TUV Rheinland approval document No. CU 72503210 0001.
It authorizes you to label the listed product(s) with the TUV Rheinland Mark identified in the approval document. For compliance, the Test Mark must be on the approved unit.

Your product is subject to regular factory follow-up inspections as well as annual certificate and factory registration fees.

In using the TUV Rheinland Mark you are obligated to comply with the TUV Rheinland of North America Service Agreement.

If we can be of any further assistance to you, please do not hesitate to contact us.

With kind regards,

Certification Body

Bowen Dong

Enclosure

Certificate

Certificate no. CU 72503210 0001

License Holder:

AESC Jiangsu Co., LTD
No.66 Shentai Road, Shengang Sub-District,
Jiangyin City, Wuxi
214000 Jiangsu
P.R. China

Manufacturing Plant:

Envision Energy Co., Ltd.
No.3 Shenzhuang Road, Linggang New City Low-Carbon Industrial Park,
Shengang Street Jiangyin City,
214443 Jiangsu
P.R. China

Report Number: CN251VG2 001
Client Reference: Liu Zhenyuan
Certification acc. to: ANSI/CAN/UL 9540:2023

Product Information

Certified Product: Lithium Ion Battery System
Model Designation: HE-L5030A
Technical Data:
Nominal voltage[Vdc]: 1331.2
Rated capacity [Ah] : 3780
Other data : See appendix

Remarks:
Appendix: 1, 1-78

Date of issue: 2025-08-05 (yr/mo/day)

TÜVRheinland
C US

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TUV Rheinland of North America, Inc.
400 Beaver Brook Rd, Boxborough, MA 01719
Tel +1 (978) 266 9500, Fax +1 (978) 266-9992

Prüfbericht-Nr.: *Test report no.:*	**CN251VG2 001**	**Auftrags-Nr.:** *Order no.*:	326103326 P01891648	
Kunden-Referenz-Nr.: *Client reference no.*:	2247138	**Auftragsdatum:** *Order date:*	2025-04-07	
Auftraggeber: *Client*:	AESC Jiangsu Co., Ltd. No.66 Shentai Road, Shengang Sub-District, Jiangyin City, Wuxi, 214000 Jiangsu Province, P.R. China			
Prüfgegenstand: *Test item*:	Lithium Ion Battery System			
Bezeichnung / Typ-Nr.: *Identification / Type no.*:	HE-L5030A			
Auftrags-Inhalt: *Order content*:	cTÜVus Mark approval			
Prüfgrundlage: *Test specification*:	ANSI/CAN/UL 9540: 2023			
Wareneingangsdatum: *Date of sample receipt*:	2025-05-15			
Prüfmuster-Nr.: *Test sample no:*	20250515-S001~ 20250515-S004			
Prüfzeitraum: *Testing period*:	2025-05-15 - 2025-06-25			
Ort der Prüfung: *Place of testing*:	See page 4 for details			
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüfergebnis*: *Test result**:	Pass			



geprüft von: tested by: Depeng Cao		**genehmigt von:** *authorized by*: Iris Ren	
Datum: *Date:* 2025-08-04		**Ausstellungsdatum:** *Issue date:* 2025-08-04	
Stellung / Position:	Sachverständige(r)/Expert	**Stellung** / Position:	Sachverständige(r)/Expert

Sonstiges / *Other*: See the following pages for General product information and comment.

Zustand des Prüfgegenstandes bei Anlieferung: *Condition of the test item at delivery*: Prüfmuster vollständig und unbeschädigt *Test item complete and undamaged*

* Legende:	P(ass) = entspricht o.g. Prüfgrundlage(n)	F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
** Legend:*	*P(ass) = passed a.m. test specification(s)*	*F(ail) = failed a.m. test specification(s)*	*N/A = not applicable*	*N/T = not tested*

Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht auszugsweise vervielfältigt werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens.
This test report only relates to the above mentioned test sample. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.

Prüfbericht-Nr.: CN251VG2 001
Test report no.:

Anmerkungen
Remarks

1	Alle eingesetzten Prüfmittel waren zum angegebenen Prüfzeitraum gemäß eines festgelegten Kalibrierungsprogramms unseres Prüfhauses kalibriert. Sie entsprechen den in den Prüfprogrammen hinterlegten Anforderungen. Die Rückverfolgbarkeit der eingesetzten Prüfmittel ist durch die Einhaltung der Regelungen unseres Managementsystems gegeben. Detaillierte Informationen bezüglich Prüfkonditionen, Prüfequipment und Messunsicherheiten sind im Prüflabor vorhanden und können auf Wunsch bereitgestellt werden. *The equipment used during the specified testing period was calibrated according to our test laboratory calibration program. The equipment fulfils the requirements included in the relevant standards. The traceability of the test equipment used is ensured by compliance with the regulations of our management system.* *Detailed information regarding test conditions, equipment and measurement uncertainty is available in the test laboratory and could be provided on request.*
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3	Prüfklausel mit der Note * wurden an qualifizierte Unterauftragnehmer vergeben und sind unter der jeweiligen Prüfklausel des Berichts beschrieben. Abweichungen von Prüfspezifikation(en) oder Kundenanforderungen sind in der jeweiligen Prüfklausel im Bericht aufgeführt. *Test clauses with remark of * are subcontracted to qualified subcontractors and descripted under the respective test clause in the report.* *Deviations of testing specification(s) or customer requirements are listed in specific test clause in the report.*
4	Die Entscheidungsregel für Konformitätserklärungen basierend auf numerischen Messergebnisen in diesem Prüfbericht basiert auf der "Null-Grenzwert-Regel" und der "Einfachen Akzeptanz" gemäß ILAC G8:2019 und IEC Guide 115:2021, es sei denn, in der auf Seite 1 dieses Berichts genannten angewandten Norm ist etwas anderes festgelegt oder vom Kunden gewünscht. Dies bedeutet, dass die Messunsicherheit nicht berücksichtigt wird und daher auch nicht im Prüfbericht angegeben wird. Zu weiteren Informationen bezueglich des Risikos durch diese Entscheidungsregel siehe ILAC G8:2019. *The decision rule for statements of conformity, based on numerical measurement results, in this test report is based on the “Zero Guard Band Rule” and “Simple Acceptance” in accordance with ILAC G8:2019 and IEC Guide 115:2021, unless otherwise specified in the applied standard mentioned on Page 1 of this report or requested by the customer. This means that measurement uncertainty is not taken in account and hence also not declared in the test report. For additional information to the resulting risk based of this decision rule please refer to ILAC G8:2019.*

TEST REPORT
ANSI/CAN/UL 9540:2023
STANDARD FOR SAFETY
Energy Storage Systems and Equipment

Report Number..... :	CN251VG2 001
Date of issue ..... :	see cover page
Total number of pages ..... :	see cover page
Testing Laboratory ..... :	TÜV Rheinland (Shanghai) Co., Ltd.
Address ..... :	No. 177, Lane 777, West Guangzhong Road, Jing'an District, Shanghai 200072, P. R. China
Applicant's name ..... :	AESC Jiangsu Co., Ltd.
Address ..... :	No.66 Shentai Road, Shengang Sub-District, Jiangyin City, Wuxi, 214000 Jiangsu Province, P.R. China
Test specification:	
Standard ..... :	ANSI/CAN/UL 9540:2023
Test procedure..... :	cTUVus mark approval
Non-standard test method……..:	N/A
Test Report Form No. ..... :	UL 9540_2023B
Test Report Form(s) Originator.... :	TÜV Rheinland (Shanghai) Co., Ltd.
Master TRF ..... :	Dated 2024-03

General disclaimer:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing Testing Laboratory. The authenticity of this Test Report and its contents can be verified by contacting the Laboratory responsible for this Test Report.

Test item description .....:	Lithium Ion Battery System
Trademark(s). .....:	AESC
Manufacturer .....:	See cover page
Model/Type reference. .....:	See cover page
Ratings .....:	See copy of marking label and model list

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

- Attachment 1: Photo documentation (5 pages);
- Attachment 2: Critical Components List (15 pages)

Summary of testing:

Tests performed (name of test and test clause):

Following tests performed during evaluation:

Clause(s)	Test(s)
☒ cl. 30	Normal Operations Test
☒ cl. 32	Dielectric Voltage Withstand Test
☒ cl. 33	Impulse Test
☒ cl. 34	Equipment Grounding and Bonding Test
☒ cl. 35	Insulation Resistance Test
☒ cl. 36	Electromagnetic Immunity Tests
☒ cl. 38	Leakage Tests
☒ cl. 39.3	Pneumatic strength Test
☒ cl. 41.2	Outdoors installations subject to moisture exposure
☒ cl 41.3	Outdoor installation in marine environments

The DUT was complied with the requirements of UL 9540:2023.

Test Location:

SRF (Changzhou) Testing Technology Co., Ltd.
No.27, Chuangzhi Road, Kunlun Street, Liyang, Jiangsu 213000, P. R. China

Test item particulars .....:	
Energy Storage System Technologies .....:	☒ Electrochemical ESS ☐ Chemical ESS
	☐ Mechanical ESS ☐ Thermal ESS
Output field wiring terminals .....:	☐ AC ESS ☒ DC ESS
Interaction .....:	☐ Standalone mode ☐ Utility grid interaction
	☐ Standalone and multi-mode
Installation of ESS .....:	☒ Stationary ☐ Mobile
	☐ For building-in ☐ Fixed
Environmental category .....:	☐ Indoor
	☒ Outdoor (Moisture exposure)
	☒ Outdoor (Marine environments)
	☐ In seismic environments
Access location ..... :	☒ Instructed person accessible
	☐ Walk-in Unit
	☐ Restricted access location
Considered current rating of protective device as part of the building installation (A) .....:	N/A
Overvoltage Category .....:	DC circuit: II AC circuit: III Control circuit: II
Pollution degree .....:	PD 3 (PD 2 inside)
Protection class of enclosure .....:	IP55
Chemical technology of Battery system .....:	Rechargeable Lithium-ion (LFP)
Heating / Cooling systems .....:	Liquid heating and cooling
Maximum energy capacity of individual electrochemical ESS (kWh) .....:	5030
Mass of equipment (kg) .....:	Approx 43000

Possible test case verdicts:	
- test case does not apply to the test object .....:	N/A
- test object does meet the requirement .....:	P(ass)
- test object does not meet the requirement .....:	F(ail)

Testing .....:	
Date of receipt of test item .....:	See cover page
Date(s) of performance of tests .....:	See cover page

General remarks:

"(See attachment #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.

Throughout this report a ☐ comma / ☒ point is used as the decimal separator.

Factory location: Envision Energy Co., Ltd. No.3 Shenzhuang Road, Linggang New City Low-Carbon Industrial Park, Shengang Street Jiangyin City, 214443 Jiangsu P.R. China
Purpose of This Report: cTÜVus Mark approval
Report History: N/A

Description of the product:

Product Description:

1- The EUT covered by this report is DC system for energy storage, which mainly consists of 6 battery racks in parallel connection, 1 liquid chiller, 1 air conditioning, fire protection, communication device and some auxiliary power supply components integrated in 1 container.

2- The battery rack is liquid cooling type, each rack consists of 8 battery packs and 1 control box in series connection. Each battery pack mainly consists of 104 cells structured with 52S2P, 1 MSD, 1 slave BMU and related connection parts. The slave BMU used for measuring and collecting the cell parameters of each pack and uploading to BCU in control box. The control box mainly consists of protective device such as relay, fuse, Isolating switch and master BCU function as the control unit for the battery system.

3- The input auxiliary power source system should be an TN-C-S type in end-installation specifed by the manufacture.

4- Suitable external overcurrent device and manual disconnect switch should be provided for both positive and negative of main battery circuit in end-installation.

5- The insulation between the hazardous voltage circuit and the grounded metal enclosure is basic insulation. And the insulation between the hazardous voltage circuit and communication circuit is reinforced insulation.

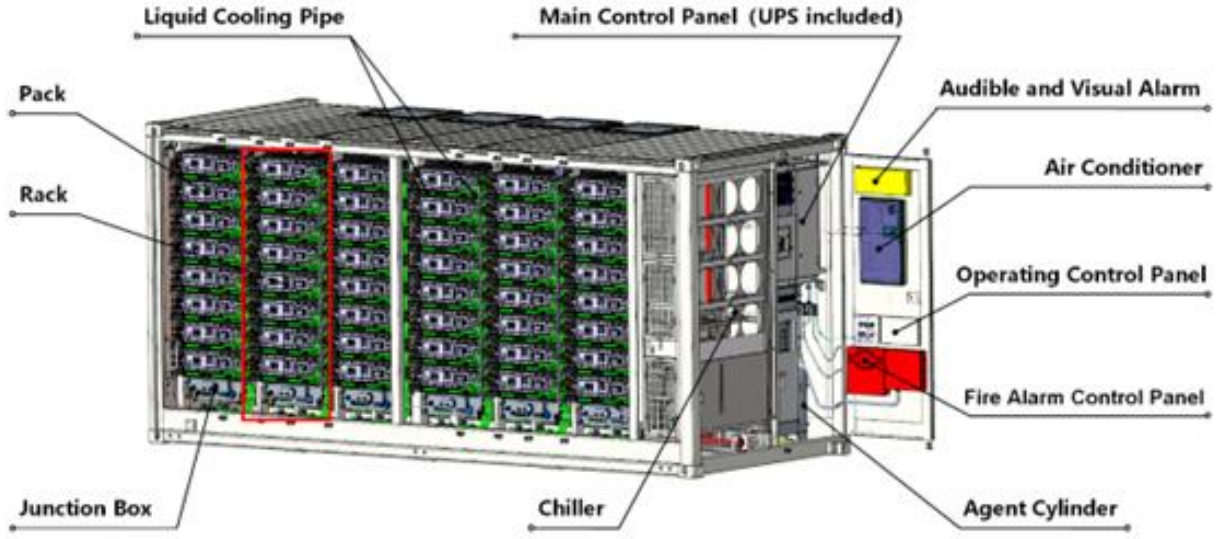
6- The battery system has overcharge, over-discharge, over current and short-circuits proof circuit. The electronic circuits and software controls for the battery system replied upon protective functions of the battery management system have been evaluated in accordance with IEC 60730-1 Annex H.

7- The EUT is outdoor type with IP55 degree, PD2 was evaluated for inside and PD3 for outside.

8- Overvoltage Category II was evaluated for the battery system, the battery system should isolate from an Overvoltage category III supply source to prevents transient overvoltage conditions in end-installation.

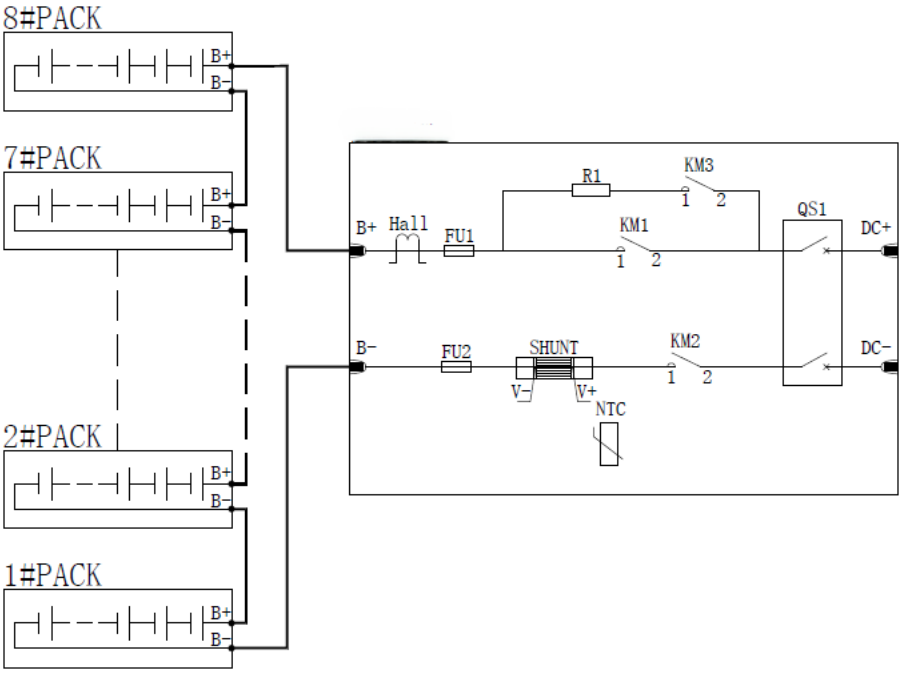
9- Suitable fire barriers or enclosure which comply with NFPA 855 should be provided and evaluated in the end-installation.

10- See below layout for detail structure.



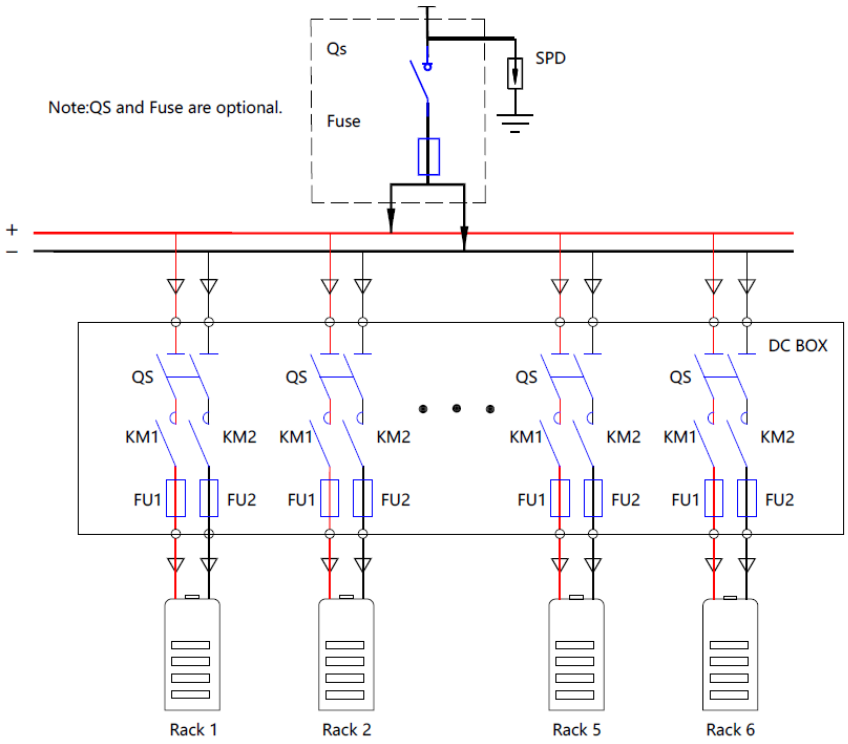
Layout for HE-L5030A

Block diagram for each battery rack:

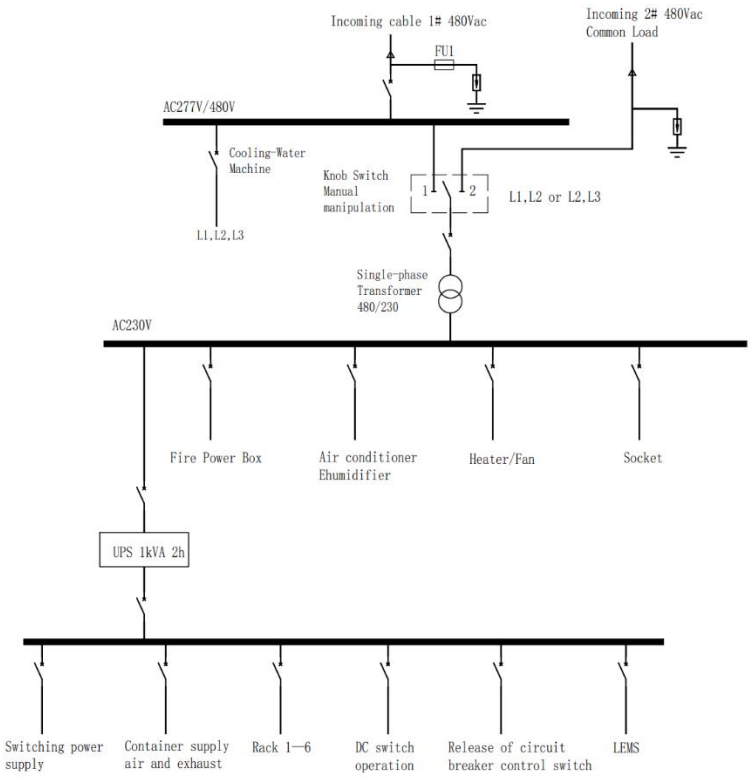


Main battery power

Block diagram for energy storage system:



Main battery power



Auxiliary power input for container

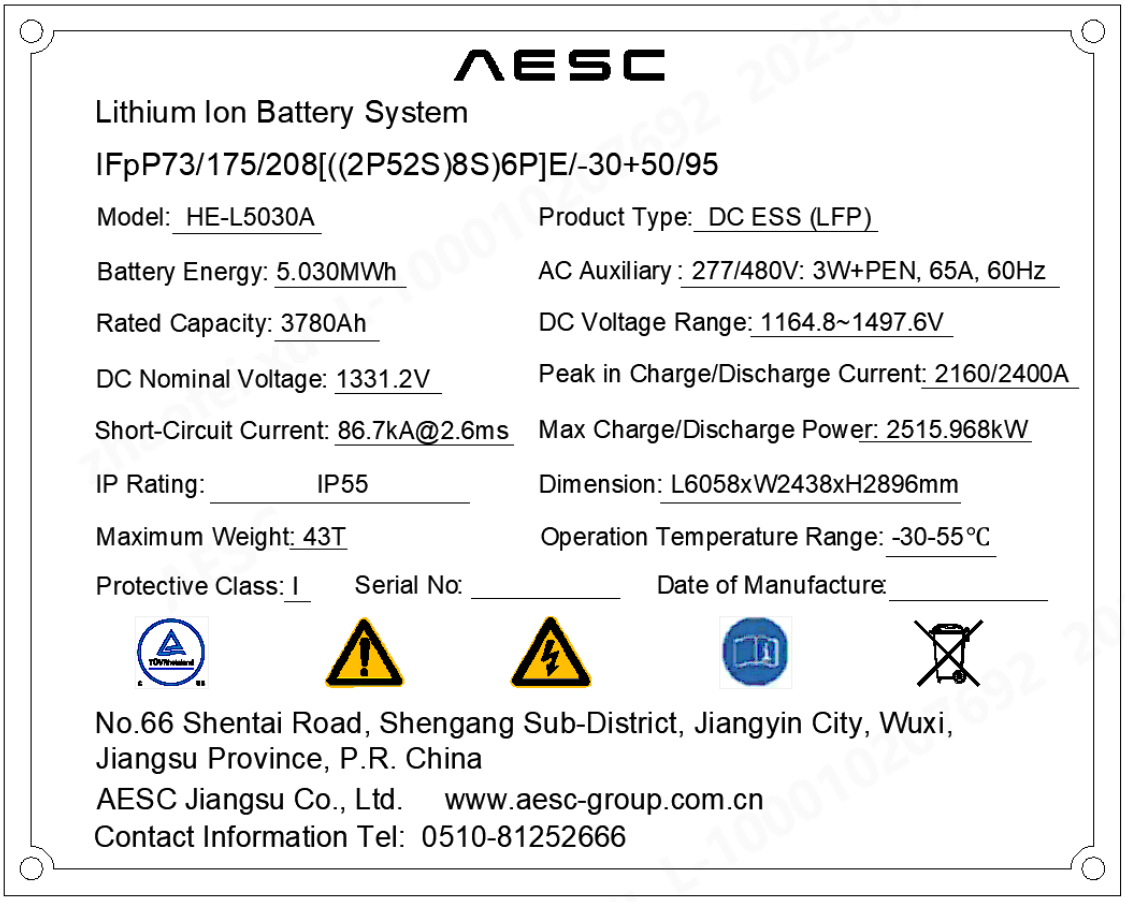
Model list for battery rack:

	Rechargeable Lithium-ion Cell	Lithium Ion Battery Pack	Lithium Ion Battery Rack
Type/model	HC-L315A	HP-L630B	HR-L630B
Battery Type	$LiFePO_4$		
Structure	-	52S2P	(52S2P)8S
Nominal Voltage [V]	3.2	166.4	1331.2
Rated Capacity [Ah]	315	630	630
Rated Energy [kWh]	1.008	104.832	838.656
Upper limit charging voltage [V]	3.65	189.8	1497.6
Discharging cut-off voltage [V]	2.5 (0<T≤60°C) 2.0 (-30<T≤0°C)	130.0	1164.8
Maximum continuous charge power [kW]	0.504	52.416	419.328
Peak current in charging [A]	201.6	403.2	360.0
Maximum continuous discharge power [kW]	1.008	52.416	419.328
Peak current in discharging [A]	201.6 (0<T≤60°C) 252.0 (-30<T≤0°C)	403.2	400.0
Charge range of ambient temperature [°C]	0 to 60	0 to 55	-30 to 55*
Discharge range of ambient temperature [°C]	-30 to 60	-30 to 55	-30 to 55
Weight [kg]	5.65±0.3	670±10	Approx 6000
Overall size: (L*W*H) [mm]:	71.8±0.6*174.26±0.6 *207.01±0.6	2214.6±5*794±5*246.2±5	Approx 2214±5*794±5*246.2±5
Enclosure Protection (IP)	-	IP67	IP20
Cooling Type	-	Liquid cooling (provide in end-installation)	
Altitude [m]	-	Below 2000	Below 2000
Note*: The system will not start charging until cell min temperature ＞0°C which controlled by BMS. External Heating device should be provided in end-installation for charging below 0°C.			

Model list for battery system:

	Lithium Ion Battery System
Type/model	HE-L5030A
Structure	((2P52S)8S)6P
Rated Energy [kWh]	5030
Battery Type	$LiFePO_4$
Rated Capacity [Ah]	3780
Maximum continuous charging/discharging power [kW]	2515.968
Peak current in charge [A]	2160
Peak current in discharge [A]	2400
Nominal Voltage [Vdc]	1331.2
Upper limit charging voltage [Vdc]	1497.6
Discharging cut-off voltage [Vdc]	1164.8
Charge range of ambient temperature [°C]	-30 to 55*
Discharge range of ambient temperature [°C]	-30 to 55*
AC auxiliary power input	277/480Vac, 3W+N+PE, 65A, 60Hz
Weight [kg]	Max 43000
Overall size: (L*W*H) [mm]:	6058*2438*2896
Enclosure Protection (IP)	IP55
Cooling Type	Liquid cooling and heating for battery Forced air cooling for distribution room
Protective class	I
Altitude [m]	Below 2000
Note*: The system will not start charging until cell min temperature > 0°C heating by liquid chiller which controlled by LEMS.	

Nameplate, Warning, and Label, etc.:



Label for HE-L5030A

Note: The “+, -” markings provide on the surface of product



SN rules:

For example: Year 25 means 2025. Month 10 means October.



Warning label for arc flash and PEE

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

INTRODUCTION			
1	**Scope**		**P**
1.1	The energy storage system is designed to receive and store energy, and consists of at least an energy storage function and energy storage protective function. The ESS can be an AC ESS or a DC ESS.	DC ESS	P
1.2	Standalone or utility interactive		P
1.3	Requirements for installation		P
1.4	Location of ESS (including indoor, outdoor, mobile ESS, residential and non-residential)	Outdoor	P
1.5	Systems using lead acid or Ni-cad batteries that fall within the scope of UL 1778/CSA C22.2 No.107.3 and only serve an uninterruptible power system (UPS) application are outside the scope of this Standard.		N/A
1.6	Maximum Energy Capacities: a) Residential use electrochemical ESS shall not exceed 20 kWh (72 MJ), and may be greater if ESS meets the UL 9540A Unit Level test requirements; b) Non-residential use electrochemical ESS shall not exceed 50 kWh (180 MJ), and may be greater if ESS meets the UL 9540A Installation Level test requirements and is marked in accordance with 45.20; c) No maximum energy capacity limit for non-residential use electrochemical ESS tested in accordance with UL 9540A and meeting the performance criteria for cell level testing; d) Non-residential electrochemical ESS for use in remote outdoor locations has no maximum energy capacity limit, and shall be marked in accordance with 45.21.	Refer to UL9540A report CN25EW8J 001.	P
2	**Components**		**P**
2.1	A component or equipment of an energy storage system covered by this Standard shall comply with the safety requirements for that component or equipment.	See attachment 2 CDF for details	P
3	**Units of Measurement**		**P**
3.1	Values and their respective units of measurement that are stated without parentheses constitute the requirement of the standard.		P
4	**Undated References**		**P**

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
4.1	Undated references imply the latest edition of the standard.		P
5	**Normative References**		**P**
5.1	Refer to Standard document for list of references.		P
6	**Glossary**		**P**
6.1-6.46	Refer to Standard for a list of definitions		P
CONSTRUCTION			
7	**Non-Metallic Materials**		**P**
7.1	a) The polymeric materials employed for enclosures shall comply with UL 746C, Path III of the Enclosure Requirements, or CSA C22.2 No. 0.17; and b) The enclosure shall be evaluated to meet the Unit Level performance criteria of UL 9540A.	Metal enclosure	N/A
	Exception: Equipment of a multi-part ESS that complies with the enclosure requirements in the appropriate standard for that equipment is not required to comply if the equipment enclosure is determined suitable for the intended environmental conditions that the ESS will be exposed to.		N/A
7.2	The following factors in (a) – (e) are taken into consideration about nonmetallic enclosure. a) Resistance to impact b) Crush resistance c) Abnormal operations d) Severe conditions; and e) Mold-Stress Relief Distortion		N/A
7.3	Additional properties about polymeric enclosures: a) Minimum 5VA flame rating b) Insulation material Property Considerations table UL 746C c) Strain-Relief Test after Mold Stress-Relief Distortion of UL 746C d) UV exposure test of UL 746C e) Water exposure and immersion test of UL 746C f) Conduit connections of UL 746C *Exception: 7.4*		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

7.4	The requirements in 7.3 do not apply to non-metallic parts forming part of the enclosure in any of the following conditions in accordance with UL 94 or CSA C22.2 No. 0.17: a) The part made of V-0, V-1, V-2, or HB-rated materials cover an opening no dimension greater than 25.4 mm (1 in.); b) The part made of V-0, V-1, V-2, or HB-rated materials cover an opening that do not give access to the user to hazardous live parts, when it is removed; c) The part made of V-0, V-1, V-2, or HB-rated materials cover an opening no dimension greater than 101.6 mm (4 in). There is no fire hazard closer than 101.6 mm (4 in) from the surface of the enclosure; or d) A barrier or device made of V-0 classed material between parts made of V-0, V-1, V-2, or HB rated material and the source of a fire risk.		N/A
	Exception: A part of a component is not required to be Classed V-0, V-1, V-2, or HB when it complies with the flammability requirements applicable to the component.		N/A
7.5	Materials employed as electrical insulation shall be resistant to deterioration that would result in an electrical shock, fire or other safety hazard. And shall comply with UL 746C. Insulated wiring is subjected to the requirements outlined in Section 11.		P
7.6	Gaskets and Seals relied upon for safety, shall be determined suitable for the environmental conditions and chemical substances they are anticipated to be exposed to in their end use.		N/A
7.7	Compliance with 7.6 for gaskets and seals relied upon to prevent ingress of moisture into the enclosure, can either comply with the Gaskets Tests Clause of UL 50E/CSA C22.2 No. 94.2 or comply with UL 157 or ASTM D412 for the anticipated exposures.		N/A
8	**Metallic Enclosures and Parts Resistance to Corrosion**		**P**
8.1	Metallic enclosure parts for BESS shall be of non-combustible materials; otherwise, it shall be evaluated to verify compliance with its performance criteria through UL 9540A Unit Level testing.		P
8.2	Metallic enclosures shall be corrosion resistant		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
8.3	Conductive parts with dissimilar metals in contact at terminals and connections shall not be subject to corrosion due to electrochemical action.		P
9	**Enclosures and Guarding of Hazardous Parts**		**P**
9.1	The enclosure(s) shall have the strength and rigidity required to resist the possible physical during its intended use. The enclosure strength requirements outlined in UL 50, UL 1741, IEC 62477-1, UL 2755, ISO 1496-1 or equivalent standard shall be applied to demonstrate compliance.		P
	Exception: For smaller systems that are less than or equal to 50 kWh, the enclosure strength may be evaluated to the enclosure requirements of this Standard and tested in accordance with the applicable tests of Section 40.		N/A
9.2	UL 2416 compliant rack assemblies that serve as the internal support structure for the ESS are used within the rated load range		N/A
9.3	Openings in the enclosure shall be designed to prevent inadvertent access to hazardous parts. For a minimum IP rating of IP2X with consideration of the end use installation.		P
	Exception: An Energy storage system intended for location in restricted access locations need not meet this accessibility criterion if provided with warning markings for service and other personnel having access to the system.		N/A
9.4	In service access areas, bare parts of hazardous voltage circuits, shall be located or guarded so that accidental shorting is unlikely		P
9.5	Enclosures of systems located where they will be subject to exposure to water and other elements shall be rated for the level of intended exposure		P
10	**General Electrical Safety of Systems and Additional Requirements for Walk-in Units**	Not a walk-in System	**N/A**
10.1	Instructions include measures and procedures for worker safety per NFPA70E, CSA Z462 and section 2 of the C22.1		N/A
10.2	Walk in enclosures have suitable mechanical load ratings for equipment and persons inside		N/A
10.3	Shipping container type enclosures if modified comply with ASTM D3169		N/A
10.4	The enclosures for outdoor walk-in units exceeding 53x8.5x9.5ft shall be evaluated as an indoor environment		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

10.5	Explosion venting system of walk-in unit shall comply with the applicable requirements in 24.5		N/A
10.6	Procedures for safe entry and exit		N/A
10.7	Personnel doors of walk-in units shall be designed to prevent persons from becoming trapped within the unit and shall be able to be opened from the inside without use of a tool or key.		N/A
10.8	Work space dimensions and requirements shall be in accordance with NFPA 70, or CSA C22.1, or in accordance with IEEE C2 as applicable to where the system is installed. The space requirement shall also provide for appropriate arc flash safety under specified personal protective equipment (PPE).		N/A
10.9	Areas of access shall be designed to prevent tripping, slipping or falling when persons enter, exit. Surfaces and parts within a walk-in unit shall be designed to prevent inadvertent hazards to personnel within the enclosure through appropriate guarding, electrical and thermal insulation methods and cautionary warnings and signage in accordance with this Standard.		N/A
10.10	Protection against contact with hazardous voltage parts in the energy storage system shall be in accordance with 9.3 or through the use of guarding to prevent access with cautionary warnings and signage where only qualified personnel are allowed access.		N/A
10.11	Type of protection shall be determined by an arc flash risk assessment conducted according to NFPA 70E and CSA Z462. The arc flash assessment results shall be labeled on the ESS.		N/A
10.12	Unprotected arc flash boundary shall be considered one that has an arc rating above 5 J/cm^2 (1.2 cal/cm^2) incident energy level		N/A
10.13	A fully walk in enclosure shall be designed to automatically provide mechanical ventilation using 100 % outdoor air.		N/A
10.14	Electrical circuits that are an integral part of the ESS including those that are part of a walk-in enclosure including lighting, controls, power, HVAC, emergency lighting, alarm circuits, and the like shall comply with the appropriate requirements for the type of equipment and the specific application within the ESS.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
10.15	Electrical equipment subject to condensation shall be suitable for outdoor use or suitably protected against contact with water and protected against unsafe conduction of hazardous voltages to personnel via water as a conduction path.		N/A
10.16	Lighting shall be supplied in enclosed working spaces in accordance with Article 410 of the NFPA 70 or Section 30 of CSA C22.1		N/A
10.17	ESS of more than one supply source shall be provided with information and markings to indicate which disconnect device or devices are required to be operated to completely isolate the equipment.		N/A
10.18	Protection against lightning surges in accordance with NFPA 70, CSA C22.1 or IEEE C2 as applicable		N/A
11	**Wiring and Electrical Supply Connections**		**P**
11.1	Wiring shall be insulated and acceptable for the purpose		P
11.2	Wiring methods and electrical supply connections of energy storage systems shall be in accordance with NFPA 70 or CSA C22.1, or IEEE C2 as applicable to where the system is installed.		P
11.3	An ESS shall have provision for connection of the system to an external wiring system consisting of:a) Wiring terminals or wiring leads; b) A means for connection of cable or conduit in accordance with the codes in 11.2.		P
11.4	A wiring terminal or lead that is supplied as a component of the ESS shall be rated and sized for connection to a field wiring conductor having an ampacity of no less than 125% of the ac or dc current that the circuit carries during rated conditions and in accordance with the codes in 11.2.		P
11.5	A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is to be connected, and shall not be smaller than 2.08 mm^2 (14 AWG). A field-wiring lead shall not be less than 152.4-mm (6-in) long.		P
	Exception No. 1: Communications cable may be less than 2.08 mm^2 (14 AWG).		P
	Exception No. 2: Field wiring harness accessories supplied by the manufacturer and evaluated for use with the system.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

11.6	Field-wiring compartments, in which branch circuit connections are to be made, shall: a) Permit the connection of the supply wires after the ESS is installed; b) Permit the connection to be introduced and connected easily and safely; and c) Be located so that the connections can be readily inspected after the ESS is installed.		P
11.7	Internal wiring shall be routed, supported, clamped or secured in a manner that reduces the likelihood of excessive strain on wire and on terminal connections; loosening of terminal connections; and damage of conductor insulation.		P
11.8	A hole by which insulated wires pass through the system enclosure or elements providing separation within the enclosure shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, to prevent abrasion of the insulation.		P
11.9	Where multiple conductors are installed in parallel, they shall be installed in groups consisting of not more than one conductor per phase, neutral or ground so that the current in each group sums to zero. Where conductors pass through a metal opening, all conductors in a group shall pass through the same opening.		N/A
12	**General Electrical Equipment**		**P**
12.1	Replaceable fuses marking with the fuse ratings & type shall be located adjacent to each fuse or fuse holder. Information on proper fuse shall also be included in the routine service manual instructions.		P
12.2	A hazardous voltage ESS shall have a manual disconnect to prevent inadvertent access to hazardous voltage parts during servicing. If not provided, the installation instructions shall indicate the type and ratings of the disconnect to be provided in the installation and how it is to be installed in accordance with NFPA 70E and CSA Z462.		P
12.3	Fuses, circuit breakers and disconnect devices shall be rated for the application.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
12.4	Transformers installed as part of the ESS shall be of the dry type or type filled with a non-combustible dielectric medium. Such transformers shall be installed in accordance with the requirements of NFPA 70 or CSA C22.1, or in accordance with Section 15 of IEEE C2 as applicable to where the system is installed.		N/A
12.5	Oil filled transformers shall be permitted for use in outdoor locations in accordance with the applicable local codes or utility requirements.		N/A
12.6	Convenience receptacles provided for maintenance and servicing of the ESS shall be rated for outdoor use if the system is intended to be installed where the receptacle is exposed to the outdoor environment or outdoor environmental conditions.		N/A
12.7	The inverter and other equipment connected to the output terminals of the battery or other storage device of the ESS shall be able to safely withstand the potential short circuit current from the storage device. The rated input short circuit current of the inverter and other equipment shall be equal to or greater than the rated output short circuit current of the battery or other energy storage mechanism. Compliance can be determined through evaluation of the output short circuit ratings of the energy storage mechanism (e.g., for the battery) as determined by testing in UL 1973.		P
13	**Electrical Spacings and Separation of Circuits**	See appended table Cl.13	**P**
13.1	Electrical circuits within the ESS at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits or potential for arc flash.		P
13.2	Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in Table 13.1 or as outlined in UL 62368-1/CSA C22.2 No. 62368-1, Clearances, Clause 5.4.2, and Creepage Distances, Clause 5.4.3.	Comply with UL 62368-1	P
	Exception No. 1: The spacing requirements in UL 840, CSA C22.2 No. 62109-1, UL 62109-1, IEC 60664- 1, or CSA C22.2 No. 0.2, shall be acceptable alternatives. The anticipated pollution degree and overvoltage category is determined by the design and application of the ESS assembly or subassembly under evaluation.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 2: Electrical spacings within components and parts of an ESS previously determined to comply with an appropriate safety standard for the equipment need not be evaluated.		P
13.3	Under voltages above 60 volts DC or 30 volts AC, if the insulating compound is completely filled within the enclosure and the insulation layer is at least 0.4 millimeters thick, providing supplementary or reinforced insulation, and the components have passed the dielectric withstand test, then there are no minimum clearance requirements for these parts. For circuits at or below 60 volts DC, as well as for basic or functional insulation, there are no minimum insulation thickness requirements.		N/A
13.4	Conductors of circuits operating at different voltages shall be reliably separated from each other through the use of mechanical securements unless they are each provided with insulation acceptable for the highest voltage involved.		P
14	**Insulation Levels and Protective Grounding**		**P**
14.1	Hazardous voltage circuits shall be insulated from accessible conductive parts and SELV circuits as outlined in 14.2 through the following: a) Basic insulation and provided with a protective grounding system for protection in the event of a fault of the basic insulation that complies with 14.3; b) A system of double or reinforced insulation; or c) A combination of (a) and (b).		P
14.2	Safety extra low voltage (SELV) circuits, as defined in 6.40, that are insulated from accessible conductive parts through functional insulation only are considered accessible.		P
14.3	Accessible non-current carrying metal parts that could become live in the event of an insulation fault shall be bonded to the equipment ground terminal.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
14.4	The methods of protective bonding and grounding of an ESS shall be in accordance with Article 250 of NFPA 70 or Section 9 of IEEE C2 as applicable to where the system is located. When sizing the protective bonding and grounding wire, the rating and fault current path of all sources of supply connected to the equipment or system shall be considered. If used, grounding (bonding) braids used in the ESS or from the ESS to the grounding electrode shall comply with UL 467/CSA C22.2 No. 41, and sized according to the Grounding – Size of Terminal or Bonding Conductor requirements of UL 508A or CSA C22.1. In Canada, the methods of bonding and grounding an ESS shall be in accordance with Section 10 and 36 of CSA C22.1.		P
14.5	Parts of the protective grounding system shall be securely fastened and provided with metal-to-metal contact that will ensure the continuity of the grounding system.		P
14.6	With reference to 14.5, when connecting conductive parts to be bonded, paint or coatings in areas of contact shall be removed or paint piercing lock washers shall be used with securement bolts or screws to provide good metal to metal contact.		P
14.7	With reference to 14.5, methods of securement considered reliable and ensuring good metal-to-metal contact can consist of the following methods: a) Terminal blocks; b) Pressure connectors, grounding lugs and similar grounding and bonding equipment connectors; c) Fusion welding processes; d)Machine screw-type fasteners that engage not less than two threads or are secured with a nut; and e) Thread-forming machine screws that engage not less than two threads in the enclosure.		P
14.8	For ESS greater than 100 V between conductors or to ground, the battery circuits can be ungrounded if the system is provided with a ground fault detector and indicator to monitor ground faults.		N/A
15	**Safety Analysis and Control Systems**		**P**

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
15.1	ESS shall be provided with a safety analysis such as a failure modes and effects analysis (FMEA) that identifies critical safety components and circuits of the system. Guidance for analysis can be found in the following standards: a) IEC 60812 b) IEC 61025; and c) MIL-STD-882E.		P
15.2	When conducting this analysis, it is important that the interaction of the various parts of the ESS be evaluated as noted in 15.1 to determine that there are no hazards introduced in the system as a result of their interaction.		P
15.3	Mechanical, thermal and other hazards besides electrical to be considered.		P
15.4	Analysis of thermal ESS shall ensure that there is sufficient monitoring and control of pressure, thermal and fluid flow to ensure that the various parts of the system are maintained within their specifications for pressure temperature and fluid levels.		N/A
15.5	Electrical and electronic controls of the ESS that are determined to be critical for safety shall comply with an appropriate safety standard for the control and used within their ratings. Electronics and software controls determined to be critical for safety are to be tested to verify electromagnetic immunity in accordance with Section 36 if this testing is not part of the functional safety standard requirements, and shall be evaluated for functional safety to one of the following sets of standards and safety ratings as applicable to the system: a) UL 991 and UL 1998; b) CSA C22.2 No. 0.8 (Function Class B requirements); c) The Annex for Requirements for Electronic Controls, Annex H of UL 60730-1 or CSA E60730-1 (Function Class B requirements); d) IEC 61508 (all parts) (minimum of Safety Integrity Level (SIL) "2" requirements for active protective devices with software controls); e) ISO 13849-1 and ISO 13849-2 (minimum of Performance Level (PL) "c" requirements for active protective devices with software controls); or f) ISO 26262 (all parts) (minimum Automotive Safety Integrity Level (ASIL) "C" requirements for active protective devices with software controls).	Evaluated with UL 60730-1 Annex H	P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
15.6	Required SIL, PL, or ASIL for a safety function shall be permitted to be reduced if the manufacturer provides additional safety analysis.		N/A
15.7	Considering interaction of the various parts of the system for their impact on each other. In particular, a number of disruptive interactions shall be considered in all cases.		P
15.8	Software that can be updated remotely to meet the requirements outlined in Section 16.		N/A
16	**Remote Software Update Enabled ESS**	No such function	**N/A**
16.1	Critical and/or critical supervisory software (UL 1998)		N/A
16.1.1	The requirements in 16.1.2 – 16.1.7 apply when the manufacturer declares the ESS has critical and supervisory and related critical supervisory sections of software per UL 1998, and has the functionality to remotely update this software.		N/A
16.1.2	The critical/supervisory sections of UL 1998 software, intended to be updated, shall comply with UL 1998.		N/A
16.1.3	User authorization is required prior to any remote update of critical/supervisory sections of UL 1998 software.		N/A
16.1.4	The remote update of software shall occur when the ESS is in a risk addressed state.		N/A
16.1.5	The remote software update shall comply with UL 5500		N/A
16.1.6	The correct operation of the ESS safety functions shall be maintained after the critical/supervisory sections of software in accordance with UL 1998 software is updated.		N/A
16.1.7	Functional test of a remote software update using the procedure outlined in Operational Verification of Remote Software Update Capability in 36.9 after implementing a remote software update.		N/A
16.2	Class B software (UL 60730-1 or CSA E60730-1)		N/A
16.2.1	The ESS has Class B software in accordance with UL 60730-1 or CSA E60730-1, and has the functionality to remotely update this software.		N/A
16.2.2	The requirements for Controls Using Software in UL 60730-1 or CSA E60730-1 are met.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
16.2.3	The remotely actuated control function, including the software update function, shall comply with the requirements for Remotely Actuated Control Functions in UL 60730-1 or CSA E60730-1.		N/A
16.2.4	Remotely actuated control functions may be connected to separate, independent devices, which may themselves contain control functions or provide other information. Any data exchange between these devices shall not compromise the integrity of the Class B control function.		N/A
16.2.5	User authorization is required prior to any remote update of Class B software, UL 60730-1 or CSA E60730-1.		N/A
16.2.6	The remote update of software shall occur when the ESS is in a risk addressed state.		N/A
16.2.7	The correct operation of the ESS's safety functions shall be maintained after the Class B software is updated per UL 60730-1 or CSA E60730-1.		N/A
16.2.8	A functional test of a remote software update using the procedure outlined in Operational Verification of Remote Software Update Capability in 36.9 after implementing a remote software update.		N/A
17	**Remote Controls**	No such function	**N/A**
17.1	Energy storage systems which have the ability to be controlled and operated remotely shall be provided with an accessible means to disconnect the system from the remote control for maintenance or other local servicing of the system.		N/A
17.2	Remote disconnect controls marking		N/A
18	**Communication Systems**		**P**
18.1	General		P
18.1.1	Communication protocols used by ESS for communication between its various parts and the grid shall be in accordance with those of the intended grid application.		P
18.2	External warning communication system (EWCS)		P
18.2.1	Electrochemical ESS using lithium-ion batteries have an energy capacity of 500 kWh or greater shall be provided with an external warning communication system		P

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Clause	Requirement + Test	Result - Remark	Verdict
18.2.2	The information inputs to the EWCS comes from the battery management systems (BMS) or the energy storage management system (ESMS)		P
18.2.3	The EWCS shall communicate with an operator station and be capable of sending information to an external operating station.		P
18.2.4	The EWCS and the sources providing information to the EWCS shall be evaluated as part of the safety analysis of the system		P
18.2.5	The EWCS shall be installed as an integral component of the ESS. It can be supplied by the lithium batteries it is monitoring, but the EWCS shall also have a dedicated backup power source independent of the batteries it is monitoring to prevent data to and from the EWCS being lost or interrupted as part of the primary power source failure, or delayed by more than 10s. The backup power source shall be capable of providing power for at least 5h for the data input and operator communication portion of the system. This back power source need not supply any visual or audible sirens supplied as a part of the system for more than 5 min.	UPS battery used for backup power source with enough backup time.	P
18.2.6	Instructions of the EWCS including its back up power source shall be provided. If installed indoors, the instructions shall reference the Notification Appliances Chapter of NFPA 72. Visual alarms shall be in accordance with UL 1638, and audio alarms shall be in accordance with UL 464/ULC 525 with the maximum sound level not exceed 110 dBA at the minimum hearing distance. For outdoor installations, visible alarms installed on the ESS, shall be located no less than 203.2 cm (80 in) nor more than 243.8 cm (96 in) above the ground.		P
19	**Heating and Cooling Systems**		**P**
19.1	ESS that relies upon integral thermal management systems to prevent overheating or operation outside the specified safe operating range, shall be designed to safely shutdown upon failure of the thermal management system.		P
20	**Piping Systems, Pressure Vessels, Fuel and Other Fluid Supply Connections and Controls**		**P**
20.1	Piping systems, pressure vessels, fuel and other fluid supply connections and controls shall comply with 20.2 – 20.10.		P
	Exception No. 1: Systems that are evaluated as part of a battery to UL 1973 need not comply with 20.2 – 20.10.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

	Exception No. 2: Coolant systems can be evaluated to the performance requirements of the Specific Requirements for Liquid Cooled PDS clause in UL 61800-5-1 or CSA C22.2 No. 61800-5-1.		N/A
20.2	Piping systems utilized to carry fluids in an ESS such as water, heated air, fuel gases, etc. shall comply with ASME B31 (all applicable parts), or CSA B51, or CSA B52, or CSA Z662, or CSA B149.1 as applicable.		P
20.3	Pressure vessels and related equipment including pressure relief devices that fall under the scope of ASME BPVC, or CSA B51, shall comply with the applicable requirements.		P
20.4	Flammable fuel supply connections on the ESS shall be suitable for the material contained and in accordance with the applicable part of ASME B31 based upon the fluid, temperatures and pressures they are subjected to.		N/A
20.5	A means shall be provided to prevent backflow of process gases, etc. into the fuel supply lines either as part of the ESS design or indicated in the installation instructions.		N/A
20.6	The ESS shall be designed so that process water used in the system shall be prevented from contaminating potable water sources in accordance with local regulations through the use of check valves or other means as part of the system design.		P
20.7	Piping, hose, and tubing containing fluids, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard (e.g. liquid leaking onto electrical circuits that can lead to short circuits). Pressure relief valves shall be located so that fluids are not directed toward live parts or safety critical circuits should they operate.		P
20.8	Coolant leaks shall be detected, and a warning signal shall be sent to the ESS monitoring and control system, as well as an alarm if provided.		P
20.9	Manual shut off valves shall be provided on or near the ESS. If not provided, installation instructions shall indicate type, ratings and location for installation of appropriate manual shut off valves.		P
20.10	Pressure regulators used on flammable or other hazardous gas lines shall comply with UL 252, CSA Z662, or CSA B149.1, as applicable.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

21	**Containment of Moving Parts in Mechanical ESS**		**N/A**
21.1	Moving parts shall be provided with a means to contain the parts in the event they could become loosened during operating.		N/A
21.2	The alternator/generator elements associated with mechanical ESS shall comply with UL 1004-1 and other parts (UL 1004-2, UL 1004-3, UL 1004-5, UL 1004-6, UL 1004-7, UL 1007-8, UL 1004-9) as applicable or CSA 22.2 No. 100.		N/A
22	**Noise Levels**		**P**
22.1	The noise level shall be limited to an 8-hr time-weighted average of 85 dBA when tested in accordance with 29 CFR 1910.95 (C)(1)(2). Systems that have noise levels in excess of this limit shall be provided with warning labels and instructions.	Less than 85dBA	P
23	**Hazardous Fluid Control**		**N/A**
23.1	Where the system contains fluid in excess of 208 L (55 gal) in a single vessel or an aggregate of more than 3785 L (1000 gal), secondary containment shall be provided. Methods utilized for spill control shall be sufficient to contain all of the fluid from the largest liquid vessel within the system and designed to prevent inadvertent filling with rain if located outdoors. Where flammable liquids are contained, any applicable fire detection and protection systems shall be specified or included as determined per Section 26. The spill control system shall accommodate additional water from any specified fire protection system for a period of 10 min. Automatic leak detection to annunciate the spillage of fluid shall be provided.		N/A
	Exception: If containment is not provided as part of the product, then instructions regarding the need to provide containment, fire detection and protection systems and leak detection shall be included in the instruction manual. The instructions shall also specify the minimum volume of the containment and information about compatibility of the containment system with the fluid to be contained. See 46.12.		N/A
23.2	Systems containing conductive fluids shall be designed in a manner to prevent the fluids from causing a short circuit in the event of a spill. If spill control is not provided, then the instruction manual shall provide directions on the spill control system design to prevent any short circuits from fluid spilled.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
23.3	Neutralization of spills of any hazardous fluids shall be provided if necessary to insure compatibility with any materials the fluids may contact when in the spill control system.		N/A
	Exception: If neutralization is not provided as part of the product, then instructions regarding the need to provide neutralization shall be included in the instruction manual. The instructions shall also specify the type and quantity of neutralizing material required to meet the requirements of 23.3. See 46.12.		N/A
23.4	Energy storage systems that contain fluids shall be designed to prevent venting of toxic vapors in concentrations considered to be hazardous based on an evaluation conducted in accordance with Sections 38 and 39.		N/A
24	**Combustible Vapor Concentrations**		**P**
24.1	Enclosures or areas that contain flammable fluid systems or batteries that vent hydrogen to the atmosphere shall be ventilated to prevent hazardous concentrations of flammable materials.		P
	Exception: Vented battery systems with aqueous electrolytes such as lead acid or nickel cadmium that are provided with ventilation openings in their enclosures in accordance with 24.3, need not comply.		N/A
24.2	Electrochemical ESS which are not addressed in 24.1 and which are dependent on mechanical ventilation as a protection measure against emission of flammable gas that can occur during fault conditions to prevent hazardous gas concentrations within the system, shall be equipped with a fault detection system that activates the mechanical ventilation in a manner which prevents the LFL from exceeding 25% in any non-hazardous area/zone within the ESS.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
24.3	For ESS that contain batteries or similar storage devices, openings to prevent hazardous concentrations of flammable gases within an enclosure can be used. Openings in the enclosure provided for ventilation shall be constructed to prevent accumulation of flammable gases that could lead to a hazardous condition from concentrations of hydrogen gas due to electrolysis of aqueous electrolytes for applicable battery technologies, such as vented or valve regulated lead acid and nickel batteries and applicable electrochemical capacitor technologies, greater than 25% of the LFL of hydrogen (equivalent to 1 % concentration in a volume of air).		P
24.4	As an alternative to 24.3, ventilation openings shall have a minimum opening area of: $A = 0.005NC_5 (cm^2)$ Where: A = Total cross sectional net free area of ventilation openings required (cm2) N = Number of cells in battery C5 = Capacity of battery at the 5-h rate (Ah)		P
	Exception: The area of ventilation openings can be reduced if it can be demonstrated that there is sufficient ventilation within the battery to prevent hydrogen accumulations above 25 % of the LFL of hydrogen.		P
24.5	Electrochemical ESS with integral enclosures where there is the potential for a flammable gas concentration within the enclosure from an abnormal condition shall be provided with deflagration or explosion protection in accordance with NFPA 68 or NFPA 69.	See NFPA 68 report: CN25WYUH 001, NFPA 69 report: CN25XMAG 001 for details.	P
	Exception No. 1: The protection is not required if the testing in accordance with UL 9540A with a deflagration hazard analysis demonstrates that the concentration of flammable gas measured during testing remains under 25 % LFL within the room, building, ESS cabinet, or walk-in ESS and there is no potential for partial volume deflagration.		N/A
	Exception No. 2: For ESS cabinets/enclosures, protection other than as noted can be used if it has been determined that the ESS cabinet/enclosure has been designed to effectively protect against hazards due to combustible concentrations when the ESS has been tested in accordance with the Unit Level or Installation Level test of UL 9540A.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
24.6	Portions of ESS, in which flammable vapor concentrations above 25 % LFL may be present during normal operating conditions, shall be provided with construction suitable for the classification in accordance with NFPA 70, CSA C22.1, or IEEE C2 as applicable to the intended installation.		P
24.7	Electrical compartments adjacent to classified zones within the ESS enclosure shall be maintained at positive pressure in accordance with NFPA 497, UL 60079-2 or CSA C22.2 No. 60079-2.		N/A
25	**Flammable Solids**		**N/A**
25.1	ESS containing hazardous solids (i.e. pyrophoric or water reactive metals) shall be designed and installed in accordance with NFPA 484.		N/A
26	**Fire Detection, Suppression and Propagation**		**P**
26.1	General		P
26.1.1	Fire detection and fire suppression equipment provided as an integral part of an ESS shall comply with applicable product safety standards and shall be installed in accordance with the applicable safety product standards and the manufacturer's instructions.		P
26.1.2	Energy storage systems with integral fire detection or fire suppression systems shall be provided with instructions for installing, commissioning, maintaining and testing these systems in accordance with applicable installation codes and standards. NFPA 1 and ICC IFC provide information on applicable requirements and codes for fire suppression systems. See also Appendix A.		P
26.1.3	If an integral fire detection or fire suppression system optional the ESS meets applicable requirements with or without it.		P
26.2	Large Scale Fire Testing	Refer to UL9540A report CN25EW8J 001	P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
26.2.1	Electrochemical type ESS, including but not limited to capacitor and battery ESS, shall be subjected to the large-scale fire testing in accordance with UL 9540A as follows in (a) – (d). a) Systems with increased energy capacities as required in codes and standards; b) Systems with decreased separation distances to adjacent ESS units, doors and windows, or exposures. See 46.2 and/or 46.4; c) Indoor systems; or d) Systems for installation in dwelling units (where permitted).		P
26.2.2	ESS for habitable or living space meet UL 9540A cell level test requirements		N/A
26.2.3	Electrochemical ESS intended for use in dwelling units where UL 9540A testing is indicated per the codes and standards, shall minimally meet the Unit Level Performance Criteria for residential installations identified in UL 9540A with a test that aligns with the manufacturer's installation instructions. These ESS shall be marked in accordance with 45.3(e)(3).		N/A
26.2.4	Electrochemical ESS intended for non-residential use shall be subjected to specific large scale fire testing in accordance with UL 9540A for installations described in the manufacturer's instructions.		P
27	**Power Conversion Equipment**		**N/A**
27.1	General	No PCS	N/A
27.1.1	Inverters, chargers, and charging charge control equipment that are part of an energy storage system shall be designed and rated for use with the battery system employed in the energy storage system and evaluated to UL 1741, UL 62109-1 or CSA C22.2 No. 62109-1, UL 1012, UL 62368-1/CSA C22.2 No. 62368-1, or CSA C22.2 No. 107.1 as applicable to the power conversion equipment and its application in the system.		N/A
	Exception: UL 1778/CSA C22.2 No. 107.3 may be used as an alternative to the power conversion and charger equipment standard references if applicable to the ESS application serving an uninterruptible power system (UPS).		N/A
27.2	Utility Grid Interaction		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
27.2.1	Energy storage systems intended to export energy to the electric power systems (EPS)/electric utility shall be designated as utility-interactive, grid support utility-interactive, or special purpose utility interactive and shall utilize the appropriately evaluated power conditioning systems. See 6.41, 6.44, and 6.45.		N/A
27.2.2	The inverter shall be designed to properly interconnect with the particular energy storage technology it is connected to as determined by the system safety analysis.		N/A
27.2.3	Products that rely upon internal or external utility interconnection protection functions or devices shall be specifically identified for the particular product in the ESS instructions.		N/A
27.3	Utility grid interactive inverter		N/A
27.3.1	A utility-interactive inverter, grid support utility-interactive inverters, or subassembly of an ESS shall comply with UL 1741, UL 62109-1 or CSA C22.2 No. 62109-1, or CSA C22.2 No. 107.1.		N/A
27.3.2	Utility-interactive ESS inverters shall be evaluated for compliance with additional utility interactive document(s) and standard(s) if those specific documents or requirements are referenced in the product ratings or instructions.		N/A
27.4	Standalone and multi-mode power conditioning systems		N/A
27.4.1	Power conditioning systems for standalone and multi-mode applications shall comply with UL 1741, UL 62109-1 or CAN/CSA C22.2 No. 62109-1, or CSA C22.2 No. 107.1.		N/A
28	**Energy Storage System Technologies**		**P**
28.1	Electrochemical ESS		P
28.1.1	Batteries, electrochemical capacitors, hybrid battery-capacitor systems or flow batteries used in an electrochemical ESS shall comply with the requirements of UL 1973. Testing and evaluation of the battery system, which would include the battery and its battery management system is conducted as part of evaluation to UL 1973.	Refer to UL1973 report CN25IV58 001	P
	Exception: For valve regulated or vented lead acid or nickel cadmium battery systems, see Annex D for an alternative approach.		N/A
28.2	Chemical ESS	Electrochemical ESS	N/A
28.2.1	Fuel cell systems that are part of a chemical ESS shall comply with CSA FC 1, Fuel Cell Power Systems.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
28.2.2	Stationary engine generators that are part of a chemical ESS shall comply with UL 2200 or CSA C22.2 No. 100, and CSA C22.2 No. 286.		N/A
28.2.3	Water electrolysis type hydrogen generators used in an energy storage system to provide hydrogen for storage shall be evaluated and found to be in compliance to an appropriate safety standard for the equipment.		N/A
28.2.4	Hydrogen fuel containing parts of a chemical energy storage system shall be constructed of materials suitable for gaseous hydrogen service at the pressures and temperatures of use. Pressure vessels used for storage of gaseous hydrogen and piping employed as part of a chemical energy storage system shall comply with Section 20.		N/A
28.3	Mechanical ESS	Electrochemical ESS	N/A
28.3.1	Mechanical ESS such as, but not limited to, flywheel systems or compressed air energy storage (CAES) systems shall be evaluated to determine that hazards associated with moving parts with the capacity to store kinetic energy, and high pressure and high temperature fluids contained in the system are mitigated. Compliance is determined by evaluation to the requirements of this Standard.		N/A
28.3.2	Flywheel systems and other systems with moving parts with the capacity to store kinetic energy shall comply with the Containment of Moving Parts tests of Section 37 and the Strength Tests of Section 39. Parts containing hazardous fluids shall comply with the Leakage Tests of Section 38 and the Strength Tests of Section 39.		N/A
28.3.3	Flywheel energy storage devices with a maximum surface speed of 200 m/s or less fall within standard electric generator design practice and shall be evaluated in accordance with the Standard for Electric Generators, UL 1004-4 or the Standard for Motors and Generators, CSA 22.2, No. 100.		N/A
	Exception: In some cases, flywheel energy storage systems with maximum surface speeds of 200 m/s or less may have features such as magnetic bearings that are not commonly found on ordinary electric machines as covered in UL 1004-4 or CSA 22.2, No. 100. The safety of these features shall be evaluated and tested to all applicable requirements in this Standard.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
28.4	Thermal ESS	Electrochemical ESS	N/A
28.4.1	A thermal ESS consists of gases, fluids, and/or solids storing heat energy that can be turned into electrical energy when needed through the use of energy conversion equipment (e.g. engines, generators).		N/A
28.4.2	Thermal ESS shall be evaluated to determine hazards associated with containment of high temperature and high pressure and potentially hazardous fluids are mitigated. Compliance is determined by evaluation to the requirements of this Standard. Parts containing hazardous fluids and fluids at high temperatures and pressures shall comply with the Leakage Tests of Section 38 and the Strength Tests of Section 39.		N/A
28.4.3	Stationary engine generators that are part of a thermal ESS shall comply with UL 2200 or CSA C22.2 No. 100, and CSA C22.2 No. 286. Generators that are part of a thermal ESS shall comply with UL 1004-4 or CSA C22.2 No. 100.		N/A
28.4.4	Hazardous fluid containing parts of a thermal ESS shall be constructed of materials suitable for use with that fluid at the pressures and temperatures of use. Pressure vessels used for storage and piping employed as part of a thermal ESS shall comply with Section 20. Stresses on containment parts associated with swings of high and low temperature extremes shall be considered when evaluating the suitability.		N/A
28.4.5	Containment systems for combustible materials (solids or fluids) shall be designed to prevent the potential for explosion hazards as a result of contact with moisture, contaminants, etc.		N/A
28.4.6	A thermal ESS shall have sufficient pressure controls, fluid level controls and temperature controls to prevent the potential for a hazardous condition from occurring through an out of specification operation. Compliance is determined through the safety analysis of the system and the functional safety investigation of the controls per Section 15 and the abnormal operations tests for thermal ESS in accordance with Section 31.		N/A
PERFORMANCE			
29	**General**		**P**
29.1	To be tested and determined compliant to an applicable technology safety standard. Where no applicable safety standard exists, they are to be tested in accordance with this standard.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
29.2	All tests, unless noted otherwise, are conducted in a room ambient 25 ± 5°C (77 ± 9°F).		P
29.3	Temperature shall be measured using thermocouples consisting of wires not larger than 0.21 mm2 (24 AWG) and not smaller than 0.05 mm2 (30 AWG). Measuring junction of the thermocouple held tightly against the component/location being measured.		P
29.4	The test area should be well ventilated and testers should observe safety regulations and not approach the DUT until the temperature of the test specimen has returned to ambient room temperature.		P
ELECTRICAL TESTS			
30	**Normal Operations Test**	See appended table Cl.30	**P**
30.1	A normal operations test can be waived for equipment of an ESS where a similar evaluation such as a temperature test has already been conducted under the specific technology standard.		P
30.2	An ESS is operated through a maximum of 2 cycles of charge and discharge of the system under maximum loading conditions.		P
	Exception: Normal operations testing on a subassembly may be conducted instead of the complete ESS if through analysis it can be determined to be representative of the ESS.		N/A
30.3	During the test, consideration shall be given to maximum and minimum room ambient conditions. During operation, temperatures on critical components that are temperature sensitive shall be monitored and operating parameters of components of the system monitored to determine that they are operating within their ratings. If the ESS is intended for mounting on a wall, it shall be mounted as intended in accordance with installation instructions on a flat wall in an alcove that is painted a dull black, and temperatures shall be monitored on the wall surfaces during the test.		P
30.4	During the normal operations test, the manufacturer's specified limits shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications in accordance with Table 30.1. Temperatures on accessible surfaces of the ESS shall not exceed the limits in accordance with Table 30.2.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

31	**Abnormal Operation Tests for Thermal Energy Storage Systems**	**Electrochemical ESS**	**N/A**
31.1	General		N/A
31.1.1	Thermal ESS shall remain in a safe state should the thermal controls, fluid controls or pressure controls of the system fail.		N/A
31.2	Failure of thermal controls		N/A
31.2.1	The thermal ESS shall be operated during charging and discharging with a single fault within the thermal control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.		N/A
31.2.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the test, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.		N/A
31.3	Exposure to out of specification thermal conditions		N/A
31.3.1	The thermal ESS shall be subjected to a temperature condition outside of the operating specifications of the system to determine if the controls will prevent an over temperature condition or other condition that could lead to a hazard. The ESS or a representative subassembly shall be subjected to an ambient of 70 °C (158 °F) or 20 °C (36 °F) above the maximum specified operating ambient, whichever is higher and then an ambient of -30 °C (-22 °F) or 20 °C (36 °F) below the lowest specified operating ambient, whichever is lower. The ESS shall be operated during this conditioning.		N/A
31.3.2	As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids. Thermal controls shall prevent the system from operating outside of safe limits.		N/A
31.4	Failure of pressure controls		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
31.4.1	The thermal ESS shall be operated during charging and discharging with a single fault within the pressure control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.		N/A
31.4.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.		N/A
31.5	Failure of fluid controls		N/A
31.5.1	The thermal ESS shall be operated during charging and discharging with a single fault within the various fluid level control systems relied upon for safety. Examples of these systems can include a gas system used to provide an inert atmosphere within containment chambers, a liquid leak control, etc. The test shall be repeated with the single fault in each separate fluid level control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.		N/A
31.5.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.		N/A
32	**Dielectric Voltage Withstand Test**		**P**
32.1	The dielectric voltage withstand test is an evaluation of the electrical spacings and insulation associated with the hazardous voltage circuits within the DUT.		P
32.2	Circuits at 42.4 Vpeak/ 30 Vrms or 60 Vdc or higher shall be subjected to a dielectric withstand voltage in accordance with the “Determining clearances using required withstand voltage” clause of UL 62368-1/CSA C22.2 No. 62368-1.	See appended table Cl.32&33 for details.	P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 1: Semiconductors or similar electronic components liable to be damaged by application of the test voltage shall be bypassed or disconnected.		P
	Exception No. 2: The dielectric voltage withstand test need not be conducted on integral ESS, fuel cells, and inverter systems, etc. that have already been evaluated in accordance with their individual standard requirements. Only those electrical parts external to the tested systems and their connections not previously evaluated need to be tested.		P
32.3	The voltage applied during the dielectric voltage withstand test is to be applied between the hazardous voltage circuits of the DUT and accessible non-current carrying conductive parts.		P
32.4	The voltage applied during the dielectric voltage withstand test is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the DUT.		P
32.5	The voltages applied during the dielectric voltage withstand test shall be applied for a minimum of 1 min.		P
32.6	The test equipment shall consist of a 500 VA or larger capacity transformer, the output voltage, which is variable and which is essentially sinusoidal if using ac test method, a dc output if using a dc test method. There is no trip current setting for the test equipment since the test is checking for insulation breakdown, which results in a large increase of current. Setting a trip current may result in a false failure of this test, as it is not necessarily indicative of insulation breakdown.		P
	Exception: A 500 VA or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.		P
32.7	There shall be no evidence of a dielectric breakdown as evidenced by an appropriate signal from the dielectric withstand test equipment as a result of the applied test voltage. Corona discharge or a single momentary discharge is not regarded as dielectric breakdown.		P
33	**Impulse Test**	See appended table Cl.32&33 for details.	**P**

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
33.1	The impulse voltage test is intended to evaluate the energy storage system's ability to withstand lightning or similar surges. Systems provided with protection that has already been evaluated for voltage surges (e.g. inverters meeting the Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE 1547 criteria) need not be tested.		P
33.2	The impulse voltage test shall be performed with an impulse generator able to provide voltage having a 1.2/50 µs waveform at voltages in accordance with Table 33.1, and is intended to simulate an overvoltage condition due to lightning or switching of equipment.		P
33.3	Pulses shall be applied at 1.2/50 µs for each polarity in ≥ 1s time intervals at the peak voltage for the rating of the circuit under test ± 5 % per Table 33.1. The test voltage is to be applied between the terminal/circuit under test and accessible parts. For circuits at 1000 V or less, three pulses at each polarity shall be applied. For circuits over 1000 V, 5 pulses at each polarity shall be applied.		P
	Exception: Impulse test levels can be based on the transient voltage surge suppression device rating if provided.		P
33.4	No insulation puncture, flashover, or spark-over		P
34	**Equipment Grounding and Bonding Test**	See appended table Cl.34	**P**
34.1	The impedance of the system grounding and bonding circuit shall be determined using one of the following methods: a) The circuit between the grounding terminal and the part to be grounded is measured using impedance measuring equipment; b) In accordance with the Continuity of the Equipment Grounding Circuit section, Section 18.2 of NFPA 79 (voltage drop measurement of the circuit using a 10 A low voltage supply source); or c) In accordance with test in the "Resistance of the Protective Bonding System" clause, Clause 5.6.6 of UL 62368-1/CSA C22.2 No. 62368-1 (measuring voltage drop in circuit using a low voltage supply source providing a current based upon circuit protection rating). d) The fault loop impedance measurement in accordance with IEC 60364-4-41.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
34.2	The impedance for all grounding and bonding circuits tested shall not exceed 0.1 Ω, or if using the test method in 30.1(d), the compliance criteria shall be in accordance with IEC 60364-4-41.		P
35	**Insulation Resistance Test**	See appended table Cl.35	**P**
35.1	The resistance of insulation used on hazardous voltage circuits within an ESS shall be greater than or equal to 1 MΩ.		P
35.2	The insulation resistance shall be measured using high impedance measuring equipment (e.g. mega ohmmeter) while applying a voltage of 500 Vdc between the live parts of the circuit under test and accessible conducting parts including the equipment grounding circuit, for 1 min.		P
	Exception No. 1: Energy storage systems need not be tested if the insulation resistance has been previously evaluated as part of the particular technology safety standard.		N/A
	Exception No. 2: The insulation resistance test of IEC 60364-6 can be conducted instead.		N/A
	Exception No. 3: This test can be waived if the permanently connected wiring has: *a) A cross-section of the protective earthing conductor of at least 10 mm2 if copper, or 16 mm2 if aluminum; or* *b) Provision of an additional terminal for a second protective earthing conductor of the same cross- sectional area as the original protective earthing conductor and installation instructions requiring a second protective earthing conductor to be installed.*		N/A
	Exception No. 4: The touch current measurement test of IEC 62040-1 may be conducted instead.		N/A
35.3	Resistor(s) and/or resistor networks may be removed when conducting the insulation resistance test.		P
36	**Electromagnetic Immunity Tests**	Tested as required	**P**
36.1	General		P
36.1.1	Electronics and software controls determined to be critical for safety shall demonstrate sufficient immunity to electromagnetic interference by complying with the tests specified in these sections.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
	Exception: This testing does not apply to controls within components of the ESS that have already been evaluated for EMI exposure in accordance to their applicable component standard such as UL 1741 for power conditioning systems.		P
36.1.2	Each test begins with an operation unit		P
36.1.3	The DUT shall be operated in mode(s) that include the safety function(s) being evaluated. If multiple modes are to be considered (example: equipment controlling the charging and discharging of the energy storage device), the DUT shall either be cycled through those modes during the tests, or the tests repeated in each mode. While cycling through modes, the DUT shall not exhibit any signs of loss of safety functions or risk of fire, electric shock, or personal injury.		P
36.1.4	After each test in this section, the DUT shall be inspected to verify that it is still operational. This may require Operational Verification (36.8) of the DUT if it is not possible to determine that it is fully operational by inspection. If the DUT is no longer operational, a failure analysis shall be conducted to determine the reason for the failure and to verify that the DUT has failed safely. A DUT that is no longer operational shall not be used on any remaining test.		P
36.1.5	All samples used comply with section 36.8 after the test.		P
36.2	Electrostatic Discharge		**P**
36.2.1	The DUT shall demonstrate immunity to electrostatic discharges in accordance with the test procedure specified in IEC 61000-4-2 and the modes of operation stated in 36.1.3.		P
36.2.2	The following test levels shall be used: a) ±6 kV contact discharge; and b) ±8 kV air discharge.		P
36.2.3	Complies with 36.1.4 after test		P
36.3	Radio-frequency electromagnetic field		**P**
36.3.1	The DUT shall demonstrate immunity to radio-frequency electromagnetic fields in accordance with the test procedure specified in IEC 61000-4-3 and the modes of operation stated in 36.1.3.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
36.3.2	The following test levels shall be used: a) 10 V/m from 80 MHz to 1 GHz, 1 kHz (80% AM); and b) 3 V/m from 1.4 GHz to 6.0 GHz, 1 kHz (80% AM).		P
36.3.3	During the test compies with 36.1.3		P
36.3.4	After test complies with 36.1.4		P
36.4	Fast transient/burst Immunity		**P**
36.4.1	The DUT shall demonstrate immunity to electrical fast transients/bursts in accordance with the test procedure specified in IEC 61000-4-4 and the modes of operation stated in 36.1.3.		P
36.4.2	The following test levels shall be used: a) On signal/control ports intended to be connected to cables longer than 3 m (118.1 in), ±1 kV (5/50 ns, 5 kHz); capacitive clamp shall be used; b) On input and output DC ports, ±1 kV (5/50 ns, 5 kHz); and c) On input and output AC ports, ±2 kV (5/50 ns, 5 kHz).		P
36.4.3	With reference to 36.4.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.4.2(c). External accessible DC ports shall be conducted using the test level specified in 36.4.2(b).		P
36.4.4	After test complies with 36.1.4		P
36.5	Surge Immunity		P
36.5.1	The DUT shall demonstrate immunity to surges in accordance with the test procedure specified in IEC 61000-4-5 and the modes of operation stated in 36.1.3.		P
36.5.2	The following test levels shall be used: a) For I/O signal/control ports intended to be connected to long-distance cables longer than 30 m (1181.1 in), which leave the building, and/or are for outdoor use, ±1 kV line-to-ground; b) For input and output DC ports, ±0.5 kV line-to-line, and ±1 kV line-to-ground; and c) For input and output AC ports, ±1 kV line-to-line, and ±2 kV line-to-ground.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
36.5.3	With reference to 36.5.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.5.2(c). External accessible DC ports shall be conducted using the test level specified in 36.5.2(b).		P
36.5.4	After test complies with 36.1.4		P
36.6	Radio Frequency Common Mode		P
36.6.1	The DUT shall demonstrate immunity to radio-frequency conducted disturbances in accordance with the test procedure specified in IEC 61000-4-6 and the modes of operation stated in 36.1.3.		P
36.6.2	The following test levels shall be used: a) For I/O signal/control ports intended to be connected to cables longer than 3 m (118.1 in), 10 V(150 kHz to 80 MHz, 1 kHz, 80% AM); b) For input and output DC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80% AM); and c) For input and output AC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80% AM).		P
36.6.3	With reference to 36.6.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.6.2(c). External accessible DC ports shall be conducted using the test level specified in 36.6.2(b).		P
36.6.4	During test complies with 36.1.3		P
36.6.5	After test complies with 36.1.4		P
36.7	Power Frequency Magnetic Field		**P**
36.7.1	The DUT shall demonstrate immunity to power-frequency magnetic fields in accordance with the test procedure specified in IEC 61000-4-8 and the modes of operation stated in 36.1.3.		P
36.7.2	Test level 10 A/m		P
36.7.3	During test complies with 36.1.3		P
36.7.4	After test complies with 36.1.4		P
36.8	Operational Verification		P
36.8.1	After the tests in 36.2 – 36.7 have been completed, all samples used during these tests shall comply with the following.		P
36.8.2	The manufacturer shall declare the anticipated performance of all safety functions performed by electronics and software controls.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
36.8.3	The manufacturer shall provide test procedures to verify that each of the safety functions performed by electronics and software controls is working correctly. This may include, for example, verification of correct safety function performance by simulation.		P
36.8.4	During the test procedures specified in 36.8.3, each DUT shall exhibit one of the following behaviors: a) No loss of safety functions; or b) Transition to an appropriate state to ensure safe operation of the DUT.		P
36.9	Operational verification of remote software update capability	No such function.	N/A
36.9.1	The test of 36.8 shall be conducted on safety controls intended for remote software updates in accordance with Section 16 to ensure that they are operational after the update. See 16.1.7 and 16.2.8.		N/A
MECHANICAL TESTS			
37	**Containment of Moving Parts**	**No such part.**	**N/A**
37.1	Control system fault overspeed test		N/A
37.1.1	An ESS with moving parts having the capacity to store kinetic energy that is capable of being subjected to overspeed conditions through a fault in the system controls shall be subjected to an overspeed test.		N/A
37.1.2	The system controls shall be subjected to single fault in the controls that would allow overspeed of the moving parts. The DUT shall be operated at overspeed conditions until a secondary protection control operates to stop operation of the DUT.		N/A
37.1.3	As a result of the overspeed condition, the moving part(s) shall not become loosened or disconnected in a manner that would result in a hazardous condition. If completely loosened or disconnected as a result of the overspeed conditions, the containment means shall safely contain the part(s) in accordance with the Faulted Securement Test in 37.2.		N/A
37.1.4	The system controls shall limit the overspeed to a level less than the speed defined in 37.4.		N/A
37.2	Faulted securement test		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
37.2.1	An ESS with moving parts with the capacity to store kinetic energy shall be subjected to the faulted securement test when a fault in primary securement means of the moving part has the potential to result in a hazard.		N/A
37.2.2	The moving parts of the system shall be subjected to a single fault of the primary means of securement while operated at the maximum speed anticipated during normal operation. The primary means of securement to be removed, such as a failed bearing, shaft, or other part of the securement of the moving part with respect to the stationary housing, shall be determined through a safety analysis that identifies failure of the selected means as representing the potential worst case condition. Refer to Section 15 for the safety analysis requirements.		N/A
37.2.3	This test is not required in cases where test or field data is available to support the safety analysis indicating that there is not a hazard associated with the loss of primary securement.		N/A
37.2.4	The system shall be operated until one of the following occurs: a) The part has operated for 30 min under the faulted condition; b) A protection control operates to stop operation of the DUT or hazardous moving part; or c) The part has loosened and is completely or partially disconnected from its securement means.		N/A
37.2.5	As a result of the operation with a faulted securement condition, the moving part(s) shall not become loosened or disconnected to result in a hazardous condition. If completely loosened or disconnected, the containment means for the part shall safely contained the part(s).		N/A
37.3	Blocked Shaft Test		N/A
37.3.1	An ESS with moving parts with the capacity to store kinetic energy shall be subjected to the blocked shaft test if blocking the shaft or moving parts has the potential to result in a hazard.		N/A
37.3.2	With the moving part blocked to prevent movement, the system shall be operated at the maximum ratings allowed for a zero speed condition.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
37.3.3	The system shall be operated: a) With the part blocked for 30 min and then stopped; b) Until a protection control operates to stop operation of the DUT with the blocked part; or c) Until any moving parts break off or become completely or partially disconnected from its securement means.		N/A
	Exception: Moving parts already evaluated for blocked shaft conditions as part of a component evaluation, need not be tested.		N/A
37.3.4	As a result of operating the system with a blocked shaft/moving part condition, the part shall not become loosened or disconnected to result in a hazardous condition. If the part becomes completely loosed or disconnected, the containment means for the part shall safely contain the part(s). There shall be no overheating of parts that will result in a hazard such as fire or explosion.		N/A
37.4	Mechanical integrity Test		N/A
37.4.1	An ESS with any moving part having the capacity to store kinetic energy shall have the mechanical (i.e. rotating) energy storage elements designed to have a minimum margin factor of safety. The factor of safety requirements vary depending on the material of construction. The factor of safety based on material type shall be as follows: a) For assemblies composed of laminated composite materials, the minimum factor of safety shall be at least 2.0 between the maximum principal stress that exists at the point of highest stress in each layer of the mechanical energy storage element and the ultimate strength of that layer at that point. b) For assemblies composed of ductile metallic materials exhibiting a traditional nonlinear stress-strain curve, the minimum factor of safety shall be at least 1.3 between the maximum von Mises stress that exists anywhere in the mechanical energy storage element. c) For other material types and combinations of materials including metals and laminated composites, the minimum factor of safety shall be at least 2.0 between the maximum combined stress that exists anywhere in the mechanical energy storage element at maximum normal operating speed.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
37.4.2	The mechanical energy storage element shall be subjected to an overspeed type test demonstrating the required factor of safety. The DUT shall be representative of the latest design revision and subjected to an overspeed and corresponding stress as follows in (a) or (b). For the purpose here, rotor working stress is presumed to scale exactly as the square of the rotation speed. a) Where the minimum required factor of safety is 2.0, the overspeed shall be at least 139 %. The DUT shall sustain the overspeed for a time period of 1 min without ruptures in of any part of the assembly. b) Where the minimum required factor of safety is 1.3, the overspeed shall be 120 % minimum. The DUT shall sustain the overspeed for a time period of 1 min.		N/A
37.4.3	With reference to 37.4.2, for a hollow cylindrical mechanical energy storage element, as an alternative to the dynamic test, a static test (e.g. hydrostatic or pneumatic strength test) may be performed whereby the DUT is subjected to an internal pressure that creates maximum stress in the DUT that is greater than 2x the maximum stress under normal operating conditions.		N/A
37.4.4	With reference to 37.4.2 and 37.4.3, the mechanical energy storage element DUT shall: a) Be a production mechanical energy storage element; b) Be according to the latest design revision; and c) Meet the manufacturer's quality assurance requirements for production units.		N/A
37.4.5	Alternative to 37.4.2		N/A
37.4.6	With reference to 37.4.1 – 37.4.5, the testing shall be repeated in the event of a deviation of any mechanical characteristic or material property that results in an increase of more than 10 % between calculated stress in production energy storage elements and demonstrated stress in the previously qualified mechanical energy storage element.		N/A
37.5	Bearing Failure Test		N/A
37.5.1	An ESS with moving parts with the capacity to store kinetic energy that relies upon a primary set of bearings in its moving mechanism, in any form, shall be subjected to a bearing failure test if failing the bearings has the potential to result in a hazard. Refer to Section 15 for the safety analysis requirements.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
37.5.2	With the system operating at maximum operating conditions, a failure in the primary bearings shall be induced that results in the loss of the primary bearing function and forces the DUT to spin down on its backup bearing or other suitable support system.		N/A
37.5.3	The system shall be operated: a) Until the DUT's energy is dissipated and it has come to a stop; b) Until a protection control operates to stop operation of the DUT; or c) Until any moving parts break off or become completely or partially disconnected from its securement means.		N/A
37.5.4	This test is intended to verify that the backup bearing or support system for the energy storage element is effective. This test may also suffice as the faulted securement test described in 37.2 if the safety analysis indicates a bearing failure as the worst case condition.		N/A
37.5.5	As a result of operating the system with a failed bearing condition, the moving parts shall not become loosened or disconnected to result in a hazardous condition. If the part becomes completely loosed or disconnected, the containment means for the part shall safely contain the part(s). There shall be no overheating of parts that will result in a hazard such as fire or explosion.		N/A
38	**Leakage Tests**		**P**
38.1	Energy storage systems that utilize liquid coolant or contain hazardous fluids shall be subjected to the Leakage Test in accordance with 38.2 and 38.3.		P
	Exception: Leakage testing need not be conducted if parts containing hazardous fluids and their connections have already been evaluated for external leakage as part of a component standard such as the appendix for Test Program for Flowing Electrolyte Batteries, Appendix C, of UL 1973 or CSA FC 1 for fuel cell systems.		N/A
38.2	Leakage from ESS containing hazardous fluids shall not result in the risk of fire, electric shock, or injury to persons.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
38.3	Compliance is determined by subjecting the fluid-containing parts and their connections to a fluid pressure of 1.5 times the maximum operating pressure (if testing with liquid) or 1.1 times the maximum operating pressure (if air pneumatic testing) of intended use during operation of the system. There shall be no leaks from fluid-containing parts or their connections as a result.		P
39	**Strength Tests**		**P**
39.1	General		P
39.1.1	Energy storage systems that contain hazardous fluids shall comply with the Strength Tests in accordance with 39.2 and 39.3.	39.3 Tested	P
39.2	Hydrostatic Strength Test		N/A
39.2.1	Parts of the ESS containing hazardous fluids (gases or liquids) shall be subjected to a hydrostatic strength test of 1.5 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either the liquid used in the system or water. Testing is done at room ambient temperature.		N/A
39.2.2	As a result of the hydrostatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.		N/A
39.3	Pneumatic Strength Test		P
39.3.1	The pneumatic strength test is an alternative to the hydrostatic strength test of 39.2 and is conducted in accordance with 39.3.2.		P
39.3.2	Parts of the ESS containing hazardous fluids (gases or liquids) shall be subjected to a pneumatic strength test of 1.3 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either air or inert gas. Testing is conducted at room ambient temperature.		P
39.3.3	As a result of the pneumatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.		P
40	**Enclosure and Mounting Tests**		**N/A**
40.1	Wall Mount Fixture/Test		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
40.1.1	A wall mounting apparatus of a wall mounted ESS shall have sufficient strength to support the system. Compliance is determined by the following test.		N/A
	Exception: Individual components of an ESS that are provided with their own wall mount apparatus previously tested as part of their component evaluation, need not be tested.		N/A
40.1.2	The wall mounting apparatus and ESS shall be installed in accordance with the manufacturer's specifications. A force equal to three times the weight of the ESS is additionally applied to the center of the mounting apparatus in a downward direction. The force shall be held for 1 min.		N/A
40.1.3	As a result of the applied force, there shall be no damage to the mounting apparatus and its securement means when testing the wall mounting fixture.		N/A
40.2	Enclosure impact		**N/A**
40.2.1	This test is to evaluate the mechanical integrity of the enclosure and its ability to provide mechanical protection to the ESS enclosure contents. This test is conducted on electrochemical ESS that are for residential applications or for non-residential applications that are less than or equal to 50 kWh.	Greater than 50 kWh.	N/A
40.2.2	A fully charged DUT shall be subjected to a minimum of three impacts of 6.8 J (5 ft-lb) on any surface that can be exposed to a blow during intended use. The impact shall be produced by dropping a steel sphere, 50.8 (2 in) in diameter, and weighing 535 g (1.18 lb) from a height, H, of 1.29 m (50.8 in). For surfaces other than the top of an enclosure, the steel sphere shall be suspended by a cord and swung as a pendulum, dropping through the vertical height of 1.29 m (50.8 in), with the product being impacted placed against a restraining vertical wall. See Figure 40.1. A different sample may be used for each impact.		N/A
40.2.3	After the impacts, the DUT shall be subjected to a test in accordance with Section 32. The DUT shall be examined for signs of rupture or damage that could lead to a hazard.		N/A
40.2.4	As a result of the impact test, there shall be no damage to the enclosure that could result in a hazard such as exposure of hazardous parts or result in a dielectric breakdown.		N/A
40.3	Enclosure steady force	Greater than 50 kWh.	**N/A**

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
40.3.1	The purpose of this test is to determine if the enclosure has sufficient strength to safely withstand a static force that may be applied to it. This test is conducted on electrochemical ESS that are for residential applications or for non-residential applications that are less than or equal to 50 kWh.		N/A
40.3.2	The enclosure of a fully charged DUT shall withstand a steady force of 250±10 N (56.2 lbf ±2.25 lbf) for a period of 5 s, applied in tum to the top, bottom and sides of the enclosure fitted to the DUT, by means of a suitable test tool providing contact over a circular plane surface 30 mm (1.2 in) in diameter.		N/A
40.3.3	The DUT shall be subjected to a test between live parts and the enclosure in accordance with Section 32. The DUT shall be examined for signs of rupture or damage that could lead to a hazard.		N/A
40.3.4	As a result of the steady force test, there shall be no damage to the enclosure that could result in a hazard such as exposure of hazardous parts or result in a dielectric breakdown.		N/A
40.4	Mold stress	Metal enclosure	N/A
40.4.1	The purpose of this test is to determine if an enclosure made from molded polymeric material can withstand an accelerated aging test without compromising the safety of the enclosure.		N/A
40.4.2	One complete fully discharged sample shall be placed in a full-draft circulating-air oven maintained at a uniform temperature of at least 10°C (18°F) higher than the maximum temperature of the enclosure measured during the Normal Operations Test in Section 30， but not less than 70°C (158 °F). The sample shall remain in the oven for 7 h.		N/A
40.4.3	After removal from the oven the DUT shall be subjected to a test in accordance with Section 32. The DUT shall be examined for signs of rupture and damage.		N/A
40.4.4	As a result of the mold stress conditioning, the sample shall show no evidence of mechanical damage, such as cracking of the enclosure exposing hazardous parts or result in a dielectric breakdown.		N/A
ENVIRONMENTAL TESTS			
41	**Special Environmental Installations**		**P**
41.1	General		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
41.1.1	Energy storage systems intended for installation in special environments shall be evaluated for their ability to operate safely in those environments. These environmental conditions can include exposure to salt fog for marine environments, testing for seismic ratings, high altitudes, etc. The requirements of 41.2, 41.3 and 41.4 shall apply depending upon the particular exposure. The installation instructions and nameplate labels on the ESS shall identify the special environmental conditions in accordance with 45.3, 45.17, and Section 46.		P
	Exception No. 1: Testing need not be conducted on systems or parts of the system if already covered as part of the specific technology safety standard.		P
	Exception No 2: Environmental testing on a subassembly may be conducted instead of the complete ESS if through analysis it can be determined to be representative of the ESS. The rationale used to determine the suitability of the subassembly to represent the complete ESS shall be documented.		P
41.2	Outdoor Installations subject to moisture exposure		P
41.2.1	Energy storage systems intended for installation outdoors where they will be subject to rated levels of moisture exposure shall be tested in accordance with their environmental ratings outlined in their nameplate labels and installation instructions of 45.17 and 46.13.		P
41.2.2	Based upon the ratings of the system, moisture resistance testing shall be done in accordance with either IEC 60529, UL 50E, or C22.2 No. 94.2.	IP55	P
41.2.3	At the conclusion of the test, the sample is to be subjected to the electric insulation tests of Sections 32 and 35 and examined for signs of water in the system that could result in a hazardous condition.		P
41.2.4	As a result of the water exposure, there shall be no evidence of water on parts that could result in a hazard and no reduction of spacings or breakdown/deterioration in insulation levels.		P
41.3	Outdoor installation in marine environments		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
41.3.1	Energy storage systems intended for installation outdoors in marine environments in accordance with the installation instructions in 46.13 where they will be subject to salt fog exposure, shall be tested as outlined below.		P
41.3.2	The systems shall be tested in accordance with IEC 60068-2-52 for Severities 1 or 2.	Severities 2 tested.	P
41.3.3	At the conclusion of the testing, the systems shall be subjected to the electrical insulation tests of Sections 32 and 35 to determine that insulation has not been damaged in a manner that would result in an electric shock hazard.		P
41.3.4	The system shall be examined for signs of damage as a result of salt exposure that would indicate a potential for a safety hazard (e.g. corrosion of parts that could result in weakening of a securement or an enclosure, damage to insulation). If operational, the system is to be operated to determine that it can do so without hazard.		P
41.3.5	As a result of the test, the ESS shall not show evidence of damage from salt fog exposure that could result in a hazard such as electrical, shock, overheating or damage that could result in a physical hazard.		P
41.4	Installation in seismic environments	Not intend used in seismic environments.	N/A
41.4.1	Equipment of an ESS that contains the energy storage mechanism and is intended for installation where they will be subject to seismic activity shall be evaluated and if necessary tested in accordance with their seismic ratings and installations instructions per 45.3 and 46.13. The installation instructions shall indicate the limitations of the particular seismic rating of the equipment. Standards that provide guidance on seismic evaluation such as IEEE 693, IEC 60980, ICC IBC, the seismic testing in GR-63-CORE, or similar, shall be used for this evaluation. Compliance is determined through review of documentation of the seismic evaluation for the appropriate seismic level (i.e. level marked on the equipment) or through testing for the specific seismic level in accordance with a testing standard for this purpose.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 1: There is equipment that cannot be practically evaluated by testing alone because of the size of the equipment. For those situations, it may be necessary to do a combination of analysis with testing of parts of the system. This approach is outlined in IEEE 344.		N/A
	Exception No. 2: Some standards allow for calculations and modelling as an approach for determining compliance for seismic ratings in lieu of testing.		N/A
41.4.2	The ESS shall be examined for signs of explosion, fire, combustible concentrations (if applicable to technology), rupture of the enclosure, electrolyte leakage, electric shock and loss of protection controls that lead to any of the other non-compliant results in 41.4.3.		N/A
41.4.3	As a result of the test, any of the following results in (a) – (g) are considered a non-compliant result: a) Explosion; b) Fire; c) Combustible Concentrations (if applicable to technology); d) Rupture (enclosure); e) Electrolyte Leakage (external to enclosure); f) Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown); g) Loss of protection controls.		N/A
MANUFACTURING AND PRODUCTION TESTS			
42	**Electrical Production Tests**		**P**
42.1	Dielectric Voltage Withstand Test		P
42.1.1	A dielectric withstand test as outlined in the Dielectric Voltage Withstand Test in Section 32 shall be conducted on 100 % production of ESS with working voltage exceeding 60 Vdc or 30 Vrms/42.4 Vpeak.		P
	Exception No. 1: The time for the production Dielectric Withstand Test can be reduced to 1 s.		P
	Exception No. 2: Testing can be conducted on subassemblies of the system.		P
	Exception No. 3: Testing can be waived if conducted as part of the specific technology evaluation (i.e. tested per UL 1973, etc.).		P
42.2	Grounding and Bonding system Check		**P**

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
42.2.1	The grounding and bonding system of an ESS shall be subjected to a check using an impedance measuring device. The measurements shall occur between any two locations of the grounding and bonding system.		P
42.2.2	No resistance measurements of the grounding and bonding system shall exceed 0.1 Ω or allowed limits per 34.2.		P
	Exception: This testing can be waived if it is determined that the ESS construction and production methods to ensure good grounding and bonding of the system production can be determined through a review of production practices. However, if any point of the grounding system is maintained through a single fastener, a ground bond test shall be conducted.		N/A
42.3	Check of Safety Controls		P
42.3.1	Energy storage systems shall be subjected to 100% production screening to determine that any active controls utilized for safety are functioning.		P
	Exception: This check of the safety controls can be conducted on subassemblies or components of the system before final assembly.		P
43	**Mechanical Production Tests**		**N/A**
43.1	Integrity at Maximum Abnormal Operating Speed	Electrochemical ESS.	N/A
43.1.1	Every production mechanical storage element shall be subjected to a maximum abnormal operating speed test. The test shall be performed at the maximum speed reached during the Overspeed Test of 37.1. The test shall be performed in an environment which will safely contain any mechanical failure of the mechanical storage element.		N/A
43.1.2	As an alternative to 43.1.1, the components of a mechanical energy storage element (e.g. forged disk) shall be processed consistently and tested to ensure that the materials used in its construction meet the minimum requirements assumed during the design and analysis of the element. The engineering development and production testing protocol for the components of the energy storage element shall demonstrate the level of uniformity of the material properties throughout critical sections of the component and that the material properties meet required minimum values consistently.		N/A
43.2	Production Screening of Rotors	Electrochemical ESS.	N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
43.2.1	Rotor assemblies for mechanical ESS shall be subject to 100 % production screening through the use of non-destructive testing or other means to check for cracks and other flaws. Any cracks or flaws found shall be evaluated in accordance with manufacturer's specifications.		N/A
43.2.2	As an alternative to 43.2.1, additional in progress quality checks and testing can be incorporated into the manufacturing assembly process to limit the presence of cracks or flaws in finished product. Refer to 44.1.		N/A
43.3	Leak check of hazardous fluid systems	Electrochemical ESS.	N/A
43.3.1	ESS that contain hazardous fluids including ESS with liquid coolant systems shall be subjected to a leak check in accordance with Section 38 of the assembled fluid containment system.		N/A
44	**Production Quality Control**		**P**
44.1	Manufacturers of ESS shall have documented production process controls in place that continually monitor the following key elements of the manufacturing process that can affect safety, and shall include measured parametric limits enabling corrective/preventative action to address defects (out of limit parameters) found affecting these key elements: a) Supply chain control; and b) Assembly processes.		P
MARKINGS			
45	**General**		**P**
45.1	Markings shall be legible and permanent		P
45.2	Markings and signage shall be in lettering that is sized so that it is legible from the distance from which it must be read and shall have lettering in a color that contrasts with the background.		P
45.3	An ESS shall be provided with a nameplate marking (main label) that includes parameters, product definitions, and manufacturer information, etc.		P
45.4	If the system is intended to be operated in a duty cycle, the intended duty cycle shall be included on the nameplate.		N/A
45.5	The suppression system to be installed, if applicable, shall be marked on the system.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

45.6	The operating ambient conditions in °C or °F, the weight of the system in kilograms or pounds, and the overall dimensions of the system can either be marked on the system or provided in the installation instructions.		P
45.7	For multi-part ESS, a nameplate marking (main label) noted in 45.3 shall be provided on at least one of the parts and shall identify that the system has been evaluated as a multi-part ESS.		N/A
45.8	The items in 45.4 – 45.6 shall be included as applicable to the system. With reference to 45.7, each separate part of the multi-part ESS shall have a nameplate marking as required by the equipment safety standard to which it was evaluated.		P
45.9	Where not included in the end-product standard or label, the following information shall be included in the ESS installation instructions as applicable to the ESS: a) Single-line electrical diagram b) Input short circuit current rating (SCCR) in A/kA that each component can withstand from other parts of the ESS if the connection point is a power input or bi-direction power connection; and c) Available fault current (as defined in Article 100 of NFPA 70) and time duration that the ESS part can provide to other parts of the ESS if the connection point is a power output or bi-directional power connection.		P
45.10	Contact information for the system in the event of an emergency or problems with the system.		P
45.11	Energy storage systems shall also be marked with the date of manufacture, which is permitted to be in the form of a code that does not repeat within 20 years. All external terminals and connections shall be provided with identification.		P
45.12	The point of connection to the charger earth grounding system shall be identified by the word "Ground" or the letters "G" or "GR" or the grounding symbol IEC 60417 Database, No. 5019 (upside down tree within a circle) or otherwise identified by a distinctive green color. Any other grounding terminals shall also be identified in a manner that is distinctive from the main earth ground terminal for the charger system.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

45.13	The ESS that contains hazardous voltage circuits shall be marked "WARNING: Hazardous Voltage Circuits" or be marked with the electric shock hazard symbol ISO 3864 No. 5036 (lightning bolt within a triangle). Electrical equipment parts of the ESS such as control panels and the enclosures of disconnecting devices shall also be marked with arc flash markings according to NFPA 70E or CSA Z462 and arc flash personal protective equipment (PPE) requirements, to warn service personnel of potential for arc flash hazards, and necessary protection to be worn if applicable. See also 10.11 regarding arc flash label requirements for equipment.		P
45.14	ESS other than electrochemical ESS that contain hazardous materials such as flammable solids or fluids or toxic or other hazardous materials shall be marked in accordance with NFPA 704.		N/A
45.15	Energy storage systems shall be marked as follows: "WARNING: To Reduce the Risk of Injury, read all instructions" or marked with the symbols W001 (i.e. exclamation point in triangle) and M002 of ISO 7010.		P
45.16	Energy storage systems with walk-in enclosures shall be provided with necessary cautionary markings per 10.9 and 10.10, and shall be marked with the following or equivalent: “WARNING: Risk of Electric Shock or Other Serious Injury. Care shall be taken when entering enclosure – Authorized personnel only.”		N/A
45.17	An ESS intended for installation where exposed to moisture shall be marked with the environmental rating of its enclosure (i.e. IPX2, Type 4X, etc.) suitable for that type of exposure. See 41.2.		P
45.18	The control devices and indicators required for operation or maintenance shall be marked with their function on or adjacent to the control. See also 10.7 and 45.19 regarding door signs.		P
45.19	An egress door per 10.7 shall be marked with the word "Exit" and the line-of-sight to an exit sign shall not be interrupted. Any doorway or passage that might be mistaken for an exit shall be marked "Not an Exit" or with an indication of its actual use.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
45.20	A non-residential use electrochemical ESS that complies with 1.6(b) shall be marked, "ESS with capacities exceeding 50 kWh shall include the additional fire suppression and/or fire protection identified in the installation instructions."		N/A
45.21	A non-residential use electrochemical ESS intended for use in remote outdoor locations per 1.6(d) shall be marked "For use only in remote outdoor locations as permitted in applicable installation codes and standards."		N/A
45.22	ESS disconnect controls, such as manual Emergency Power Off (EPO) disconnects, shall be marked to clearly indicate what system or part of the system they control. An EPO need not be provided with this marking if it disconnects and de-energizes the entire ESS.		P
INSTRUCTIONS			
46	**General**		**P**
46.1	The ESS shall be provided with complete instructions for installation, commissioning, operation and maintenance that includes the following information: a) Procedures for system commissioning and decommissioning; b) Complete installation instructions, including calibration, programming, control sequence descriptions for battery management and other monitoring systems; c) Initial acceptance testing procedures; d) Ongoing inspection and testing procedures; e) Instructions for retrofitting system components (non-residential use systems); and f) Instruction for providing working clearances.		P
46.2	The installation instructions shall identify the maximum rated energy capacity for the system and minimum separation distances from other ESS and from exposures (e. g. combustibles, structures) in accordance with the limitations to the system based on applicable codes or in accordance with the large scale fire testing of 26.2.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
46.3	Installation instructions for exterior wall-mounted ESSs shall identify the minimum separation distances from other ESS or from openings (e.g. windows, doors, HVAC inlets or other operable openings) in accordance with the code limitations or in accordance with the large scale fire testing of 26.2. Outdoor rated ESS marked “Suitable for Use in Residential Non-Habitable Spaces” are suitable for installation on exterior walls of residential dwelling units as indicated in the manufacturer’s instructions.		P
46.4	For systems that require the large scale fire testing of 26.2 in order to exceed code capacity limitations or reduce separation distances for their anticipated installation, the instructions shall identify the UL 9540A test report that was used to validate the anticipated installation including the testing organization, report designation, and date.		P
46.5	For ESS requiring large scale fire testing per 26.2, any additional fire suppression and/or fire protection and explosion protection identified in the UL 9540A test report shall be included in the installation instructions.		N/A
46.6	Unless further limited by manufacturer’s installation instructions, instructions for electrochemical ESS for indoor residential use shall indicate that the units are only intended to be installed in attached or detached garages, sheds, enclosed utility closets, basements, storage or utility spaces within dwelling units and are not intended for installation in habitable spaces and livings spaces in dwelling units.		N/A
46.7	Installation instructions for indoor electrochemical ESS marked “Suitable for Use in Residential Habitable Spaces” shall be permitted to indicate the units are suitable for use in residential dwelling units, including in the living or habitable spaces, provided that they meet the criteria as noted in 26.2.2.		N/A
46.8	The instructions shall be in accordance with the Technical Documentation section, Section 17 of NFPA 79, or CSA C22.2 No. 301, and in accordance with 46.2 – 46.10. For additional guidance see NEMA Z535.6. Instructions for installation, operation and maintenance of the ESS shall address electrical safety including arc flash in accordance with NFPA 70E or CSA Z462.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
46.9	All cautionary markings and ratings provided on the system, as well as system specifications needed for installation and operation of the system, shall be included in the instructions. If provided with remote controls, the system installation, operation and maintenance instructions shall be provided with instructions regarding operation of the remote controls and disconnecting the remote control in accordance with 17.1.		P
46.10	The installation information shall include instructions for making all necessary connections for electrical, communications, piping for fuels and other fluids, etc. as well as connections to other equipment that are part of the system.		P
46.11	The installations instructions shall specify that the system be installed in accordance with local electrical, building, fire and other codes or utility requirements as applicable to the installation and equipment, by qualified service personnel in accordance with the installation instructions and appropriate practices.		P
46.12	With reference to 46.9, the installation instructions for ESS, such as flow batteries, lead acid batteries, etc., containing free electrolyte (greater than 208 L (55 gal) in a single vessel or an aggregate of 3785 L (1000 gal)) shall be provided with instructions for location of eye wash stations. In addition, if necessary in accordance with building codes, installation instructions shall provide information on spill control to be installed with the system per 23.1 and 23.3.		N/A
46.13	Energy storage systems intended for installation only in certain environments such as indoors only or where exposed to moisture, seismic activity or marine environments, or to be installed in restricted access locations, shall indicate this in the installation instructions. Systems intended for exposure to moisture, marine environments or seismic activity per installation instructions shall be evaluated per Section 41.		N/A
46.14	The installation instructions for a DC ESS shall include specifications for the equipment performing electric power conditioning or conversion function that is intended to be connected for supplying the DC ESS, including if it is part of the DC load that the DC ESS is supplying.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
46.15	Indoor installation instructions for residential use ESS shall provide instructions on smoke alarms to be provided in the residence in accordance with building, fire and installation codes.		N/A
46.16	The installation instructions shall include any special handling and safeguard measures to be followed during installation and shall include details of support structures such as concrete pads, etc. required for installation at the site.		P
46.17	An ESS shall be provided with instructions for the proper operation of the system including charging and discharging for battery systems, and operation of system controls, including identification of the communication protocols used for the system per 18.1.1.		P
46.18	The ESS shall be provided with maintenance instructions for service personnel as well as a separate set of instructions for any basic maintenance procedures, including fuse replacement per 12.1, that would be handled by operators of the system.		P
46.19	The maintenance instructions shall be provided with information on field replacement of replaceable materials, components and parts for ongoing maintenance and repair of the system.		P
46.20	Mechanical ESS utilizing bearings for their moving parts, shall have a scheduled routine inspection and maintenance for bearings outlined in the manual.	Electrochemical ESS.	N/A
46.21	The installation instructions shall contain all ESS operation mode/settings, operation function/settings and protection/settings, which the inverters can provide.		P
ANNEX A (Normative)			
A1	**Standards for Components**		**P**
A1.1	The CSA Group and UL standards listed below are used for evaluation of components and features of products covered by this Standard.		P
ANNEX B (Informative) – General Battery Safety Considerations			
B1	**General**		**P**
B1.1	The battery specific safety requirements for this Standard can be found in the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications, UL 1973. See 28.1. The following includes some general safety recommendations for cells and batteries used in electrochemical type ESS.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

B2	**Design Recommendations**		**P**
B2.1	Battery systems should have two-fault tolerance for all catastrophic failures including overcharge, overdischarge, short circuit and extreme temperatures.		P
B2.2	The chargers used for charging the energy storage battery systems should be designed for the chemistry of the battery to be charged. The charging algorithm should be verified to ensure that the charging procedure is suitable for the battery chemistry and battery design.		P
B2.3	Protection circuits should be verified by test in the relevant battery design configuration and worst case environments to confirm that they provide the required protective functions.		P
B2.4	Cell level protection should not be relied upon for battery pack protection unless it can be verified through analysis and testing of the battery that the cell protection provides sufficient protection at the battery pack level.		P
B2.5	For lithium ion batteries and any other chemistry as determined by the battery system safety analysis, voltage should be monitored for every series element, temperatures should be monitored throughout the battery pack, and battery level current monitoring should be carried out continuously with alarm and control circuits able to react. Thermal runaway protection should be provided. Such protection should be verified through testing that it provides sufficient protection of the battery pack. Any off-nominal values should be recorded by the battery management system (BMS).		P
B2.6	For aqueous battery chemistries such as lead acid or nickel cadmium, battery or module level voltage, temperature and current monitoring should be carried out continuously with alarm and control circuits able to react. If possible, any off-nominal values should be recorded by the control system.		N/A
B2.7	Consideration should be given for conducting high fidelity thermal analysis when developing battery designs to determine the appropriate locations of the thermal sensors used in the battery.		P

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
B2.8	All temperature sensor readings should be continuously recorded and controls set in place to trigger a stoppage of charging or discharging of the battery when the temperature readings go above the manufacturer's rating of that particular cell or battery design.		P
B2.9	If the battery is used only periodically, the battery should be designed to prevent cells from going into an overdischarge mode due to the long term storage conditions.		P
B2.10	For lithium battery designs and other technologies as determined through safety analysis, cells should be spaced or insulated from other cells appropriately or through other mechanisms to prevent cell to cell thermal runaway propagation in the event that any one cell experiences a thermal runaway event.		P
B2.11	If temperature control is required for the battery system, the failure of the temperature controls, such as failure of heaters, cooling systems, or their controls, should not impose a safety hazard.		P
B2.12	For systems requiring heaters for operation, heater designs should not result in temperatures that exceed specified safe operating temperatures of the batteries.		N/A
B12.13	For systems requiring active cooling systems, a failure of the cooling system due to breach or breakage in the cooling lines should not result in a leakage that will cause short circuiting of the cells inside the battery pack leading to a hazardous condition. Coolant leakage lines should be routed or secured to mitigate the potential for leakage on live parts and if necessary fluid monitor and controls of the coolant system may need to be provided.		N/A
B12.14	For lithium batteries and other technologies as determined by the battery safety analysis, to prevent any unforeseen hazards due to a complex design and usage environment, the thermal runaway propagation test should be performed on a subset of the battery system design.		P
B12.15	All parameters such as cell voltages, battery voltage, battery current (sub-module currents, if applicable) and temperatures should be verified to be within the specification for the cells and battery system.		P
ANNEX C (Normative for Canada and Informative for the US) – Safety Marking Translations			**P**

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
	This Annex includes the markings required to be translated and suggested French translations. For Canada, this Annex is a normative (mandatory) part of this Standard. For the US, this Annex is an informative (non-mandatory) part of the Standard.		P
ANNEX D (Normative) – Approach For Evaluating Valve Regulated Of Vented Lead Acid Or Nickel Cadmium Battery Energy Storage Systems			**N/A**
D1	**General**		N/A
D1.1	Scope of appendix - vented lead acid and nickel cadmium battery energy storage systems	Rechargeable Li-ion Battery system	N/A
D1.2	Safety concerns of lead acid or nickel cadmium		N/A
D1.3	Address hydrogen venting in installation of lead acid or nickel cadmium		N/A
D2	**Construction**		N/A
D2.1	The batteries and components of the battery systems shall be installed in accordance with NFPA 70 or CSA C22.1.		N/A
D2.2	Valve regulated or vented lead acid or nickel cadmium cells and monobloc batteries shall comply with the requirements of the Annex for Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries in UL 1973 for these types of batteries.		N/A
D2.3	Cells and monobloc batteries shall be installed in an ESS in accordance with the battery manufacturer’s instructions for spacings between batteries and other required spacings, cell/battery installation orientation, wiring and connection requirements, environmental and other protections to be provided in the installation.		N/A
D2.4	Support structures for vented and valve regulated lead acid and nickel cadmium batteries shall be suitable for handling the maximum anticipated weight of the installed cells and batteries. The rack system shall comply with the criteria outlined in the Annex for Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries of UL 1973.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
D2.5	ESS employing lead acid or nickel cadmium batteries shall comply with the applicable criteria outlined in this Standard with regard to materials, enclosures, electrical safety, insulation levels and protective earthing, combustible concentrations, fire detection and suppression, and power conversion equipment as applicable to the ESS. Short circuit protection used in the system to protect the batteries and limit their short circuit current output shall be rated for dc applications.		N/A
D2.6	The charging system for these batteries shall prevent charging outside of the battery specifications through the use of current and temperature monitoring and control on the batteries. The system may also use voltage monitoring and controls to prevent out of condition specifications. Charging systems for these batteries shall comply with the requirements for power conversion equipment in Section 27 and shall also comply with the battery manufacturer’s specifications for chargers.		N/A
D2.7	Ventilation provided for the ESS shall maintain hydrogen concentration within the ESS to less than 25 % LFL. If relying upon mechanical ventilation to maintain the safe concentrations within an ESS enclosure, it shall be monitored and alarmed at a constantly attended location, should the mechanical ventilation fail.		N/A
D2.8	The battery system exceeding 240 Vdc shall be provided with disconnects in accordance with Article 706 of NFPA 70 or Section 64 of CSA C22.1, for servicing of the battery system.		N/A
D2.9	Installation of ESS systems of lead acid or nickel cadmium batteries, shall abe installed with ventilation in accordance to applicable fire and building code requirements and the battery manufacturer’s installation instructions.		N/A
D2.10	ESS systems with vented lead acid or nickel cadmium batteries shall be provided with spill control in accordance with the building, fire and installation codes and manufacturer’s instructions. See 23.1.		N/A
D2.11	ESS systems with lead acid or nickel cadmium cells or batteries shall be marked in accordance to Section 45 as applicable to the system.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
D2.12	Installation instructions for an ESS with lead acid or nickel cadmium batteries shall provide sufficient details of installation including any separation distances, limits to the installations such as indoors only installation in accordance with Section 46.		N/A
D2.13	Maintenance and operating instructions for ESS employing lead acid or nickel cadmium cells and batteries.		N/A
D3	**Performance**		N/A
D3.1	General		N/A
D3.1.1	Table D3.1 shall be applied to an ESS system using lead acid or nickel cadmium batteries, which have been evaluated to the UL 1973.		N/A
ANNEX E (Informative) – Guidance On Capacity And Separation Distance Limits For Electrochemical ESS			**P**
E1	**General**		**P**
E.1.1	Installation Codes control fire and other hazards in electrochemical ESS installations through the use of limitations on energy capacity and through separation distances between ESS and exposures (e.g. walls, openings, etc.). These limitations may be revised based upon large scale fire testing and authority having jurisdiction (AHJ) approval at the installation site. The information provided below in Table E1.1 and Table E1.2 is based upon the limitations for energy capacity and separation distances for electrochemical ESSs in accordance with the model fire and installations codes in the United States. Since the limitations in these codes are subject to revision and also because they are subject to local adaptation, this information should be used for guidance only.		P
ANNEX F (Normative) – Metal Compatibility Table			**P**
ANNEX G (Normative) – Cleanagent Direct Injection Battery Rack Coolant System Units			**N/A**
G1	**General**		**N/A**
G1.1	These requirements cover the construction and operation of halocarbon clean agent direct injection battery rack coolant system units intended to be installed, inspected, tested, and maintained in accordance with NFPA 2001, NFPA 855, and NRC NFC.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict

G1.2	These clean agent direct injection battery rack coolant system units are intended to distribute clean agent directly onto lithium ion or similar battery modules following detection by the system that the cells are overheating and/or venting. The design of the integral battery rack clean agent coolant system is dependent upon the battery module and rack assembly and is ultimately evaluated for effectiveness through large scale fire testing in accordance with UL 9540A.		**N/A**
G2	**Glossary**		**N/A**
G2.1-G2.6	Explanations of relevant terms		**N/A**
G3	**Construction**		**N/A**
G3.1	Piping		N/A
G3.1.1	Piping and tubing used in the system shall have a piping thickness in accordance with ASME B31.1. Piping, tubing, fittings, and the joints so formed shall comply with the Valve Leakage Test and Hydrostatic Pressure Test of UL/ULC 2166. The assembled piping system shall comply with the Leakage Tests of UL 9540.		N/A
G3.2	Pressure relief valves		N/A
G3.2.1	Pressure relief valves in the agent distribution network shall be subjected to the Start-To-Discharge Test of UL 1973 unless the pressure release valves comply with ASME BPVC. The relief valve shall not release to an area where the agent can result in a hazard.		N/A
G3.3	Pressure regulators		N/A
G3.3.1	Pressure regulators shall be evaluated in accordance with UL/ULC 2166, UL 252 or UL 144 for suitability.		N/A
G3.4	Solenoid valves		N/A
G3.4.1	Electrically operated valves shall comply with UL 864, ULC S527, UL 429 or CSA C22.2 No. 139 and be suitable for the conditions of service.		N/A
G3.5	Electrical controls		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
G3.5.1	An analysis of the direct injection battery rack coolant system unit control assembly consisting of the various input sensors, the fire alarm control panel and outgoing signals to the agent supply cylinder shall be analyzed to ensure that all components of the control system work in coordination as anticipated to react to a cell propagation event in the modules. Methods outlined in Section 15 of this Standard shall be utilized to perform this analysis.		N/A
G3.5.2	Fire Alarm Control Panels shall comply with UL 864 or ULC S527 and shall have sufficient input and output channels for the system. The input signals to the fire control panel shall be compatible with the panel.		N/A
G3.5.3	Manual pull switches shall comply with UL 38 or ULC S528 and be compatible with the fire alarm control panel and rated for the circuit. The manual pull switch shall be located where it is accessible.		N/A
G3.6	Input sensors and detectors		N/A
G3.6.1	Detectors and other input sensors to the fire alarm control panel shall be evaluated in accordance with the appropriate standard for that device.		N/A
G3.6.2	The signals from these various detection devices shall be compatible with the fire control panel in accordance with G3.5.		N/A
G3.6.3	If input signals from the battery management system (BMS) to the fire control panel are relied upon for the operation of the direct injection coolant system, these communication signals shall be determined compatible with the fire control panel in accordance with G3.5.		N/A
G3.7	Alarms		N/A
G3.7.1	A visual and audio alarm shall be provided with the direct injection coolant system and they shall operate when the direct injection coolant system operates.		N/A
G3.7.2	Visual alarms shall be in accordance with UL 1638 or ULC 526, and audio alarms shall be in accordance with UL 464/ULC 525.		N/A
G3.8	Wiring and terminals		N/A
G3.8.1	Wiring within the direct injection coolant system shall be in accordance with NFPA 70, NFPA 72 or CSA C22.1 and this Standard.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict
G3.8.2	The wiring and connections between parts of a direct injection coolant system shall be protected or enclosed, or they shall be in a cord or cable that has been evaluated and determined to be rated for the application.		N/A
G3.8.3	Internal wiring shall be routed and secured so that the wires and electrical connections are not subjected to stress or mechanical damage in accordance with this Standard.		N/A
G3.8.4	Internal wiring of circuits that operate at different potentials shall be separated by barriers or shall be segregated, unless the conductors of the circuits of lower voltage are provided with insulation for the highest voltage in accordance with this Standard.		N/A
G3.8.5	Duplicate terminals or leads, or an equivalent arrangement, shall be provided for circuits of devices intended to be connected to initiating-device circuits of the fire control unit; one for each incoming and one for each outgoing wire.		N/A
G3.9	Clean agent assembly component requirements		N/A
G3.9.1	The clean agent tank assembly shall be located where it can be inspected, recharged and subjected to any other specified maintenance activities without impacting its ongoing protection functions.		N/A
G3.9.2	The requirements of UL/ULC 2166 summarized in Table G3.1 shall apply. Where UL/ULC 2166 references “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A
G4	**Performance**		**N/A**
G4.1	General		N/A
G4.1.1	The direct injection coolant systems shall be subjected to the applicable performance tests as noted in this Annex.		N/A
G4.2	Clean agent assembly tests (UL/ULC 2166 Tests)		N/A
G4.2.1	The requirements of UL/ULC 2166 summarized in Table G4.1 shall apply. Where UL/ULC 2166 references “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A
G4.3	Start to discharge test		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

G4.3.1	The start to discharge test shall be conducted on relief valves other than those employed on the clean agent cylinder assembly in accordance with UL 1973.		N/A
	Exception: This test may be waived on relief valves that comply with ASME BPVC and that are used within their ratings.		N/A
G4.4	Direct injection coolant system tests		N/A
G4.4.1	Large scale fire test		N/A
G4.4.1.1	The direct injection coolant system shall be tested in accordance with the unit level test of UL 9540A when installed in the specific battery rack assembly with intended modules that the system is designed to protect.		N/A
G5	**Production Tests**		**N/A**
G5.1	The applicable production tests of the Manufacturing and Production Tests, General section of UL/ULC 2166 shall apply.		N/A
G5.2	The start-to-discharge production line test of the Manufacturing and Production Line Tests, General section of UL 1973 shall apply to relief valves that have not been determined to comply with the ASME BPVC and are used in the system.		N/A
G5.3	The requirements of UL/ULC 2166 summarized in Table G5.1 shall apply. Where UL/ULC 2166 references “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A
G6	**Markings**		**N/A**
G6.1	Each direct injection battery rack coolant system unit shall be marked with an identifying part or model number and the manufacturer's or private labeler's name or other equivalent designation.		N/A
G6.2	A cylinder/valve assembly, in addition to being marked with operating, recharging, inspection and maintenance instructions (see G7.3), shall be marked with the year of manufacture, or the last two digits of the year of manufacture.		N/A
G6.3	Operating, recharging, inspection and maintenance instructions and other relevant information shall be marked on the cylinder/valve assembly.		N/A
G6.4	Each clean agent container shall be legibly marked in accordance with UL/ULC 2166.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

G6.5	The requirements of UL/ULC 2166 summarized in Table G6.1 shall apply. Where UL/ULC 2166 references “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A
G7	**Instructions**		**N/A**
G7.1	A copy of the installation, operating, recharging, inspection, and maintenance instruction manual is to be furnished for the direct injection coolant system. These instructions shall also be provided for the evaluation and testing of the system.		N/A
G7.2	The instructions shall reference the limitations of each direct injection coolant system and shall include operating detail, schedule of pipe, installation, maintenance, and testing requirements and so on.		N/A
G7.3	Routine maintenance of the system shall be outlined in the maintenance manual and shall include the maintenance procedures to be conducted and the frequency with which the maintenance procedures are conducted on the system. The maintenance schedule shall consist of monthly, semi-annual and annual intervals of routine inspection and maintenance in accordance with the manufacturer’s specifications.		N/A
G7.4	The requirements of UL/ULC 2166 summarized in Table G7.1 shall apply. Where UL/ULC 2166 references the “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

Cl.13	TABLE: Electrical Spacings and Separation of Circuits					P
Clearance cl and creepage distance dcr at/of:	System / Impulse voltage (V)	U r.m.s. (V)	Required cl (mm)	cl (mm)	Required dcr (mm)	dcr (mm)
Control Box						
DC+ to DC- (FI)	6000	1500 dc	5.5	See below	15.0	See below
--at P+, P- connector	-	-	-	16.5	-	>30.0
--at B+, B- connector	-	-	-	29.0	-	>30.0
Battery circuit to Enclosure/PE (BI)	6000	1500 dc	5.5	See below	15.0	See below
-at Fuse	-	-	-	33.0	-	33.0
-at Relay	-	-	-	26.8	-	30.5
-at +/- connector	-	-	-	12.6	-	27.4
AC auxiliary input to Enclosure/PE (BI)	2500	230/400ac	1.5	See below	4.0	See below
--at input connector	-	-	-	10.2	-	14.2
BCU board						
Battery circuit to PE (BI)	6000	1500 dc	5.5	See below	7.5	See below
-at connector J6	-	-	-	18.5	-	18.5
Battery circuit to communication circuit (RI)	8000	1500 dc	8.0	See below	15.0	See below
-at Transformer TR5	-	-	-	33.9	-	33.9
Battery Pack						
DC+ to DC- (FI)	6000	1500 dc	5.5	See below	15.0	See below
--at B+, B- connector	-	-	-	12.6	-	27.4
Battery circuit to Enclosure/PE (BI)	6000	1500 dc	5.5	See below	15.0	See below
--at B+, B- connector	-	-	-	12.6	-	27.4
-at connect busbar	-	-	-	18.8	-	>30.0
-at sampling wiring	-	-	-	8.3	-	25.6
BMU Board						
Battery circuit to PE (BI)	6000	1500dc	5.5	See below	7.5	See below

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

-at connector X1	-	-	-	17.2	-	17.2
Battery circuit to communication circuit (RI)	8000	1500dc	8.0	See below	15.0	See below
-at Transformer T1/T2	-	-	-	24.9	-	24.9
Container (Distribution cabinet)						
-at main input MCCB (OCV III)	4000	230/400ac	3.0	11.3	4.0	15.3
-at QF4 (OCV II)	2500	230/400ac	1.5	9.2	4.0	11.4
- at QF2 (OCV II)	2500	230/400ac	1.5	9.0	4.0	11.3
B+, B- to Enclosure/PE (BI)						
-at main busbar	6000	1500 dc	5.5	>50.0	15.0	>50.0
B+ to B- (FI)						
-at main busbar	6000	1500 dc	5.5	>50.0	15.0	>50.0
Energy Source Definition:						
The Product provides Protective grounding for enclosure.						
Supplementary information: System voltage max 1500 Vdc considered, PD = PD2. Altitude ≤ 2000m. Material Group I for PCB board, MG IIIa or IIIb for other insulators. OVC II for battery.						

Cl.30	**TABLE: Normal Operation Test**					**P**
AC				Battery system		
Rated Voltage (V)	Rated Current (A)	Frequency (Hz)	Rated Power (kW)	Measured Voltage (Vdc)	Measured Current (A)	Measured Power (kW)
--	--	--	--	1098.8 to 1483.0	Max 2296.5 for discharge, Max 2027.6 for charge	Max 2489.8 for discharge, Max 2503.9 for charge

Work condition [1)]	Rated Battery System voltage	Battery System current
Charging and discharging	1331.2	See above

Measuring location:	Max. measured Temp. [ºC]	Max. measured Temp. correct to TMA) [°C]	Max. Temp. limit) [°C]
Control box			
PCB in BCU	61.7	72.7	130
Enclosure of BCU board	62.3	73.3	85
Terminal of BCU	63.3	74.3	125
Isolating switch(QS)	64.6	75.6	120

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

Insulation tube of P+ copper	74.9	85.9	105
Breaker (K1)	67.5	78.5	85
Terminal of copper	66.4	77.4	85
Metal enclosure of HV control box	51.2	69.2	70
Internal wire of JP2	63.8	74.8	105
Hall	63.1	74.1	105
External of HV breaker	88.0	99.0	125
Air breaker	57.1	68.1	85
Fan	68.2	79.2	85
Internal of HV breaker	67.8	78.8	125
Relay(KM1)	70.6	81.6	85
P+ connector	62.6	73.6	125
Battery pack			
Power line between pack	58.0	69.0	85
MSD	77.0	88.0	120
Metal enclosure of module	39.0*	50.0*	70
Enclosure of BAU board	46.3	57.3	85
FA1 body	43.8*	54.8*	125
Cell 1	45.6	56.6	60
Cell 2	44.6	55.6	60
Cell 3	45.2	56.2	60
Container			
Handle of container	45.0	56.0	60
Metal door of container	46.9	57.9	60
Main power wire	74.9	85.9	125
Wire of PCS	64.3	75.3	125
Breaker in Electrical compartment	45.6	56.6	85
DC breaker 1	50.5	61.5	85
DC breaker 2	49.5	60.5	85
Enclosure of UPS	44.3	55.3	60
Enclosure of air conditioner	44.4	55.4	60
Enclosure of liquid cooler	48.3	59.3	60
ambient	44.0	55.0	--

UL 9540			
Clause	Requirement + Test	Result - Remark	Verdict

Supplementary information:

The test was conducted at ambient temperature 44°C with max charge/discharge power 2515.968kW, and corrected to max operating temperature 55°C without derating.

The cooling system was continuous working with 480L/min and target cooling temperature 20ºC during the test.

Cl.32&33	**TABLE: Dielectric Strength and Impulse**		**P**
Test Location:	**Dielectric Voltage**	**Impulse Voltage**	**Pass / Fail**
Battery circuit			
Battery system P (+) to PE (BI)	4414	6000	Pass
Battery system P (-) to PE (BI)	4414	6000	Pass
Battery power circuit (+) to Communication circuit (RI)	6000	8000	Pass
Battery power circuit (-) to Communication circuit (RI)	6000	8000	Pass
Auxiliary power supply circuit			
AC input (L, N) to PE (BI)	2120	2500	Pass
AC input (L, N) to Communication circuit (RI)	4240	4000	Pass
Supplementary information: BI: Basic insulation; RI: Reinforced insulation.			

Cl.34	**TABLE: Equipment Grounding and Bonding Test**		**P**
Tested between:	Voltage	Current	Resistance
Control box enclosure to PE	--	25A	24.9mΩ
Pack enclosure to PE	--	25A	23.1mΩ
Rack to PE	--	25A	26.5mΩ
Auxiliary cabinet enclosure to PE	--	25A	22.2mΩ
Supplementary information: /.			

Cl.35	**TABLE: Insulation Resistance Test**	**P**
Tested between:	Measure Resistance (MΩ)	Comments
Battery + to PE	> 550	--
Battery - to PE	> 550	--
Auxiliary L to PE	> 550	--
Auxiliary N to PE	> 550	--
Supplementary information:/.		

--End of report—

Photo Documentation

CN251VG2 001 attachment 1

of

Lithium Ion Battery System

HE-L5030A

AESC Jiangsu Co., Ltd.

This documentation consists of 5 pages (including this cover page)



Front view of battery system



Back view of battery system



Right view of system



Left view of system



Internal view 1 of battery system



Internal view 2 of battery system



Internal view 3 of battery system



Internal view 4 of battery system

Constructional Data Form for Electrical Products

(For TUV Rheinland (Shanghai) use only)
Certificate # File # CN251VG2 001

License Holder	:	**AESC Jiangsu Co., Ltd.** No.66 Shentai Road, Shengang Sub-District, Jiangyin City, Wuxi, 214000, CHINA
Factory	:	**Envision Energy Co., Ltd.** No.3 Shenzhuang Road, Linggang New City Low-Carbon Industrial Park, Shengang Street Jiangyin City,214443 Jiangsu P.R. China
Type of Product	:	**Lithium Ion Battery System**
Model Number	:	**HE-L5030A**
Trademark	:	AESC
Rating	:	**As below table**

TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.**	2025/07/01
	(Place)	(Date)
	(Stamp and signature of applicant)	

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Constructional Data Form for Electrical Products

(For TUV Rheinland (Shanghai) use only)
Certificate # File # CN251VG2 001

Model list for battery rack:

	Rechargeable Lithium-ion Cell	Lithium Ion Battery Pack	Lithium Ion Battery Rack
Type/model	HC-L315A	HP-L630B	HR-L630B
Battery Type	$LiFePO_4$		
Structure	-	52S2P	(52S2P)8S
Nominal Voltage [V]	3.2	166.4	1331.2
Rated Capacity [Ah]	315	630	630
Rated Energy [kWh]	1.008	104.832	838.656
Upper limit charging voltage [V]	3.65	189.8	1497.6
Discharging cut-off voltage [V]	2.5 (0<T≤60°C) 2.0 (-30<T≤0°C)	130.0	1164.8
Maximum continuous charge power [kW]	0.504	52.416	419.328
Peak current in charging [A]	201.6	403.2	360.0
Maximum continuous discharge power [kW]	1.008	52.416	419.328
Peak current in discharging [A]	201.6 (0<T≤60°C) 252.0 (-30<T≤0°C)	403.2	400.0
Charge range of ambient temperature [°C]	0 to 60	0 to 55	-30 to 55*
Discharge range of ambient temperature [°C]	-30 to 60	-30 to 55	-30 to 55
Weight [kg]	5.65±0.3	670±10	Approx 6000
Overall size: (L*W*H) [mm]:	71.8±0.6*174.26±0.6*207.01±0.6	2214.6±5*794±5*246.2±5	Approx 2214±5*794±5*246.2±5
Enclosure Protection (IP)	-	IP67	IP20

TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.**	2025/07/01
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Cooling Type	-	Liquid cooling (provide in end-installation)	
Altitude [m]	-	Below 2000	Below 2000
Note*: The system will not start charging until cell min temperature > 0°C which controlled by BMS. External Heating device should be provided in end-installation for charging below 0°C.			

Model list for battery system:

	Lithium Ion Battery System
Type/model	HE-L5030A
Structure	((2P52S)8S)6P
Rated Energy [kWh]	5030
Battery Type	$LiFePO_4$
Rated Capacity [Ah]	3780
Maximum continuous charging/discharging power [kW]	2515.968
Peak current in charge [A]	2160
Peak current in discharge [A]	2400
Nominal Voltage [Vdc]	1331.2
Upper limit charging voltage [Vdc]	1497.6
Discharging cut-off voltage [Vdc]	1164.8
Charge range of ambient temperature [°C]	-30 to 55*
Discharge range of ambient temperature [°C]	-30 to 55*

Deping Cao	**AESC Jiangsu Co., Ltd.**	2025/07/01
	(Place)	(Date)
TUV Rheinland (Shanghai) Co., Ltd.	Shijin Yang	
	(Stamp and signature of applicant)	
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Constructional Data Form for Electrical Products

(For TUV Rheinland (Shanghai) use only)
Certificate # File # CN251VG2 001

AC auxiliary power input	277/480Vac, 3W+N+PE, 65A, 60Hz
Weight [kg]	Max 43000
Overall size: (L*W*H) [mm]:	6058*2438*2896
Enclosure Protection (IP)	IP55
Cooling Type	Liquid cooling and heating for battery Forced air cooling for distribution room
Protective class	I
Altitude [m]	Below 2000
Note*: The system will not start charging until cell min temperature > 0°C heating by liquid chiller which controlled by LEMS.	

TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.**	2025/07/01
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Constructional Data Form for Electrical Products

(For TUV Rheinland (Shanghai) use only)
Certificate # File # CN251VG2 001

List of Critical Components:

Object / part No.	Manufacturer/ trademark	Type / model	Technical data	Standard	Mark(s) of conformity[1)]
Battery string	AESC Jiangsu Co., Ltd.	HR-L630B	Voltage:1331,2V. Capacity:315Ah	ANSI/CAN/UL 1973:2022	TUV R:CU 72502863 0001
Surge Protector (Branch)	SICHUAN ZHONGGUANG LIGHTNING PROTECTION TECHNOLOGIES CO LTD	ZGG40-385(2+0)	L-PE/N-PE Uc 385Vac,In:20 Ka, -40~80°C	UL 1449 CSA C22.2 NO. 269.5-17	E339436
Surge Protector (auxiliary power)	SICHUAN ZHONGGUANG LIGHTNING PROTECTION TECHNOLOGIES CO LTD	ZGG40-385(3+1)	L-N Uc 385Vac N-PE Uc 260Vac,In:20 Ka, -40~80°C	UL 1449 CSA C22.2 NO. 269.5-17	E339436
Surge Protector (Main circuit)	SICHUAN ZHONGGUANG LIGHTNING PROTECTION TECHNOLOGIES CO LTD	ZGGS40-890PV	Uc 1500Vdc ,In:20 kA,-40~85°C	UL 1449 CSA C22.2 NO.269.5-17 CSA C22.2 NO. 8-13	E339436
FUSE FOR Surge Protector	XI'AN Sinofuse Electric Co Ltd	FGB-A-5H	80A, AC 690V, -40~+85℃	UL 248-13	E353337
Uninterruptible Power System (UPS)	Schneider Electirc IT Corporation	SPRM1KLU	Input 230Vac, Output 220Vac/230Vac/240Vac, Capacity 1KVA, 40 Hz~60 Hz	UL 1778	E95463

TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.**	2025/07/01
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Alternate.	DELTA ELECTRONICS INC	RT PRO-1K	Input 230Vac, Output 220Vac/230Vac/240Vac, Capacity 1KVA, 50/60±0.05Hz	UL 1778	E173762
Alternate.	Lianzheng Electronic (Shenzhen) Co Ltd	9SX1000I	Input 230Vac, Output 220Vac/230Vac/240Vac, Capacity 1KVA, 40-70Hz, 50/60Hz	UL 1778 CSA C22.2 No. 107.3-14	E321205
Battery (UPS)	Schneider Electirc IT Corporation	SPRM36BP-9AHU	36V, 18Ah	UL 1778	E95463
Alternate.	DELTA ELECTRONICS INC	RT PRO-1KB	48V, 9Ah	UL 1778	E173762
Alternate.	Lianzheng Electronic （Shenzhen） Co Ltd	9SXEBM36T	72V, 9Ah	UL 1778 CSA C22.2 No. 107.3-14	E321205
Main input Circuit Breakers	Noark ELECTRIC USA INC	M1S100T3	Ue 600Vac, In 100A, Icu 35kA(480Vac), 3P, -40~70°C	UL 489 CSA C22.2 NO.5	E355392
Branch Circuit Breaker for water cooling system	Noark ELECTRIC USA INC	B1E3P80	Ue 480Vac, In 80A, Icu 5kA, 3P, -30~75°C	UL 1077 CSA C22.2 NO.235	E355391
Branch Circuit Breaker for auxiliary transformer	Noark ELECTRIC USA INC	B1H2C10	Ue 240Vac, In 10A, Icu 10kA, 2P, -30~75°C	UL 489 CSA C22.2 NO.5-02	E355392

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Constructional Data Form for Electrical Products

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Certificate # File # CN251VG2 001

Branch Circuit Breakers	Noark ELECTRIC USA INC	B1N1C16	Ue 240Vac, In 16A, Icu 10kA, 1P, -30~75°C	UL 489 CSA C22.2 NO.5-02	E355392
Alternate	Noark ELECTRIC USA INC	B1N1C6	Ue 240Vac, In 6A, Icu 10kA, 1P, -30~75°C	UL 489 CSA C22.2 NO.5-02	E355392
AC-DC Power	DELTA ELECTRONICS INC	DRL-24V120W1ENA	Input 100-240Vac, 50/60HZ；Output 24Vdc, 5A	UL 62368-1	E131881
UPS power supply circuit, heater power supply circuit	Noark ELECTRIC USA INC	Ex9C18113PP7	230V, 18A,-40°C~65°C	UL 60947-1 UL 60947-4-1A	E353866
Auxiliary circuit 24V Relay	PHOENIX CONTACT GmbH & C., KG	RIF-2-RPT-LDP-24DC/4X21	4PDT, 24Vdc, Ie 6A, -40°C~65°C	UL 508 CSA C22.2 NO.14	E113228
Alternate.	XIAMEN HONGFA ELECTROACOUSTIC CO LTD	HF18FZ-AS/24-4Z231-C2-H2	4PDT, 24Vdc, Ie 5A, -40°C~70°C	UL 508	E253370
Alternate.	PHOENIX CONTACT GmbH & Co., KG	RIF-1-RPT-LDP-24DC/2X21	2PDT, 24Vdc, Ie 8A, -40°C~70°C	UL 508 CSA C22.2 NO.14	E172140
Alternate.	XIAMEN HONGFA ELECTROACOUSTIC CO LTD	HF18FZ-AS/24-2Z23-C2-H2	2PDT, 24Vdc, Ie 7A, -40°C~70°C	UL 508	E253370
Temperature relay	PFANNENBERG GMBH	FLZ520_17111000003	240Vac,10A, Setting range: -20°C~40°C	UL873 CSA C22.2 NO. 24	E251765
Fuse for Voltage sampling circuit	KING WAHOO ELETRONICS CO LTD	5TC	In 1.25A, -40°C~125°C	UL248-14	E302100

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Certificate # File # CN251VG2 001

Current transformer	NORATEL AS	SUL192E-480230	Input 480Vac, Output 230Vac, 3KVA	UL5085	E115159
Electricity meter	Jiangsu Acrel Electrical Manufacturing CO., Ltd.	ADL3000-E-B/KC	Input 277/480V ±10%, 3~6A -25°C~+55°C	UL61010-1 CAN/CSA-C22.2 NO. 61010-1-12 UL 61010-2-030 CSA C22.2 NO.61010-2-030:18 UL 61010-2-201 CSA C22.2 NO.61010-2-201	E527278
Water immersion sensor	MiEnJi （Zhejiang）Sensor Technology Co., Ltd.	ME-DSJ-T2	24Vdc, -40°C~+60°C	UL60730-1	E540765
Trunking	SHANGHAI RICHENG ELECTRONICS CO LTD	HVDR5050/HVDR4060/HVDR3050	PVC, 4mm slots, -40°C~+65°C	UL94-V0	E306674
Terminal Blocks	NINGBO SUPU ELECTRONICS CO LTE	TP4-2	4mm², 600Vac, 30A, -40°C ~+105°C	UL 1059 CSA C22.2 NO. 158-10	E330768
alternate	NINGBO SUPU ELECTRONICS CO LTE	TPD2.5-2-PV	2.5mm², 600Vac, 20A, -40°C ~+105°C	UL 1059 CSA C22.2 NO. 158-10	E330768
alternate	NINGBO SUPU ELECTRONICS CO LTE	TPD2.5-2	2.5mm², 600Vac, 20A, -40°C ~+105°C	UL 1059 CSA C22.2 NO. 158-10	E330768
alternate	NINGBO SUPU ELECTRONICS CO LTE	TPTS2.5-2-PET	2.5mm², 600Vac, -40°C ~+105°C	UL 1059 CSA C22.2 NO. 158-10	E330768

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Certificate # File # CN251VG2 001

alternate	NINGBO SUPU ELECTRONICS CO LTE	TPTS2.5-2	2.5mm², 600Vac, 20A, -40°C ~+105°C	UL 1059 CSA C22.2 NO. 158-10	E330768
alternate	NINGBO SUPU ELECTRONICS CO LTE	TU16-2	16mm², 600Vac, 85A, -40°C ~+105°C	UL 1059 CSA C22.2 NO. 158-10	E330768
alternate	NINGBO SUPU ELECTRONICS CO LTE	TU35-2-PE	35mm², 600Vac, -40°C ~+105°C	UL 1059 CSA C22.2 NO. 158-10	E330768
alternate	NINGBO SUPU ELECTRONICS CO LTE	TU35-2	35mm², 600Vac, 150A, -40°C ~+105°C	UL 1059 CSA C22.2 NO. 158-10	E330768
EPO Button	Eaton Industries Gmbh	Push buttonsM22-PV Contact elements M22-CK02 Accessories: M22-A M22-AXGPV M22-XAKI	IP67 DC24V	UL 508	E29184
Auxiliary circuit 230V Relay	PHOENIX CONTACT GmbH & Co. KG	RIF-1-RPT-LV-230AC/2X21MS	2PDT, 230Vac, Ie 5A, -40°C~70°C	UL 508	E113228
Alternate.	XIAMEN HONGFA ELECTROACOUSTIC CO LTD	HF18FZ-AS/A230-2Z231-C2-H2	230V, 7A,-40°C~70°C	UL 508	E253370
Network Switch	Jiangsu Knetcon Technology Co., Ltd.	NCS3008-8T	10/100Base T(X); 24V DC; IP40;-10°C to +75°C	UL 61010-1	E547905

TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.**	2025/07/01
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Constructional Data Form for Electrical Products

(For TUV Rheinland (Shanghai) use only)
Certificate # File # CN251VG2 001

LOCAL EMS	ADVANTECH CO LTD.	TGW7000	2U,220V CPU J6413，8G memory，1TB SSD，6x 1GB ethernet ports	UL 62368, IEC 62368-1 FCC	E180881
Fire protection system					
Cable	SHENZHEN LILUTONG TECHNOLOGY INDUSTRY CO LTD	FPLR	Working voltage: 300V, 14AWG, 16AWG, 18AWG	UL 1424	E502147
Cable	SHENZHEN LILUTONG TECHNOLOGY INDUSTRY CO LTD	1015	Working voltage: 600V 16AWG,18AWG	UL758	E309471
Electric fan	Fulltech Electric Co Ltd	UF-T25GBPB23H 1D8AN	Air Volume：820±15% CFM AC 230V (50/60Hz)	CSA C22.2 NO. 113-18 - 11 th Ed	E136370
Fire Alarm Releasing Control Unit	POTTER ELECTRIC SIGNAL CO L L C	ARC-100	426.2*408.2*97.5mm 3.0 Amps @ 120 VAC 50/60 HZ 2.0 Amps @ 240 VAC 50/60 HZ	UL864	S735
Fire alarm bell	POTTER ELECTRIC SIGNAL CO L L C	PDC-624	φ150mm，Sound pressure at 3m：95dB	UL 464	S3274
Gas Detector （H2）	Crowcon Detection Instruments (Beijing) Ltd	Xgard Bright	10~30VDC，0-100% LEL	UL1203	E513699

Deping Cao TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.** (Place) Shijin Yang (Stamp and signature of applicant)	2025/07/01 (Date)

Note: Any errors or omissions in the CDF shall be reported to TUV Rheinland immediately upon recipt by the applicant.

Constructional Data Form for Electrical Products

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Gas Detector （CO）	Crowcon Detection Instruments (Beijing) Ltd	Xgard Bright	10~30VDC，0-1000 ppm	UL1203	E513699
Temperature Detector	POTTER ELECTRIC SIGNAL CO L L C	PAD300-HD	24VDC Alarm temperature interval：57~85℃ Detected temperature rise：8.3°C/min	UL 521	S8368
Smoke Detector	POTTER ELECTRIC SIGNAL CO L L C	PAD300-PD	24VDC Alarm threshold interval：1.1 to 3.5%/ft (3.6 to 11%/m)	UL 268	S24776
Alternate. (Fire protection system)					
Cable	SHENZHEN LILUTONG TECHNOLOGY INDUSTRY CO LTD	FPLR	Working Voltage：300V, 14AWG, 16AWG, 18AWG	UL 1424	E502147
Cable	Shanghai AEIN Wire&Cable Co Ltd	FPLR	Working Voltage：300V, 14AWG, 16AWG, 18AWG	UL 1424	E537809
Cable	LTK Electric Wire (Huizhou) Ltd	1015	Working Voltage：600V,16AWG, 18AWG	UL1015	E148000
Fire Alarm Releasing Control Unit	Siemens Industry Inc	FC922	700*546*146mm 2.0 Amps @ 120 VAC 50/60 HZ 2.0 Amps @ 240 VAC 50/60 HZ	UL864	S522

TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.**	2025/07/01
	(Place)	(Date)
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Smoke Detector	Siemens Industry Inc	OP921	Operating Voltage Range：16 - 30VDC Alarm temperature interval：57~79℃ Detected temperature rise：8.3°C/min	UL 268	S2378
Temperature Detector	Siemens Industry Inc	HI921	Operating Voltage Range：16 - 30VDC SENSITIVITY RANGE:1.41 - 3.76 % ft	UL 521	S726
Fire alarm bell	Siemens Industry Inc	MBDC-6	Operating Voltage Range：16 - 33VDC φ150mm Sound pressure at 3m: 92dBA	UL 464	E39088
Gas Detector (H2)	Crowcon Detection Instruments (Beijing) Ltd	Xgard Bright	10~30VDC，0-100% LEL	UL1203	E513699
Gas Detector (CO)	Crowcon Detection Instruments (Beijing) Ltd	Xgard Bright	10~30VDC，0-1000 ppm	UL1203	E513699
Liquid Cooling System					

TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.**	2025/07/01
	(Place)	(Date)
	(Stamp and signature of applicant)	

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Liquid cooling unit	Kelvin New Energy Technology Wuxi Co., Ltd.	BTMS600-ESH10	60KW，480V	CAN/CSA C22.2 NO. 60335-1:16 ANSI/UL 60335-1 CAN/CSA C22.2 NO. 60335-2-40:22 ANSI/UL 60335-2-40	CSA:80253306
Alternate.	Kelvin New Energy Technology Wuxi Co., Ltd.	BTMS600-ESA2X	60KW，480V	ANSI/UL 60335-1, UL 60335-2-40, CAN/CSA-C22.2 No. 60335-1:16, CSA C22.2 No. 60335-2-40:22	CSA:80230385
Alternate.	Shenzhen Envicol Technology Co., Ltd.	EMW600HCNC3E	60KW，480V	ANSI/UL 60335-1 ANSI/UL 60335-2-40	5026063(ETL)
Air conditioner	Shenzhen Envicol Technology Co., Ltd.	EC20HDNC1G	2000W，220V	UL 60335-1 UL 60335-2-40	UL-US-2442406-0
Alternate.	Shenzhen Envicol Technology Co., Ltd.	MC06HDNC1D	600W，230V	UL 60335-1 UL 60335-2-40	UL-US-2431730-1

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Dehumidifier	Suzhou Blackshields Environment Co., Ltd.	DH0150D	150W，230V	ANSI/UL60335-1 ANSI/UL60335-2-40 CAN/CSA C22.2 NO.60335-1:16 CAN/CSA C22.2 NO.60335-2-40:22	CSA:80255978
Alternate.	Shenzhen Envicol Technology Co., Ltd.	MC03CDNC1A	170W，220V	ANSI/UL60335-1 ANSI/UL60335-2-40	UL-US-2450043-0
Container	JIANGXI SHIP DATA TECHNOLOGY CO., LTD.	/	SPA-H+rock wool, 6058*2438*2896mm	/	/
Alternate.	Dongfang International Container (Qidong) Co., Ltd.	/	SPA-H+rock wool, 6058*2438*2896mm	/	/
Alternate.	Fujian CIMC New Energy Technology Co., Ltd.	/	SPA-H+rock wool, 6058*2438*2896mm	/	/
Alternate.	Changshu Yahgee Modular Building Co., Ltd.	/	SPA-H+rock wool, 6058*2438*2896mm	/	/
Supplementary information: 1) Provided evidence ensures the agreed level of compliance. See OD-CB2039.					

Deping Cao TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.** (Place)	2025/07/01 (Date)
	Shijin Yang (Stamp and signature of applicant)	
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Constructional Data Form for Electrical Products

(For TUV Rheinland (Shanghai) use only)
Certificate # File # CN251VG2 001

Routine Safety Testing:

Required: ☒ **Not Required:** ☐ ***Reason:*** ***Class III product:*** ☐

Other: Class 1

Test Details:	**Test Points:**	**Test Values**
☒ **Dielectric Strength:**	**From battery +/- to enclosure**	**4414Vdc/1min.**
	From battery +/- to Communication terminal	**6000Vdc/1min.**
	From Auxiliary power input L/N to enclosure	**2120 Vdc/1min**
	From Auxiliary power input L/N to Communication terminal	**4240 Vdc/1min**
☒ **Ground Continuity:**	**From enclosure to Ground terminal**	**25A, ≤0.1Ω**
☐ **Insulation Resistance:**		
☐ **Leakage Current:**		
☐ **Other:**		

Deping Cao TUV Rheinland (Shanghai) Co., Ltd.	**AESC Jiangsu Co., Ltd.** (Place)	2025/07/01 (Date)
	Shijin Yang (Stamp and signature of applicant)	

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Appendix B

UL 9540A TEST REPORTS

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

Project Number.....:	**4791271040**
Date of issue.....:	**224-06-21**
Total number of pages.....:	**34**
UL Report Office .....:	**UL(Changzhou) Quality Technical Service Co., LTD.**
Applicant's name.....:	**Envision Dynamics Technology (Jiangsu) Co., Ltd**
Address .....:	**No. 66, Shentai Road, Shengang Subdistrict, Wuxi, Jiangsu, 214000, 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

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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 .....:	HC-L315A
Ratings (Vdc, Ah) .....:	315Ah, 3.2Vdc
Chemistry of test item……:	Lithium iron phosphate
Original Equipment Manufacturer (OEM):	Envision Dynamics Technology (Jiangsu) 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 (MH65212)
Average cell surface temperature at gas venting, °C:	**159**
Average surface temperature at thermal runaway, °C:	**246**
Gas Volume:	**160.4 L**
Lower flammability limit (LFL), % volume in air at the ambient temperature	**7.75**
Lower flammability limit (LFL), % volume in air at the venting temperature	**7.45**
Burning velocity (S_u) cm/s:	**83.39**
Maximum pressure (P_{max}) psig:	**95.83**

Cell Gas composition

Gas		Measured %
Carbon Monoxide	CO	12.896
Carbon Dioxide	CO2	23.467
Hydrogen	H2	51.380
Methane	CH4	4.980
Acetylene	C2H2	0.243
Ethylene	C2H4	2.458
Ethane	C2H6	0.845
Propadiene (Allene)	C3H4	0.005
Propylene	C3H6	1.252
Propane	C3H8	0.254
-	C4 (Total)	0.417
-	C5 (Total)	0.099
-	C6 (Total)	0.021
Benzene	C6H6	0.012
Dimethyl Carbonate	C3H6O3	1.453
Ethyl Methyl Carbonate	C4H8O3	0.217
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 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)..... :	William Mao(T), Yangyang Zhu	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) ..... :	N/A	N/A
Project Handler (name, signature)..... :	Iris Q Li	Iris Li
Reviewer (name, signature) ……..:	Albert He	Albert He
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)..... :	Iris Q Li
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 **16** through **18***)

Attachment B: Cell Instrumentation Photos - (*Pages **19** through **19***)

Attachment C: Cell Temperature Profiles during testing - (*Pages **20** through **22***)

Attachment D: Cell Testing Photos - (*Pages **23** through **32***)

Attachment E: Cell vent gas test chamber photo and profile of chamber gas analysis (O_2 and Pressure) - (*Pages **33** through **33***)

Attachment F: Cell Gas Analysis Report - (*Pages **34** through **34***)

Photo of cell/Stack:





Test Item Charge/Discharge Specifications:	
• **Charge power, W:**	**504**
• **Standard full charge voltage, Vdc:**	**3.65**
• **Charge temperature range, °C:**	**0~60**
• **End of charge voltage, V:**	**3.65**
• **Discharge power, W:**	**504**
• **End of discharge voltage, Vdc:**	**2.5**
• **Discharge temperature range, °C:**	**-30~60**

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.....:	Cell model HC-L315A
Date of receipt of test item .....:	2024-04-09
Date (s) of performance of tests.....:	2024-04-09~2024-04-18
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: Envision Dynamics Technology (Hubei) Co., Ltd No.5, Xicheng Street, Shiyan, Hubei, 442003, CN Factory -2: Envision Dynamics Technology (Ordos) Co., Ltd. No. 1, Wei Shisi Dong Road, Jiangsu Industrial Park, Ejin Horo Banner, Ordos, Nei Mongol Zizhiqu, 017200, CN
General product information and other remarks: The tested cell is a Lithium-ion battery cell, Model HC-L315A. Each cell has a capacity of 315 Ah and nominal voltage 3.2 Vdc. The overall dimensions of cell are 71.8±0.6 mm (depth) by 174.26±0.6 mm (width) by 207.01±0.6 mm (height) with blue film. The weight of cell is 5650±300g. Note: The cell samples submitted for test were manufactured by factory -1.	

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	71.8±0.6 mm (depth) by 174.26±0.6 mm (width) by 207.01±0.6 mm (height) with blue film	—
	Cell Weight, g	5650±300g	—
5.1.2	Cell Certification:	Yes	—
	Standard Used for Cell Certification:	UL 1973	—
	Organization that Certified Cell:	UL (MH65212)	—
5.1.1, 5.4.1	Cell/Stack Ratings: • Nominal Voltage, Vdc •Nominal Capacity, Ah	3.2 315	— —
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

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
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 See also Table 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 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	Two heaters 152.4 mm 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 See Table 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.	
	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

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
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.	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	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
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, D	C
7.3.1.9	The temperature at the onset of thermal runaway was documented.	See Table 4 See Attachment C, 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
7.4	**Cell vent gas composition test**		
7.4.1	Cell vent gas was generated and captured by forcing a cell into thermal runaway with the methodology developed in 7.3, inside a pressure vessel	Size of pressure vessel used: 99.11 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): 0.29	C

UL 9540A, Edition 4,			
Clause	Requirement + Test	Result - Remark	Verdict
		Oxygen concentration measured (% volume): 0.003 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.	2024/04/19: 26.2°C/ 34.0%RH/ 1012.5hPa 2024/04/22: 24.5°C /52.1%RH/ 1012.5hPa	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
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**	The following criteria are used to determine when module level testing will be necessary	C
7.7.1	a) Thermal runaway cannot be induced in the cell; and	The thermal runaway was initiated with external heater on the cells 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

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

Table 1 – Specified conditioning parameters			
Charging:		Discharging	
Power (CW), W	504	Power (CW), W	504
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**
1	2024-04-09 9:28 AM	2024-04-09 3:48 PM
2	2024-04-10 8:53 AM	2024-04-10 11:16 AM
3	2024-04-11 11:38 AM	2024-04-11 4:27 PM
4	2024-04-14 10:10 AM	2024-04-14 5:38 PM
5	2024-04-17 1:21 PM	2024-04-17 8:08 PM

Table 3 - Test Initiation Details					
	Cell Test 1	**Cell Test 2**	**Cell Test 3**	**Cell Test 4**	**Cell Test 5**
Test Date	2024-04-09	2024-04-10	2024-04-11	2024-04-14	2024-04-17
Test Start Time	3:48 PM	11:16 AM	4:27 PM	5:38 PM	8:08 PM
Initial Lab Temperature	21.7°C	20.2°C	20.2°C	22.4°C	20.2°C
Initial Relative Humidity	68.4%RH	63.9%RH	61.4%RH	72.2%RH	72.4%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	3.398	3.415	3.399	3.396	3.401
Average Heating Rate, °C/min	4.5	4.5	4.5	4.5	4.5
Venting Time after the test start (hh:mm:ss)	00:36:10	0:36:01	0:36:24	0:35:59	0:38:25
Venting Temperature, °C	160	159	161	154	170
Thermal Runaway Time after the test start (hh:mm:ss)	00:57:35	0:57:27	0:57:14	0:57:23	0:58:03
Thermal Runaway Temperature, °C	249	248	254	234	248
Refer to Attachment C for surface temperature profiles during testing					

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

Table 5 – Average Vent and Thermal Runaway Temperatures	
Average of Cell Vent Temperatures, °C	159
Average of Cell Thermal Runaway Temperatures, °C	246
#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	12.896	10.9
Carbon Dioxide	CO2	23.467	N/A
Hydrogen	H2	51.380	4.0
Methane	CH4	4.980	4.4
Acetylene	C2H2	0.243	2.3
Ethylene	C2H4	2.458	2.4
Ethane	C2H6	0.845	2.4
Propadiene (Allene)	C3H4	0.005	1.9
Propylene	C3H6	1.252	1.8
Propane	C3H8	0.254	1.7
-	C4 (Total)	0.417	N/A
-	C5 (Total)	0.099	N/A
-	C6 (Total)	0.021	N/A
Benzene	C6H6	0.012	1.2
Dimethyl Carbonate	C3H6O3	1.453	N/A
Ethyl Methyl Carbonate	C4H8O3	0.217	N/A
Total	-	100	-

[1] Extracted LFL values from ISO 10156-2017

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

Table 9 – Gas composition excluding the constituents with boiling points higher than 60°C[2]			
Gas		**Measured %**	**Component LFL**
Carbon Monoxide	CO	13.120	10.9
Carbon Dioxide	CO2	23.874	N/A
Hydrogen	H2	52.270	4.0
Methane	CH4	5.066	4.4
Acetylene	C2H2	0.247	2.3
Ethylene	C2H4	2.501	2.4
Ethane	C2H6	0.859	2.4
Propylene	C3H6	1.274	1.8
Propane	C3H8	0.259	1.7
Propadiene	C3H4	0.005	1.9
-	C4 (Total)	0.424	N/A
-	C5 (Total)	0.101	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.

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

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, [159 °C] (% vol in air)	7.45
Burning Velocity Measurement, S_u cm/sec	83.39
Maximum Pressure P_{max}, psig	95.83

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

	TABLE: Critical components information				
Object / part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cell Model	Envision Dynamics Technology (Jiangsu) Co., Ltd	HC-L315A	3.2Vdc, 315Ah, LFP	UL 1973	UL (MH65212)
Separator	Shenzhen Senior Technology Material Co., Ltd.	11SPE00558	PE Thickness: 12±2 um	—	—
Electrolyte	—	—	EC/DMC/EMC/PC/VC/LiPF6	—	—
Case	—	—	Aluminium (0.54~0.74) mm (front)/ (0.7~0.9) mm (side)/ (1.5±0.05) mm (bottom)	—	—
Insulators/ location in cell	—	—	Top Insulation plate: PP Mylar: PP Bottom plate: PP Top Cap: PPS, PP	—	—
Vent	—	—	Aluminium Vent Pressure: 0.6±0.2 MPa	—	—

Attachment A: Cell Conditioning (Charge/discharge) Profiles - (*Pages **16** through **18***)

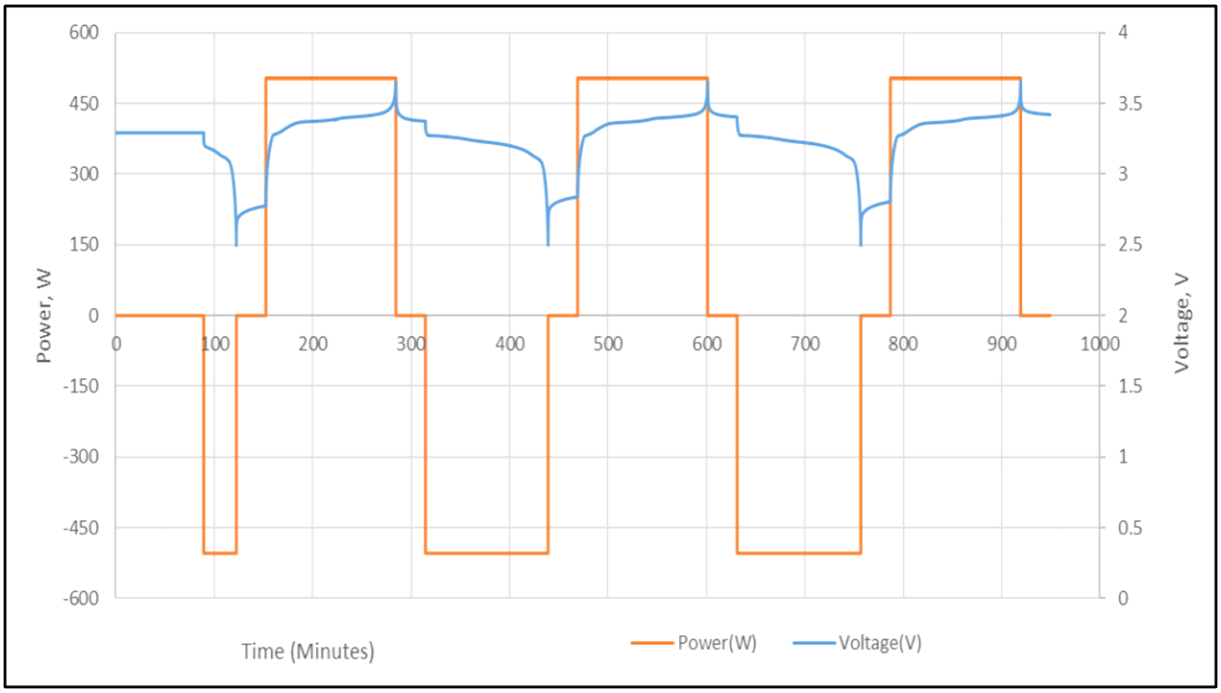


Figure 1: Cell 1 Conditioning (Charge/discharge) Profiles

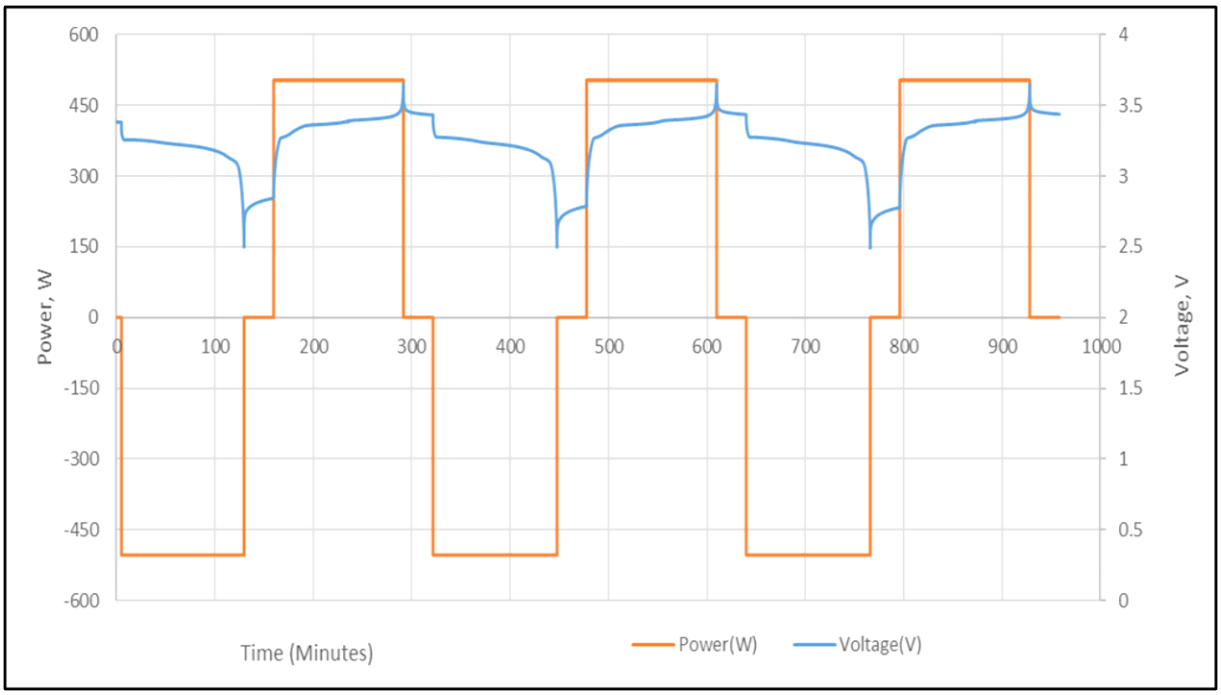


Figure 2: Cell 2 Conditioning (Charge/discharge) Profiles

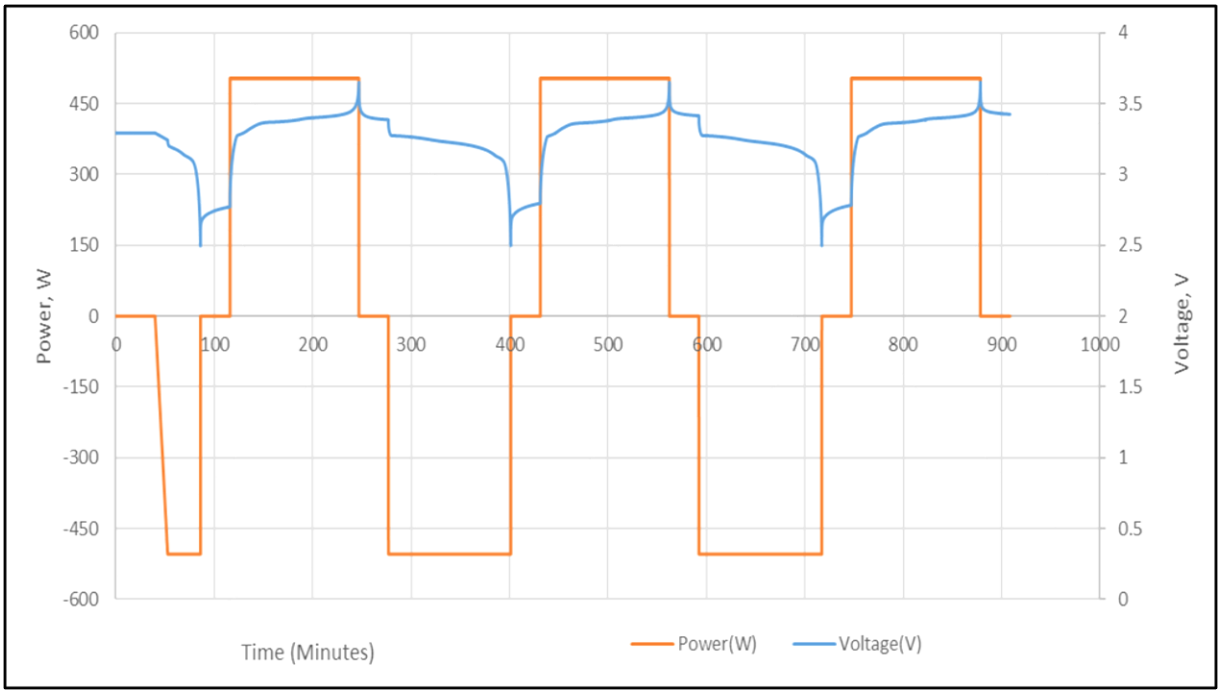


Figure 3: Cell 3 Conditioning (Charge/discharge) Profiles

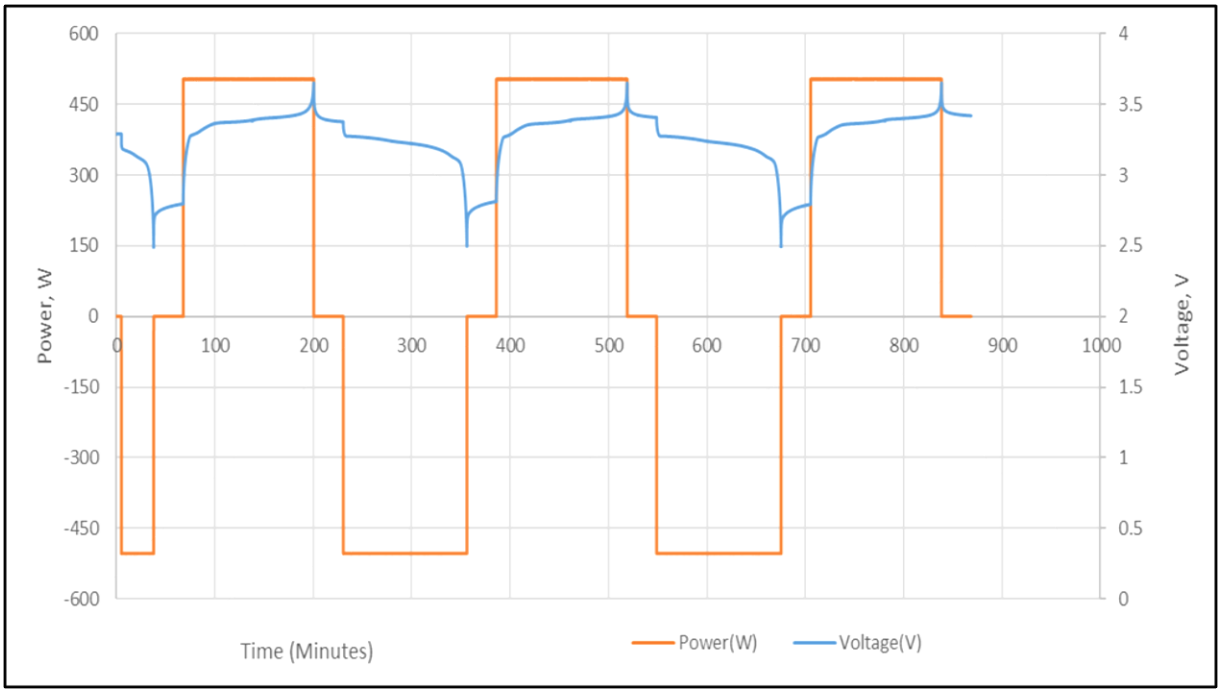


Figure 4: Cell 4 Conditioning (Charge/discharge) Profiles

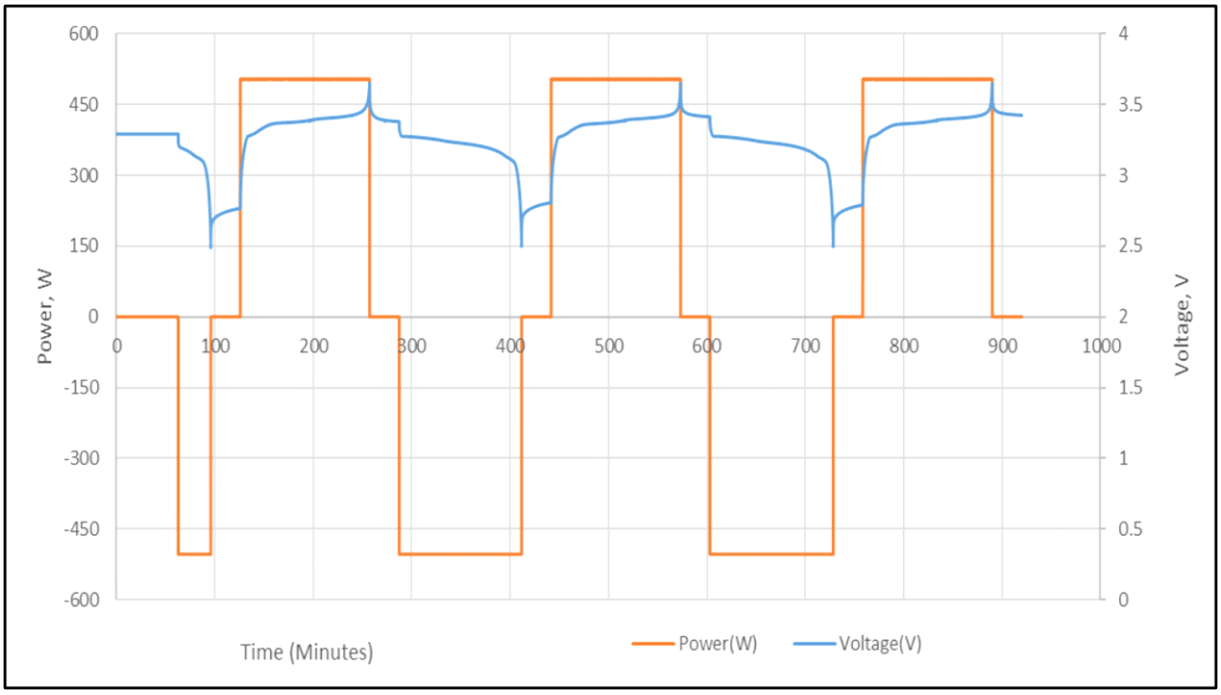
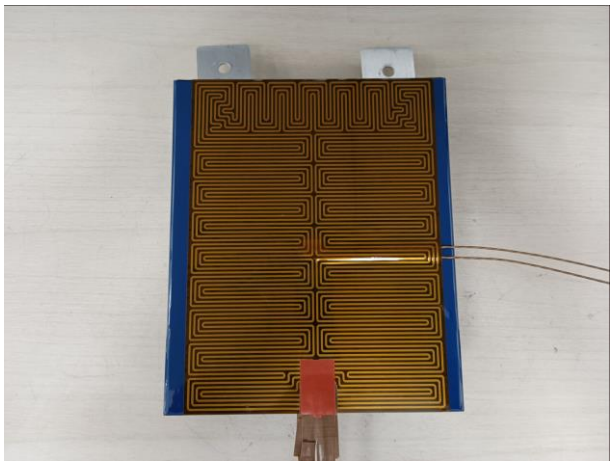
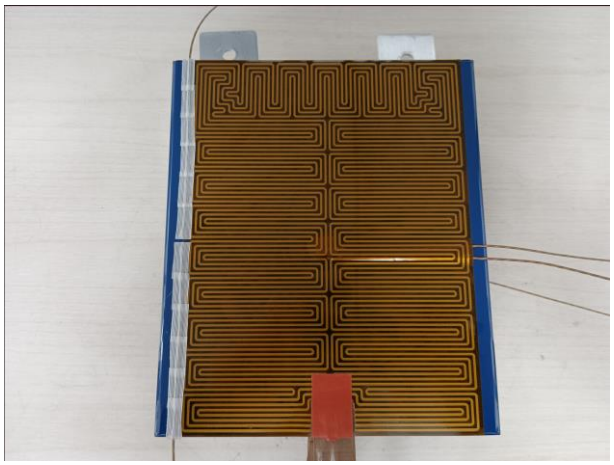


Figure 5: Cell 5 Conditioning (Charge/discharge) Profiles

Attachment B: Cell Instrumentation Photos - (*Pages **19** through **19***)







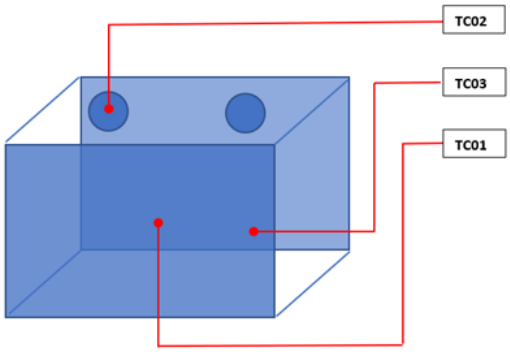


Figure 6: Sample Instrumentation Prior to Test
Note: heaters were placed on two sides of the cell after thermocouples were instrumented.
Note: TC01 between cell body and heater; TC02 on the cell positive; TC03 on the cell body not covered by heater; TC04 Ambient temperature; V1 cell voltage.

Attachment C: Cell Temperature Profiles during testing - (*Pages **20** through **22***)

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.

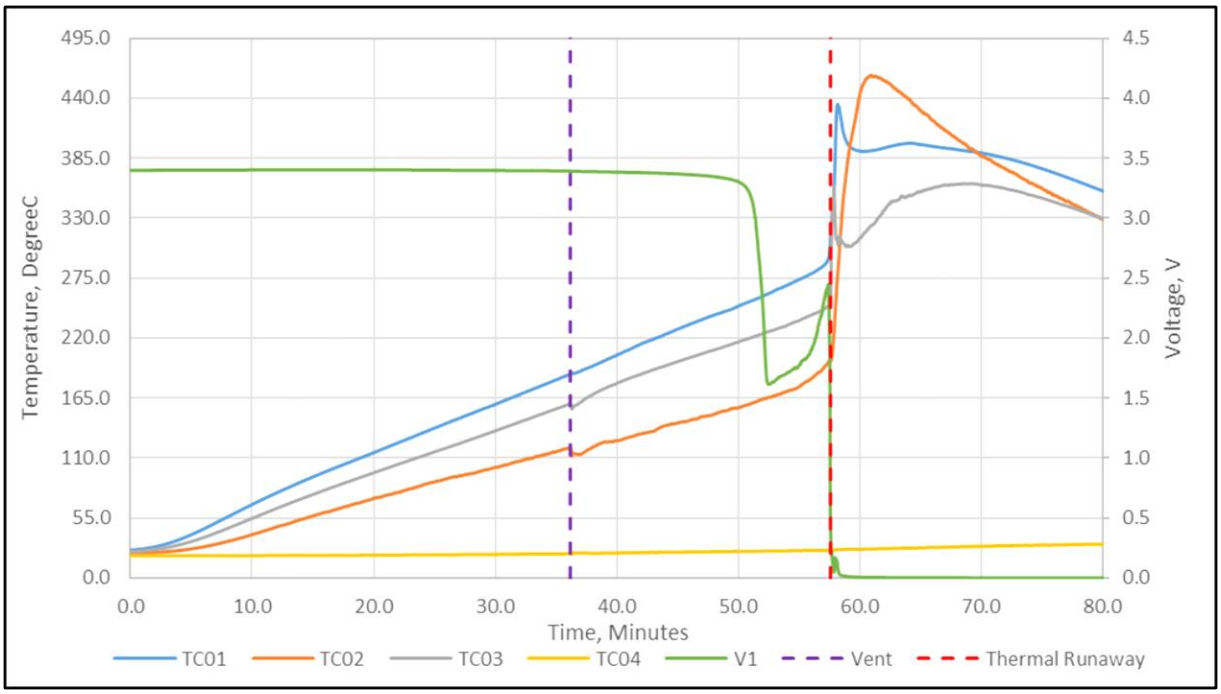


Figure 7: Cell 1 – External Heating 4.5°C per minute

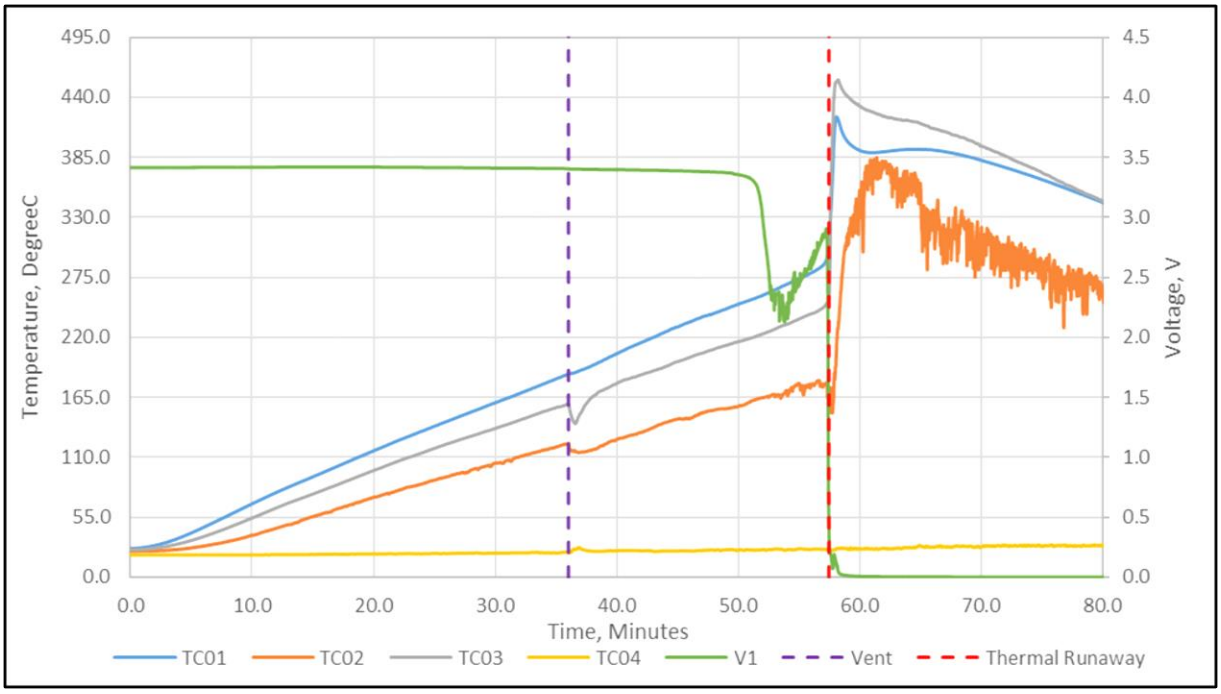


Figure 8: Cell 2 – External Heating 4.5°C per minute

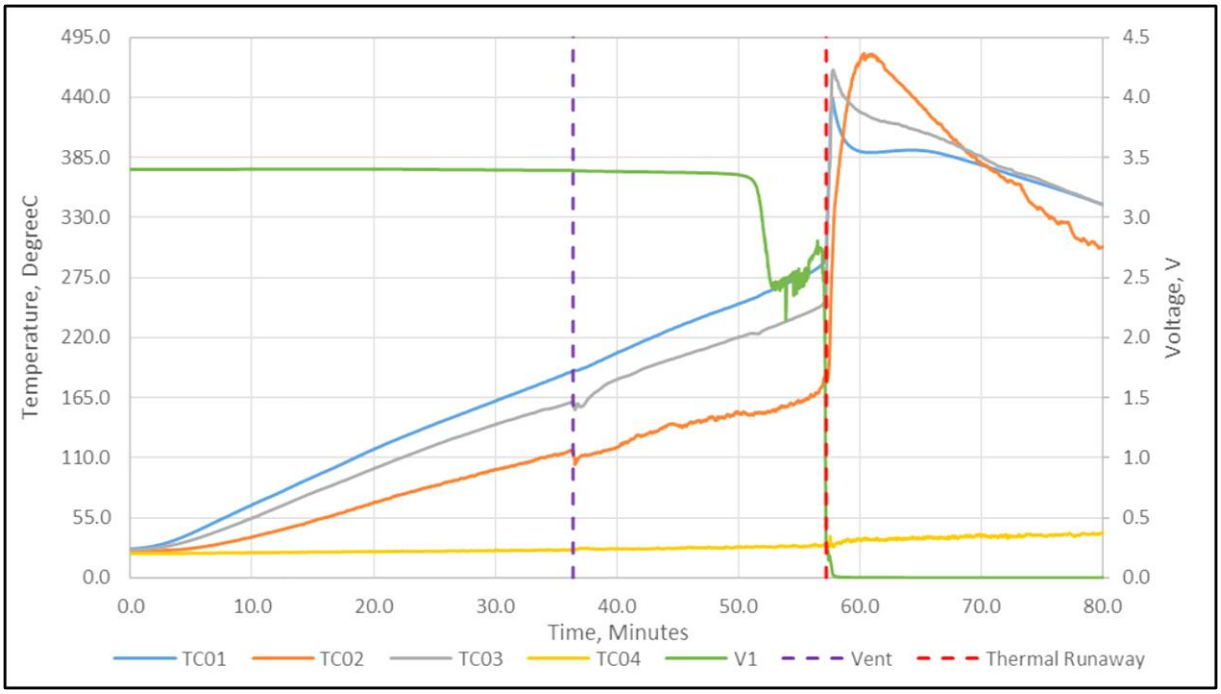


Figure 9: Cell 3 – External Heating 4.5°C per minute

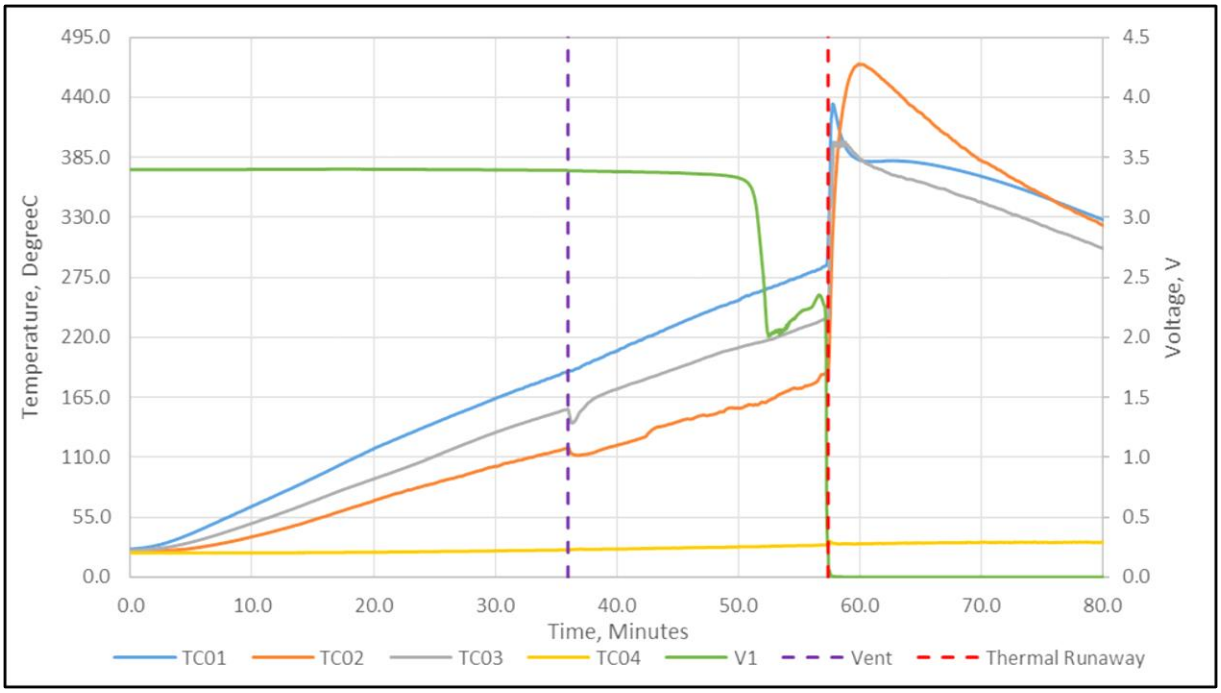


Figure 10: Cell 4 – External Heating 4.5°C per minute

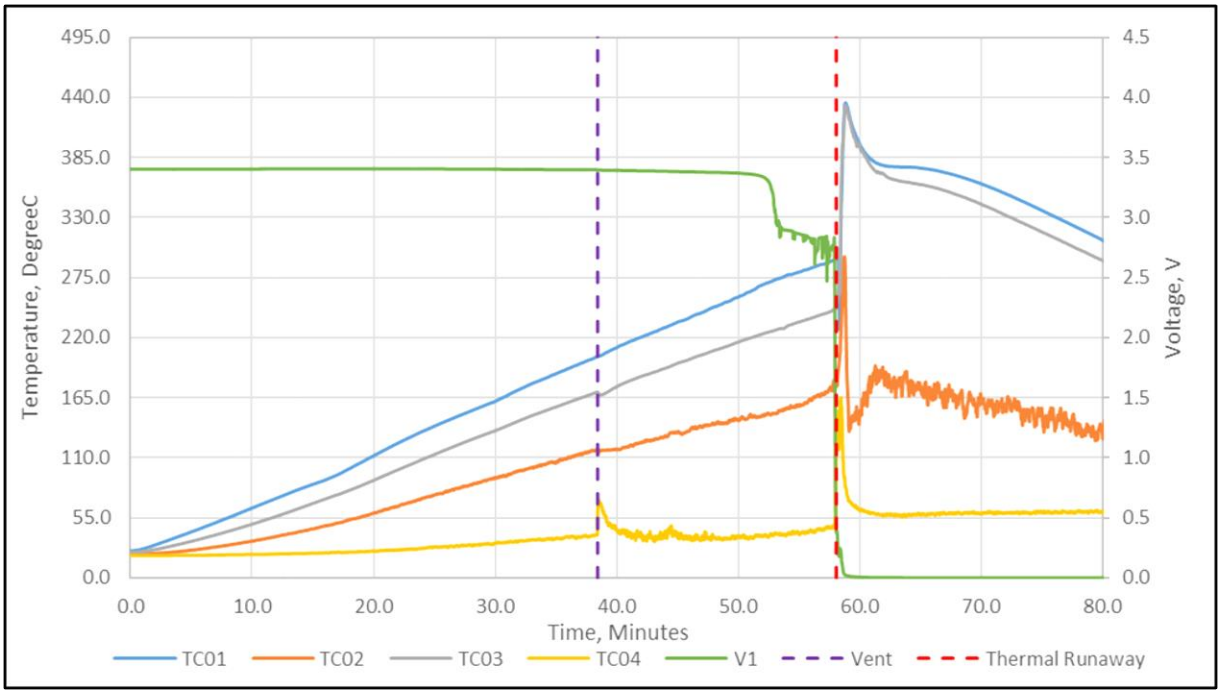
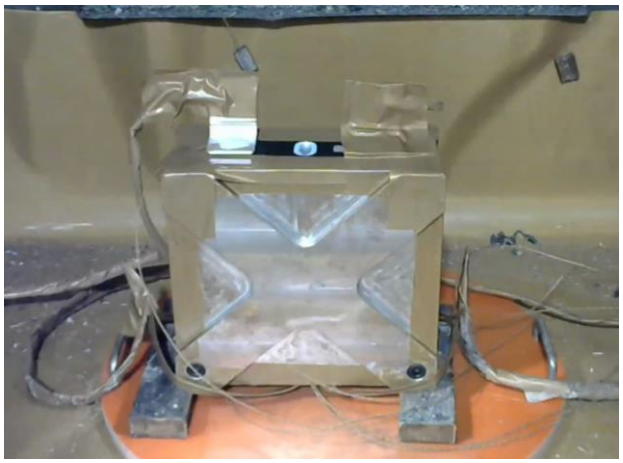
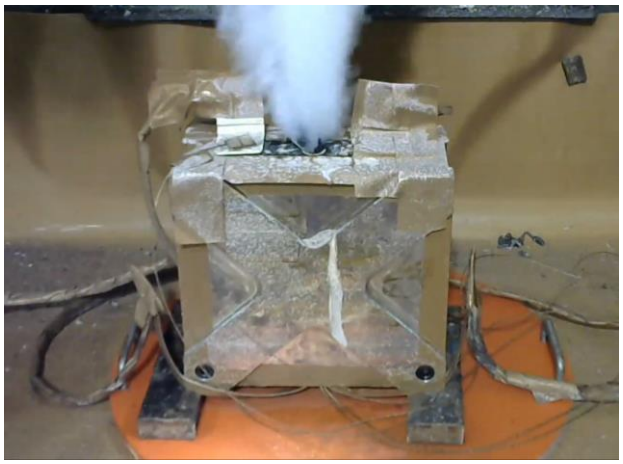


Figure 11: Cell 5 – External Heating 4.5°C per minute

Attachment D: Cell Testing Photos - (*Pages **23** through **33***)

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.

<table>
<tr><td></td><td></td></tr>
<tr><td>(a) Test Start
[00:00]</td><td>(b) Cell Venting
[36:10]</td></tr>
<tr><td></td><td></td></tr>
<tr><td>(c) Thermal runaway behavior
[57:35]</td><td></td></tr>
<tr><td colspan="2">Figure 12: Highlights of Cell 1 Testing</td></tr>
</table>

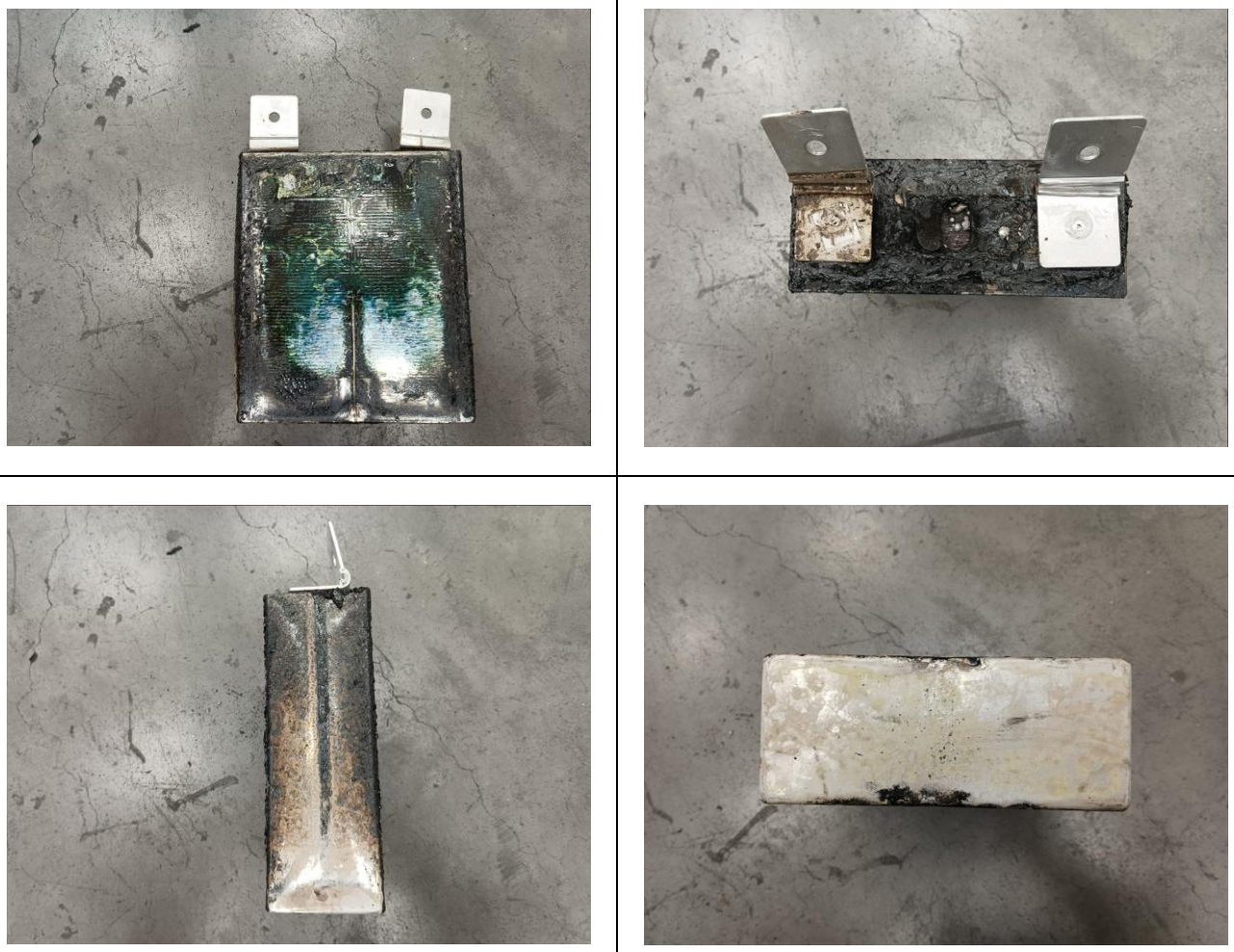
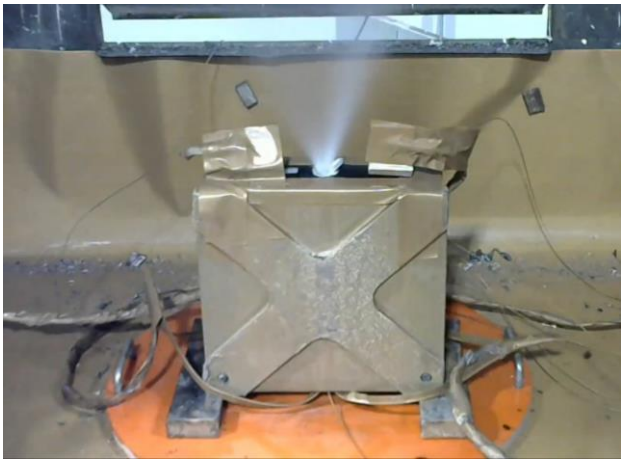


Figure 13: Sample 1 Post Test Photos

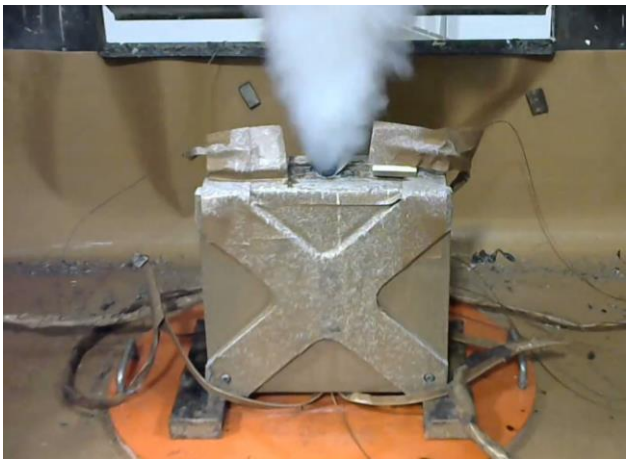
Cell Sample 2 – below figure shows highlights of cell testing. Cell venting and thermal runaway were observed, however no evidence of fire. Figure on next page shows photos of cell after testing.



(a) Test Start
[00:00]



(b) Cell Venting
[36:01]



(c) Thermal runaway behavior
[57:27]

Figure 14: Highlights of Cell 2 Testing

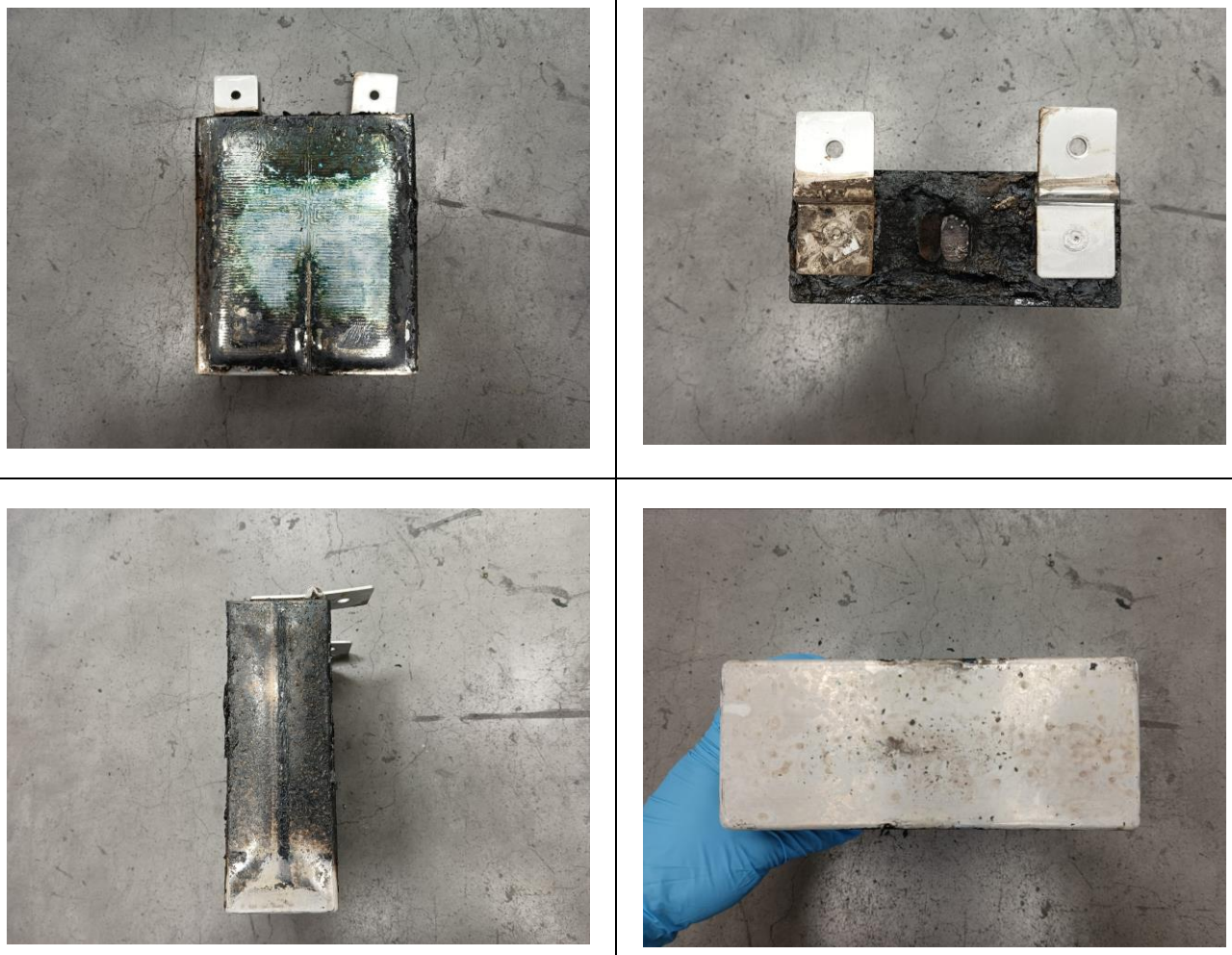


Figure 15: Sample 2 Post Test Photos

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
[36:24]



(c) Thermal runaway behavior
[57:14]

Figure 16: Highlights of Cell 3 Testing

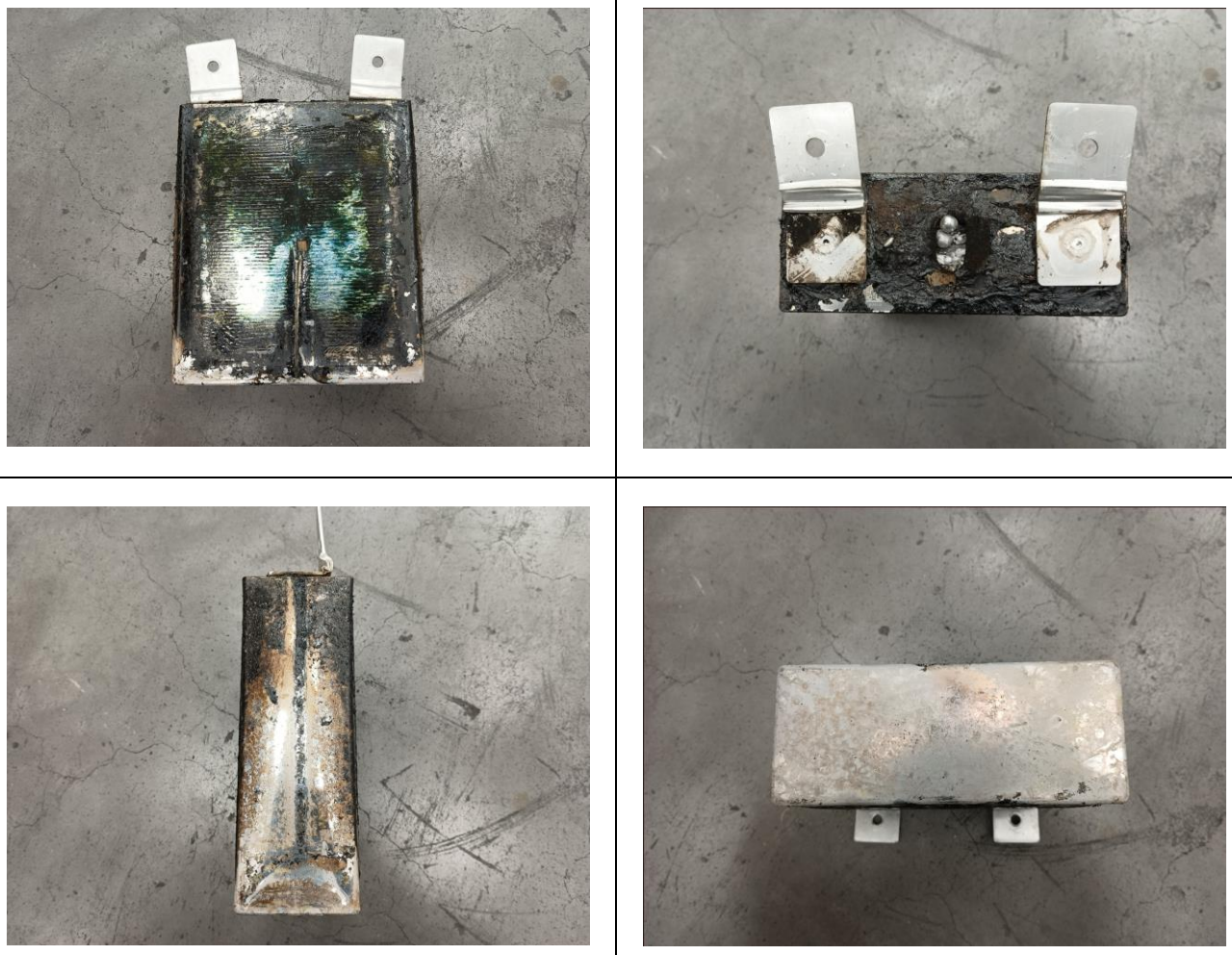
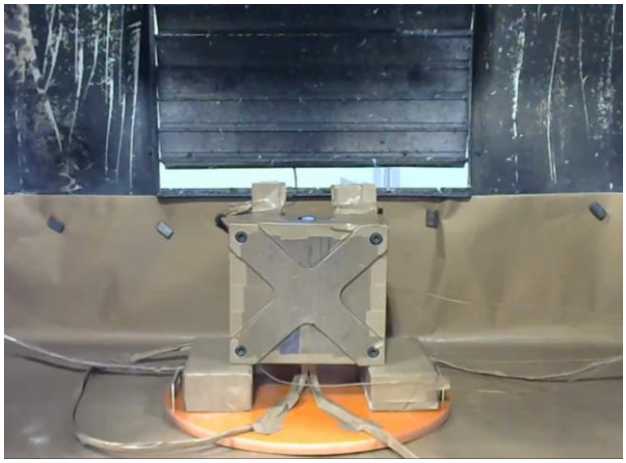
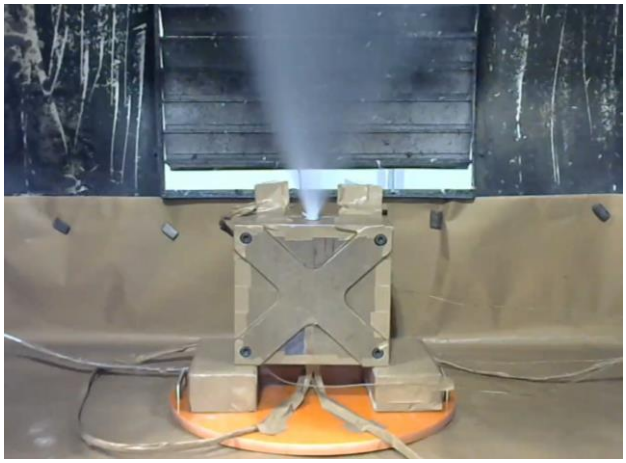


Figure 17: Sample 3 Post Test Photos

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
[35:59]



(c) Thermal runaway behavior
[57:23]

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
[38:25]



(c) Thermal runaway behavior
[58:03]

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) - (*Pages **33** through **33***)

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 99.11 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 0.003%, with initial pressure 0.29psig).

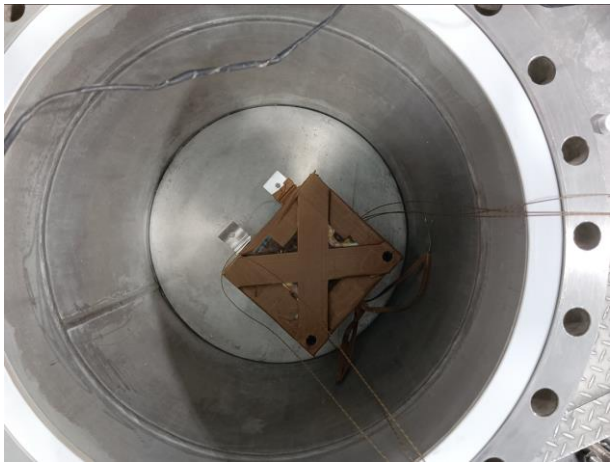


Figure 22: Sample 5 instrumented and inside gas test chamber

$\phi_{O2,\ chamber}$=	0.003	%

Pinitial,chamber=	0.29	psig

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

Attachment F: Cell Gas Analysis Report - (*Pages **34** through **34***)

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

Item	Measure	Chemical formula	Conc.(%)
1	Carbon Monoxide	CO	12.896
2	Carbon Dioxide	CO_2	23.467
3	Hydrogen	H_2	51.380
4	Methane	CH_4	4.980
5	Ethylene	C_2H_4	2.458
6	Acetylene	C_2H_2	0.243
7	Ethane	C_2H_6	0.845
8	Propane	$CH_3CH_2CH_3$	0.254
9	Propylene	C_3H_6	1.252
10	Propadiene (Allene)	C_3H_4	0.005
11	Isobutane	$CH_3CH(CH_3)CH_3$	0.012
12	Butane	C_4H_{10}	0.057
13	Isobutylene	C_4H_8	0.235
14	1-Butene	C_4H_8	0.054
15	trans-2-Butene	C_4H_8	0.024
16	cis-2-Butene	C_4H_8	0.034
17	Pentane	C_5H_{12}	0.086
18	trans-2-Pentene	C_5H_{10}	0.013
19	cis-2-Pentene	C_5H_{10}	0.001
20	1,4-Pentadiene	C_5H_8	0.000
21	Hexane	C_6H_{14}	0.004
22	1-Hexene	C_6H_{12}	0.018
23	Benzene	C_6H_6	0.012
24	1-Heptene	C_7H_{14}	0.000
25	Toluene	C_7H_8	0.000
26	Styrene	C_8H_8	0.000
27	Dimethyl Carbonate	$C_3H_6O_3$	1.453
28	Ethyl Methyl Carbonate	$C_4H_8O_3$	0.217
29	Diethyl Carbonate	$C_5H_{10}O_3$	0.000
	Total	Measurement result	100.000

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

Project Number. .....:	**4791603240**
Date of issue.....:	**2025-01-27**
Amendment No.1.....:	**2025-07-25**
Total number of pages .....:	**30**
UL Report Office .....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name .....:	**AESC Jiangsu Co., LTD**
Address.....:	**No. 66, Shentai Road, Shengang Subdistrict, Wuxi, Jiangsu, 214000, China**
Test specification:	4th Edition, Section 8, November 12, 2019
Standard.....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure .....:	8.1 – 8.4
Non-standard test method .....:	N/A

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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	
Cells in Module:	
●Manufacturer Name	**AESC Jiangsu Co., LTD**
●Part Number	**HC-L315A**
●Chemistry	**Lithium iron phosphate**
●Format	**Prismatic**
Ratings (Vdc, Ah) :	**3.2Vdc, 315Ah**
Was the cell certified? :	**Yes**
Standard the cell was certified to:	**UL 1973**
Organization that certified the cell:	**UL (MH65212)**
Average cell surface temperature at gas venting, °C:	**159**
Average cell surface temperature at thermal runaway, °C:	**246**
Gas Volume:	**160.4 L**
Lower flammability limit (LFL), % volume in air at the ambient temperature:	**7.75**
Lower flammability limit (LFL), % volume in air at the venting temperature:	**7.45**
Burning velocity (S_u) cm/s:	**83.39**
Maximum pressure (P_{max}) psig:	**95.83**

Cell Gas Composition:

Gas		Measured %
Carbon Monoxide	**CO**	**12.896**
Carbon Dioxide	**CO2**	**23.467**
Hydrogen	**H2**	**51.380**
Methane	**CH4**	**4.980**
Acetylene	**C2H2**	**0.243**
Ethylene	**C2H4**	**2.458**
Ethane	**C2H6**	**0.845**
Propadiene (Allene)	**C3H4**	**0.005**
Propylene	**C3H6**	**1.252**
Propane	**C3H8**	**0.254**
-	**C4 (Total)**	**0.417**
-	**C5 (Total)**	**0.099**
-	**C6 (Total)**	**0.021**
Benzene	**C6H6**	**0.012**
Dimethyl Carbonate	**C3H6O3**	**1.453**
Ethyl Methyl Carbonate	**C4H8O3**	**0.217**
Total	**-**	**100**

Module level Information	
Model No:	HP-L630A
Ratings (Vdc, Ah) :	166.4Vdc, 630Ah

Module cell configuration (xS/**y**P**) ……:**	52S2P
Module dimensions (W x **D** x **H** (mm)**) :**	2197.7±5 mm*794±5 mm*246.2±5 mm
Module weight (kgs) :	670±10kg
Module enclosure material:	Top metal enclosure and Front panel: made of Unsaturated Polyester, minimum thickness 1.6 mm Bottom enclosure: made of aluminum alloy, minimum thickness 2.0 mm
Original Equipment Manufacturer (OEM):	AESC Jiangsu Co., LTD
Branding Manufacturer (if not OEM):	Envision Energy Co., Ltd.
Was the module certified? :	No
Standard the module was certified to:	N/A
Organization that certified test item:	N/A

Cell failure test method performed for the module level (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*)
☐ Others

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

Description of components employed within the module that serve to supress propagation (fire protection features).
There was thermal insulation pad between each adjacent cell in the module, total 96 pcs.

Number of initiating cells failed to achieve propagation.	**1**
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to one adjacent cells
Maximum Smoke Release Rate (m^2/s)	0.21
Total Smoke Released: (m^2)	5.90
Total smoke released duration	00:32:23 to 1:40:00
Peak Chemical Heat Release Rate: (kW):	No flaming occurred
External Flaming:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred

	Flying Debris:	No flying debris occurred
	Re-ignitions:	No further re-ignitions were observed during post test observation

Summary of Module level test Gas Analysis Data:

Gas Analysis:

☒ **Flame ionization detection**

☐ **Fourier-Transform infrared Spectrometer**

☒ **Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)**

☒ **White light source with photo detector (smoke release rate)**

- **Gas Composition & Volume for Each Compound (Pre-flaming and After flame):**

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	34.04	No flaming	0.04
Carbon Dioxide	Carbon Containing	46.31	No flaming	1.14
Carbon Monoxide	Carbon Containing	21.79	No flaming	0.45
Hydrogen	Hydrogen	91.52	No flaming	7.82

Summary of Module testing:

Performance Criteria in accordance with Clause 8.4 and Figure 1.1:

[X] The effects of thermal runaway was contained by the module design;

[ ] Cell vent gas (based upon the cell level test) was non-flammable

Necessity of a unit level test

[X] The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 4th edition has not been met, therefore unit level testing in accordance with UL 9540A will need to be conducted on a complete unit employing this module.

[ ] The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 4th edition has been met, therefore unit level testing in accordance with UL 9540A need not be conducted.

Testing Laboratory information

Testing Laboratory and testing location(s):

Testing Laboratory:	Beijing Building Materials Testing Academy	
Testing location/ address.....:	Block 1, B15 Yaxin Road, Doudian Town, Fangshan district, Beijing 102402, CN	
Tested by (name, signature) .....:	Qi Zhang, Fei Huang	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) .....:	N/A	N/A
Project Handler (name, signature).....:	Iris Q Li(T)/ Arui Zhou	Iris Li Arui Zhou

Reviewer (name, signature) ……..:	Albert He / Rebecca Le	Albert.He Rebecca Le
Amendment 1 Project Handler (name, signature) :	Iris Q Li	Iris Li
Amendment 1 Reviewer (name, signature) ……..:	Albert He	Albert.He

List of Attachments (including a total number of pages in each attachment):
Attachment A: Module Conditioning (Charge/discharge) Profiles - (*Pages **20** through **20***)
Attachment B: Module Construction Photos - (Pages ***21*** through ***21***)
Attachment C: Module Instrumentation Photos - (*Pages **22** through **24***)
Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing - (*Pages **25** through **25***)
Attachment E: Module Testing Photos - (*Pages **26** through **27***)
Attachment F: Module Gas Flow Rate and Heat Release Profiles - (*Pages **28** through **30***)

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Clause	Requirement + Test	Result - Remark	Verdict

Photo(s) of module:




Model: HP-L630A



Model: ENS-2P52S-L-08



Models: HP-L630B and ENS-2P52S-L08-A11

Test Item Charge/Discharge Specifications:	
• **Charge power, kW:**	**52.416**

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Clause	Requirement + Test	Result - Remark	Verdict

• **Standard Full charge Voltage, Vdc:**	**52.416kW to cell voltage of 3.6V, then charge at 10.483kW to cell voltage of 3.62V**
• **Charge temperature range, °C:**	**0~60**
• **End of charge voltage, V:**	**cell voltage of 3.62V**
• **Discharge power, kW:**	**52.416**
• **End of discharge voltage, Vdc:**	**52.416kW to cell voltage of 2.8V**
• **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)
Testing.....:	
Date of receipt of test item .....:	2024-12-09
Date (s) of performance of tests .....:	2024-12-11

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) .....:	AESC Hubei Co., Ltd. No.5, Xicheng Street, Shiyan, Hubei, 442003, CN

General product information and other remarks:

Battery Module Model HP-L630A employs cell Model HC-L315A, rated 166.4Vdc, 630Ah.

The model ENS-2P52S-L-08 for Branding Manufacturer Envision Energy Co., Ltd. was similar as model HP-L630A for AESC Jiangsu Co., LTD, except having the fire protection communication connection and suppressor fluid inlet, located on the right side of front panel.

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The model HP-L630B was similar as model HP-L630A, except adding MSD which leads a slight increase in total size, changing the fuse type to meet the new MSD, adding fire protection communication connection and suppressor fluid inlet located on the right side of front panel, and different DC High Voltage Connector type.

The model ENS-2P52S-L08-A11 for Branding Manufacturer Envision Energy Co., Ltd. was identical to the model HP-L630B for AESC Jiangsu Co., LTD.

Note: Battery models ENS-2P52S-L-08, HP-L630B and ENS-2P52S-L08-A11 have not been conducted test and for reference only.

Amendment No.1 Report:

The original Test Report under project 4791603240, dated on 2025-01-27, was modified on 2025-07-25 under project 4791861688 to include the following changes:

1. Revise the model name ENS-2P52S-L-08 was for Branding Manufacturer Envision Energy Co., Ltd., and the model name HP-L630A was for AESC Jiangsu Co., LTD.

2. Add the alternate models HP-L630B and ENS-2P52S-L08-A11.

3. Add alternate DC High Voltage Connector and MSD types for models HP-L630B and ENS-2P52S-L08-A11.

4. Add alternate DC High Voltage Connector for models HP-L630A and ENS-2P52S-L-08.

5. Update the cell Manufacturer Name on page 2 due to the new Amendment No.1 revision for cell project 4791271040 report, revised on 2025-05-16.

6. Update the page number.

5.0	**CONSTRUCTION**		**Verdict**
5.2	**Module Construction**		—
5.2.1, 5.2.3	Construction information	See Test Item Description at the beginning of this report	—
	General layout of module contents	See Attachment B	—
5.2.2	Module certified to UL 1973	No	
	Organization that certified module:	N/A	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		
8.1	**Samples**		
8.1.1	Samples conditioned through charge discharge cycling a minimum of 2 cycles.	See Attachment A for profiles See Table 1 for specifications See also Table 2.	C
8.1.2	100% SOC and stabilize from 1h to 8 h before testing		
8.1.3	Electronic controls such as BMS not relied upon during testing.		C
8.2	**Test Method**		

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Clause	Requirement + Test	Result - Remark	Verdict
8.2.1	Ambient indoor laboratory conditions: 25 ±5°C (77 ±9°F) ≤50 ±25% RH at the initiation of the test.	See Table 3 The ambient indoor laboratory condition was 13°C, 29%RH. The temperature could be referred to unit level requirements and considered to be acceptable.	M
8.2.2	Test conducted under a smoke collection hood appropriately sized for the module		C
8.2.3	The weight of the module was recorded before and after testing, (kg)	See Table 11	C
8,2,4	A sufficient number of cells were forced into thermal runaway to create a condition of cell to cell propagation within the module.	See Attachment C and F See Tables 4 and 5	C
	The location of the cell(s) forced into thermal runaway were selected to present the greatest thermal exposure to adjacent cells	See Attachment C for figures showing location within the module of the cell(s) forced into thermal runaway	C
8.2.5	The method used to initiating thermal runaway in the cell(s) were in accordance with 7.2	See Summary of Cell Testing at the beginning of this report.	C
8.2.6	The occurrence of thermal runaway was verified	See Test Results from Cell Level Test from the beginning of this report See Attachments D and F	C
8.2.7	The module was placed on top of a non-combustible horizontal surface with the module orientation representative of its intended final installation.	See Attachment E Sample was placed on the surface horizontally per client's request.	C
8.2.8	The chemical heat release rate of the module was measured with oxygen consumption calorimetry	See Table 10 See Attachment F	C
8.2.9	The chemical heat relate rate was measured for the duration of the test	See Attachment F	C
8.2.10	The chemical heat release rate was measured using the following equipment: ● Paramagnetic oxygen analyser ● Non-dispersive infrared carbon dioxide and carbon monoxide analyser ● Velocity probe ● Type K thermocouple	See Attachment F	C

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	The instrumentation was located in the exhaust duct of the heat release rate calorimeter at a location that minimizes the influences of bends or exhaust devices.		C
8.2.11	The chemical heat release rate at each of the flows was calculated in accordance with 8.2.11.	See Attachment F	C
8.2.12	The hydrocarbon content of the vent gas was measured using flame ionization detection.	See Table 8 and 9	C
	Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.	See Table 9	C
8.2.13	The hydrocarbon content of the vent gas may also be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer.	FTIR analysis was not used in accordance with the Certification Requirement Decision: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test. FTIR was considered redundant to the other gas measurement methods used.	N/A
	Vent gas velocity and temperature measurements respectively were obtained in the exhaust duct of the heat release rate calorimeter using equipment specified in 8.2.10.		C
8.2.14	The light transmission in the exhaust duct of the heat release rate calorimeter was measured using a white light source and photo detector for the duration of the test.		C
8.2.15	Smoke release rate was calculated as outlined in 8.2.15	See Table 10 See Attachment F	C
8.3	**Module level test report**		
	a. Module manufacturer and model number; b. Number of cells in module; c. Module configuration;	See Test Item Description in beginning of this report.	C
	d. Module construction features;	See Attachment C See Critical Components Table	C
	e. Module voltage corresponding to the tested SOC;	See Table 3	C
	f. Thermal runaway initiation method used;	See Attachment C	C
	g. Heat release rate versus time data;	See Table 10 See Attachment F	C

UL 9540A, Edition 4,			
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	h. Flammable gas generation and composition data;	See Attachment F See Tables 8 and 9	C
	i. Peak smoke release rate and total smoke release data.	See Table 10 See Attachment F	C
	j. Observation(s) of flying debris or explosive discharge of gases;	See Table 12	C
	k. Observation(s) of sparks, electrical arcs, or other electrical events;	See Table 12	C
	l. Identification/location of cells(s) that exhibited thermal runaway within the module;	See Tables 4 and 5	C
	m. Locations and visual estimations of flame extension and duration from the module;	See Attachments E and F See Table 7	C
	n. Module weight loss;	See Table 11	C
	o. Video of the test.		C
8.4	**Performance – Module level**		
8.4.1	The following performance conditions are met during the module level test: a) Thermal runaway is contained by module design;	Thermal runaway was contained by module design.	P
	b) Cell vent gas is nonflammable as determined by the cell level test	Cell gas report show the cell gases are flammable. See Cell Gas Composition Table.	F

UL 9540A, Edition 4,			
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Table 1 – Specified conditioning parameters			
Charging:		**Discharging:**	
Current (CP), kW	52.416, then 10.483	Current (CP), kW	52.416
Standard full Charge Voltage, Vdc	N/A	End of discharge voltage, Vdc	cell voltage of 2.8V
End of charge voltage, V	52.416kW to cell voltage of 3.6V, then charge at 10.483kW to cell voltage of 3.62V	Discharging Test Ambient, °C	-30~60
Charging Test Ambient, °C	0~60		
Refer to Attachment A for charge/discharge profiles for the module.			

Table 2 – Charge completion and module test initiation times	
Charge Completion Date and Time	**Module Test Date and Time**
2024-12-11 10:52 AM	2024-12-11 4:13 PM

Table 3 - Test Initiation Details	
	Module No.: HP10-Box5 Pro
Test Date	2024-12-11
Test Start Time	4:13 PM
Initial Lab Temperature	13.0°C
Initial Relative Humidity	29%RH
Module OCV at Start of Test, Vdc	179.1

Table 4 – Approximate time of thermal runaway propagation through module	
Time to thermal runaway	**Location**
00:52:10	Initial Cell 64
00:55:58	Cell 63

Table 5 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	The test was started, and the heater was turned on to heat the initiating cell 7 at a ratio of 4 ~ 7 °C/min. See Figure (a).
00:32:23	Venting of initiating Cell	Initiating cell 64 vented at around 143°C measured through TC 03 by an indication of sudden dip in cell's temperature curve and venting sound. See Figure (b).
00:52:10	Thermal runaway of initiating cell	Initiating cell 64 was at around 210°C. Smoke and electrolyte leakage continuously from the front panel with no flame observed and the temperature of Cell 64 began to increase in an uncontrollable manner. See Figure (c) and Figure (d).
00:55:58	Thermal runaway of adjacent cell	Thermal runaway propagated to nearby cell 63. More Gas released. See Figure (e) and Figure (f).

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01:40:00	Test Termination	Data acquisition was stopped. The module was left in the test overnight and with video monitored. See Figure (g)

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Table 6 – Gases measured and measurement methods used in unit level testing			
Measurement Method	**Gases Measured**	**Chemical Formula**	**Gas Type**
Flame Ionization Detection (FID)	Total Hydrocarbons	-	Hydrocarbons
Solid-state Hydrogen Sensor	Hydrogen	H_2	-
Non-dispersive infrared spectroscopy (NDIR)	Carbon Dioxide	CO_2	Carbon Containing
	Carbon Monoxide	CO	Carbon Containing
# - This table was modified to reflect the gases measured during testing.			

Table 7 - Gas generation periods	
Time	**Condition**
00:32:23 to 01:40:00	No Flaming
External Flaming of Gas	
Condition	**Duration (hh:mm:ss)**
External Flaming of Vent Gases:	N/A

Table 8– Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	Gas Type	During Pre-flaming (L)	During Flaming (L)	Minimum detectable flow rate (LPM)
See Table 9				

Table 9– Summary of battery gas volumes identified during thermal runaway in module test				
Gas Component	Gas Type	During Pre-flaming (L)	During Flaming (L)	Minimum detectable flow rate (LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	34.04	No flaming	0.04
Carbon Dioxide	Carbon Containing	46.31	No flaming	1.14
Carbon Monoxide	Carbon Containing	21.79	No flaming	0.45
Hydrogen	Hydrogen	91.52	No flaming	7.82

Table 10– Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR (kW)	0 (No flaming)	Maximum SRR (m^2/s)	0.21
		Total Smoke Released (m^2)	5.90

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Clause	Requirement + Test	Result - Remark	Verdict

Table 11 – Module Weight During Test, kg	
Before Test:	669 kg
After Test:	668.5 kg
Weight Loss:	0.5 kg

Table 12 – Other Observations during module test		
	Observed, Yes/No	Location
Flying debris	No	N/A
Explosive discharge of gas	No	N/A
Sparks or electrical arcs	No	N/A

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Clause	Requirement + Test	Result - Remark	Verdict

	TABLE: Critical components information				
Object / Part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Cells	Envision Dynamics Technology (Jiangsu) Co., Ltd	HC-L315A	3.2Vdc, 315Ah, LFP	UL 1973	UL (MH65212)
Top Metal Enclosure and Front Panel	Jiangsu Chinyo Technology Co Ltd	8608	V-0, minimum thickness 1.6 mm, 105°C	UL94&UL746A&UL746B	UL (E470472)
Bottom Enclosure	Jiangsu Coigne New Energy Technology Co.,LTD	-	Material: aluminum alloy Minimum thickness 2 mm Size: 2183±5mm L*794±3 mm W*45.5mm H	-	-
DC High Voltage Connector	AMPHENOL TECHNOLOGY (ZHUHAI) CO LTD	C10-766482	Rated 1500Vdc, 300A	UL 4128	UL (E496781)
Alternated DC High Voltage Connector (Not perform for testing, for reference only)	AMPHENOL TECHNOLOGY (ZHUHAI) CO LTD	C10-792419-()()()()	Rated 1500Vdc, 300A	UL 4128	UL (E496781)
Alternated DC High Voltage Connector (Not perform for testing, for reference only)	XIAMEN WAIN ELECTRICAL CO LTD	Positive: WNHVPC-3-MOG-110B-00.0 Negative: WNHVPC-3-MBK-110B-00.0	Rated 1500Vdc, 300A	UL 4128	UL (E532705)

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Clause	Requirement + Test	Result - Remark	Verdict

Alternated DC High Voltage Connector (Not perform for testing, for models HP-L630B, ENS-2P52S-L08-A11 and for reference only)	Sichuan Recodeal Interconnect System Co., Ltd.	REA6-DZ	Rated 1500Vdc, 350A	UL 4128	CSA (80169965)
Plastic material for Cover of submodules	SUZHOU OMAY OPTICAL MATERIALS CO LTD	U42B	V-0, minimum thickness 0.5 mm, 80°C	UL94&UL746A&UL746B	UL (E249605)
Plastic frame for CCS	CHENGDU KANGLONGXIN PLASTICS CO LTD	KLX FRPC-1880B	V-0, minimum thickness 0.5 mm, 125°C	UL94&UL746A&UL746B	UL (E315185)
Internal Wiring	Wuxi Huacheng Cable Co Ltd	10316	600V, 125°C, 22 AWG	UL 758	UL (E206992)
PCB	NANYA NEW MATERIAL TECHNOLOGY CO LTD	NY-2140	0~130°C	-	-
NTC	SEMITEC NTC CO LTD	103KT1608T-1P	R25=10.0kΩ±1% Operating temperature -40～125°C	-	-
Thermal insulation pad	YANTAI DARBOND TECHNOLOGY CO LTD	ES-5121	V-0, minimum thickness 1.5±0.2 mm, 50°C	UL94&UL746A&UL746B	UL (E346000)

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Pressure Relief Valve	Puw Eptfe Material Co., Ltd.	PB04A4K-50D-7S	Located on Front Pannel Vent pressure 4+1kPa Case Material: AL6063+SUS304+EPTEF Size: 50mm D*24.5± 0.8mm L	-	-
FPC	Huizhou Hongtian Electronic Materials co., Ltd	HF	110 um, 130°C	-	-
MSD (Not perform for testing, for models HP-L630B, ENS-2P52S-L08-A11 and for reference only)	Shanghai Futronics Electronic Technology Co., Ltd.	FMSD6102T03-A630L	500Vdc, 315A	UL 4128	TUV (US 506522590001)
	General Connectivity System Co., Ltd	GCMSDP00F-M0B0	500Vdc, 200A	UL 4128	UL (E527614)
	AMPHENOL PCD SHENZHEN CO LTD	MSDE6301	500Vdc, 190A	UL 4128	UL (E533382)

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

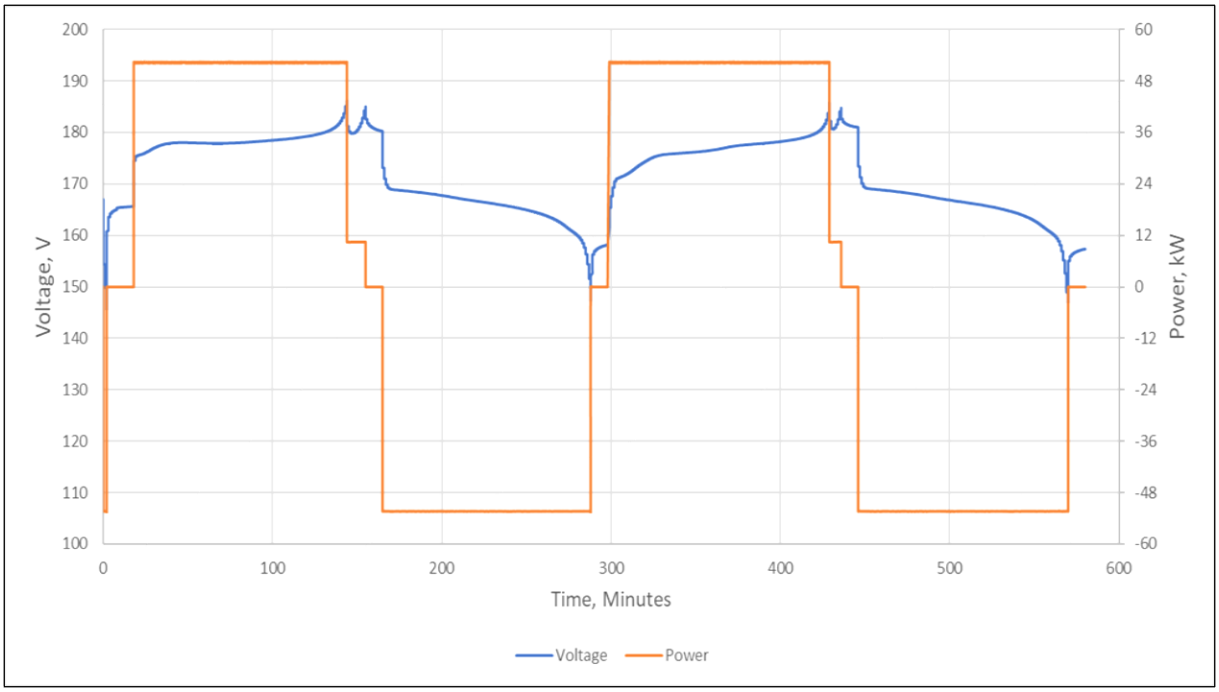


Figure 1 - Charge/Discharge Cycle

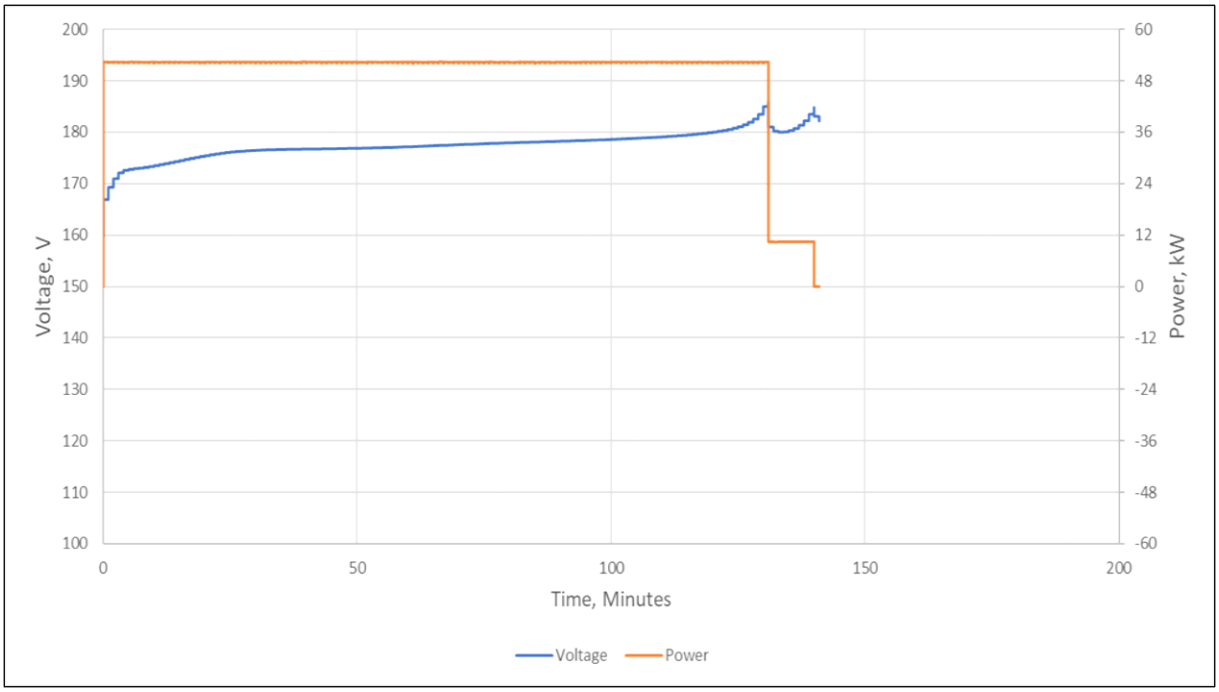


Figure 2 – Charge for 100% SOC

Attachment B: Module Construction Photos - (Pages ***21*** through ***21***)

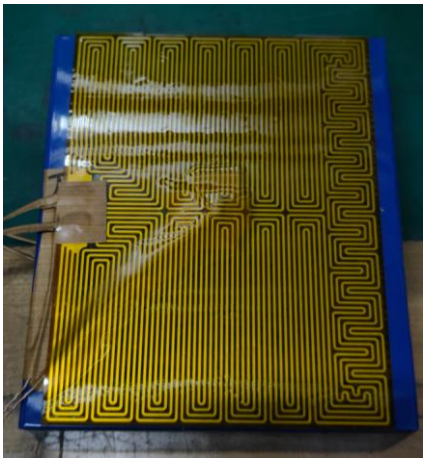


Figure 3 - Photo of cell – large side



Figure 4 - Photo of module – Side view



Figure 5 - Photo of module – Internal view



Figure 6 - Photo of module

Attachment C: Module Instrumentation Photos - (*Pages **22** through **24***)

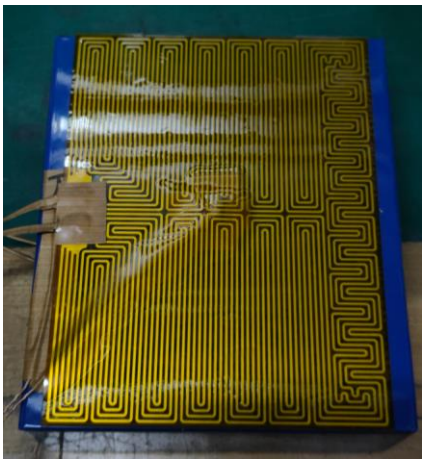


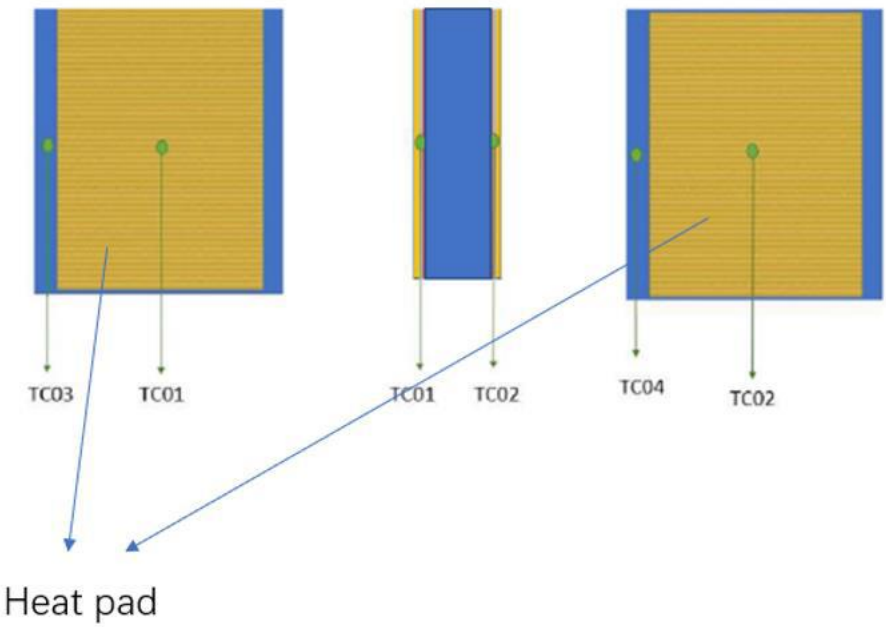
Figure 7 – Cell with heater. Two pieces of 152.4 mm by 203.2 mm for each sample.



Figure 8 – Module with heater, TCs Sampling wires.

Note:
The thermocouple TC01 was used to control the supply power to the heater to keep the heating rate at 4 ~ 7 °C/min. TC03 and TC04 were used to represent the temperature of initiating cell.

TC02, on the wide side surface center of cell 64, between the cell and heater.
TC03, TC04, on each wide side surface center of cell 64, not covered by heater.
Other TCs were attached on the wide side surface center of cells shown in below illustration.



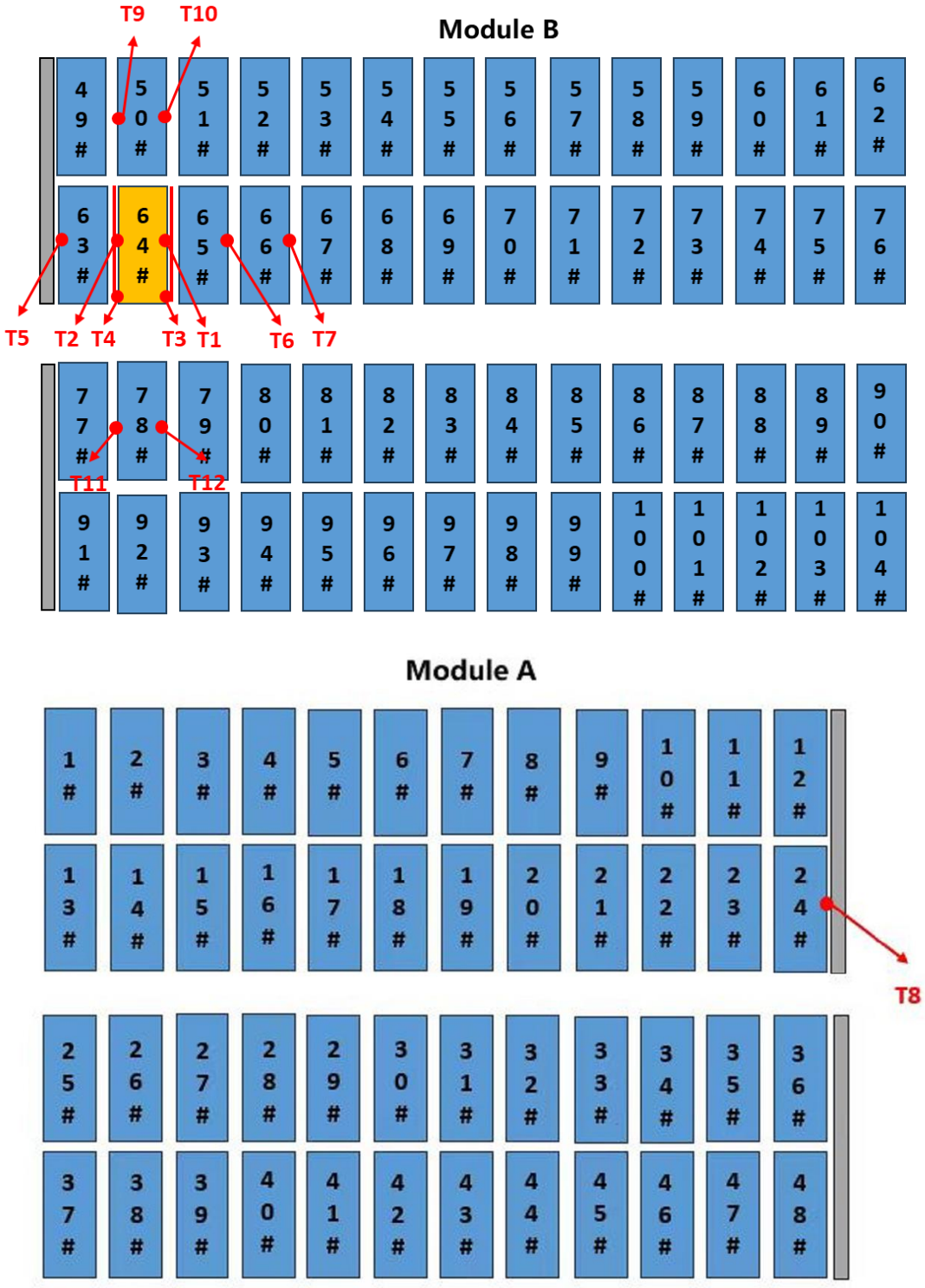


Figure 9 – Locations of TCs



Figure 10 – Module on the test platform – Side view



Figure 11 – Module on the test platform – Front view

Attachment D: Module and Initiating Cell(s) Temperature Profiles During Testing - (*Pages **25** through **25***)

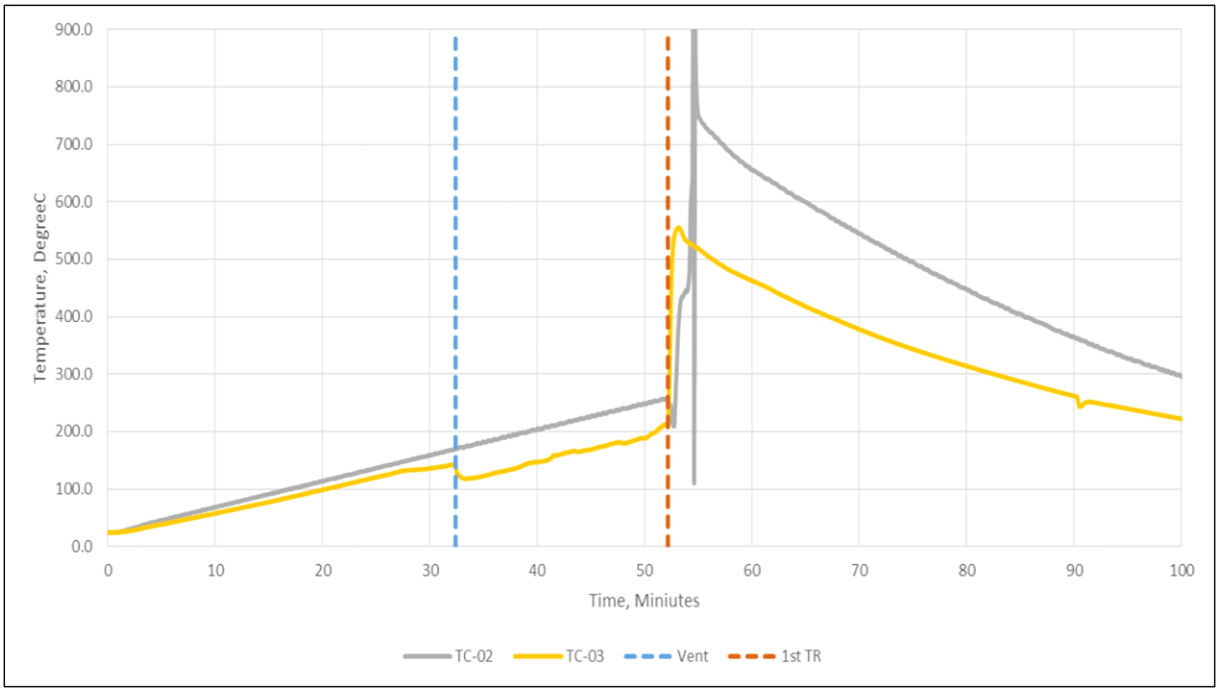


Figure 12 – Initiating cell Temperature and Voltage Profiles During Testing

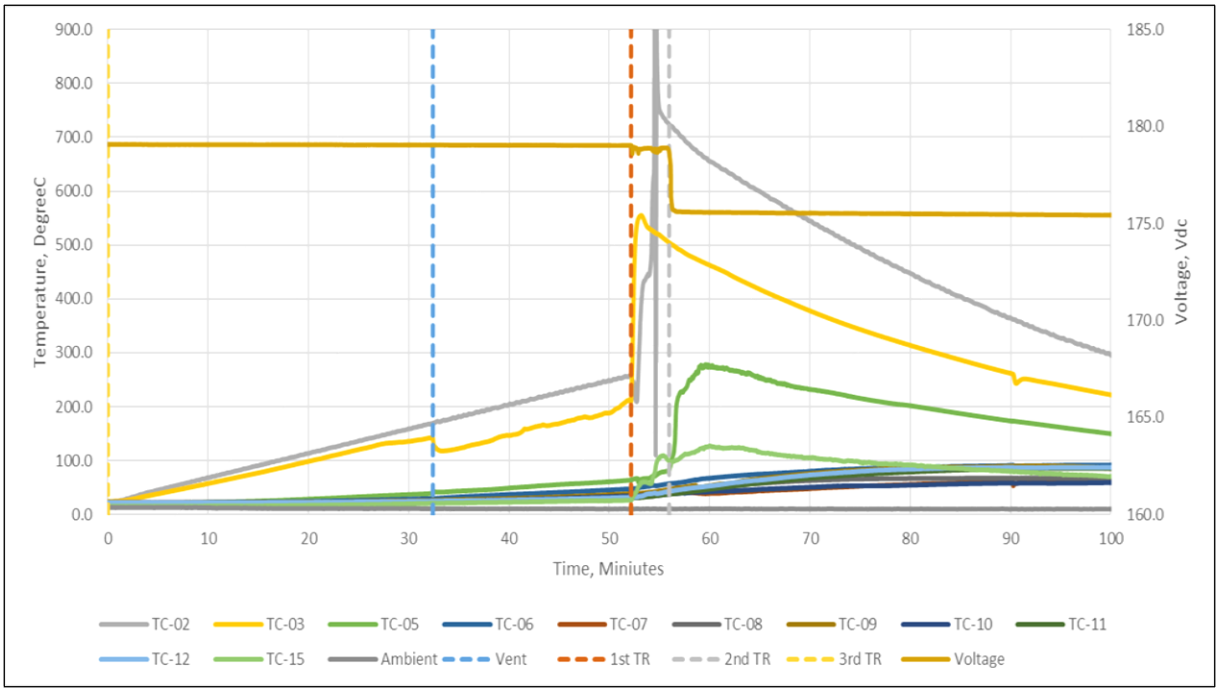
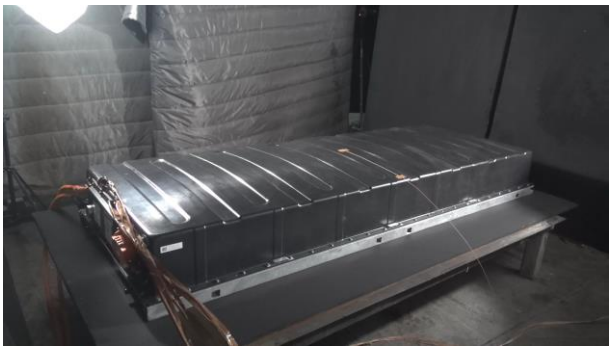
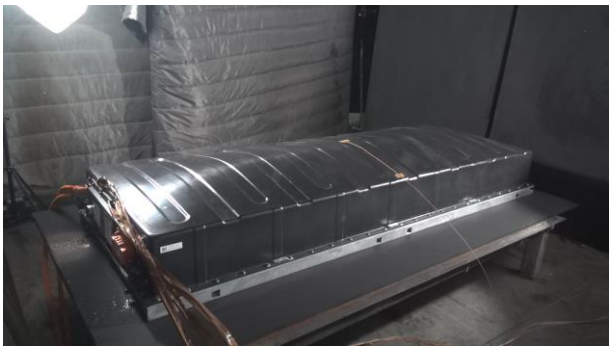


Figure 13 – Temperature Profiles Describing Cell to Cell Propagation

Attachment E: Module Testing Photos - (*Pages **26** through **27***)

	
(a) Test Start [00:00:00]	(b) Initiating Cell 64 Venting [00:32:23]
	
(c) Thermal runaway of initiating Cell 64 [00:52:10]	(d) Thermal runaway of initiating Cell 64 and smoke observed on [00:52:14]
	
(e) Thermal runaway of initiating Cell 63 [00:55:58]	(f) Thermal runaway of adjacent Cell 63 and smoke observed on [00:56:01]

	
(g) Test Termination [01:40:00]	

Attachment F: Module Gas Flow Rate and Heat Release Profiles - (*Pages **28** through **30***)

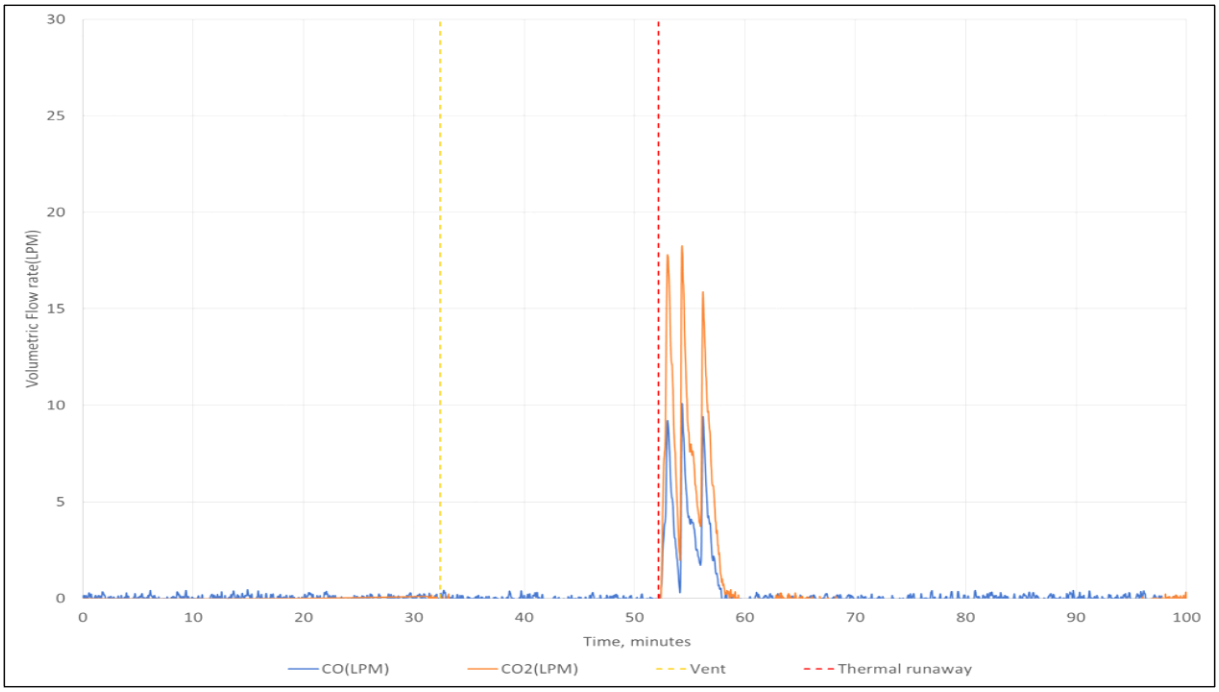


Figure 14 – CO, CO2 Volumetric flow rates

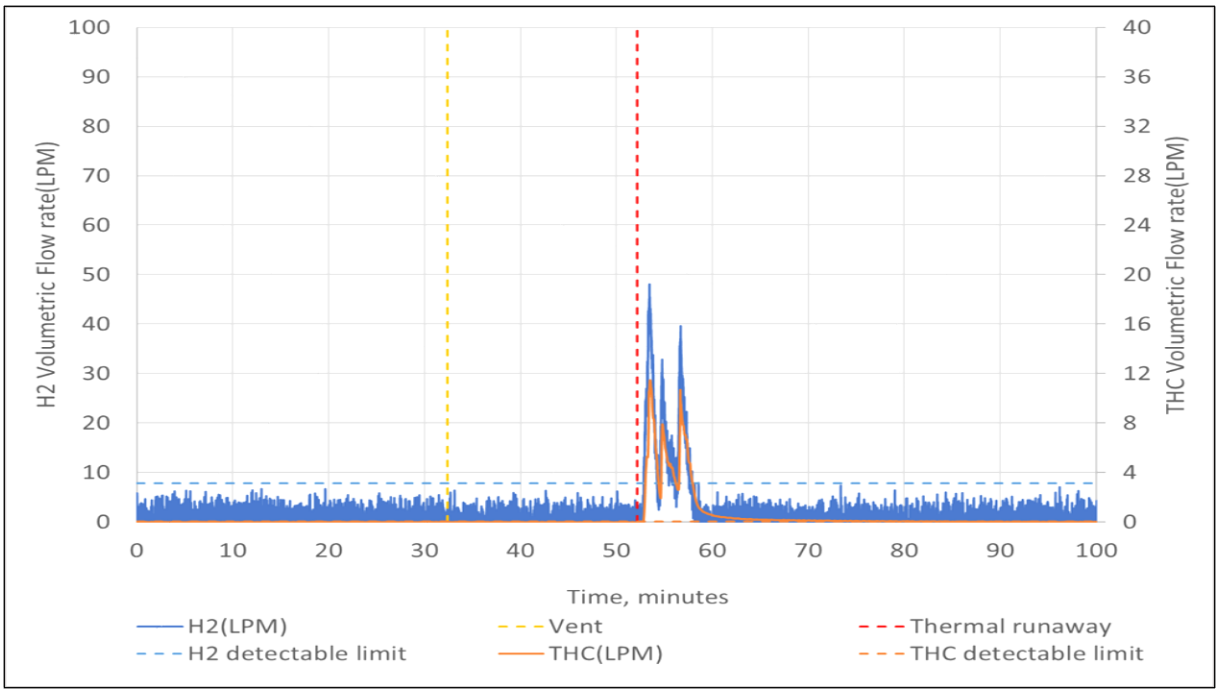


Figure 15 – THC, H2 Volumetric flow rates

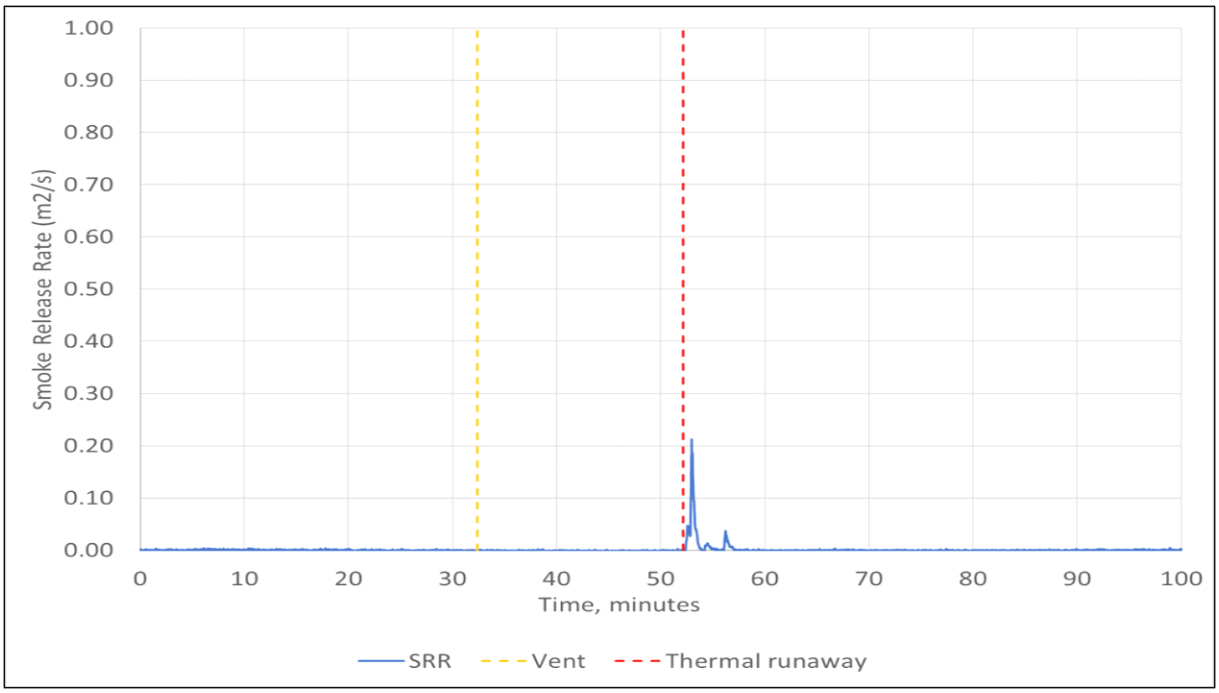


Figure 16 – Smoke release rate

Prüfbericht-Nr.: *Test report no.*:	**CN25EW8J 001**	**Auftrags-Nr.:** *Order no.*:	326103326	Seite 1 von 47 *Page 1 of 47*
Kunden-Referenz-Nr.: *Client reference no.*:	2526542	**Auftragsdatum:** *Order date:*	2025-04-07	
Auftraggeber: *Client*:	AESC Jiangsu Co., Ltd. No.66 Shentai Road, Shengang Street, Jiangyin City, Wuxi City, 214400 Jiangsu P.R. China			
Prüfgegenstand: *Test item*:	Lithium Ion Battery Rack			
Bezeichnung / Typ-Nr.: *Identification / Type no.*:	HR-L630B			
Auftrags-Inhalt: *Order content*:	Test report			
Prüfgrundlage: *Test specification*:	UL 9540A: 2025 (Fifth Edition) Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems			
Wareneingangsdatum: *Date of sample receipt*:	2024-12-15			
Prüfmuster-Nr.: *Test sample no:*	#2024121501			
Prüfzeitraum: *Testing period*:	2024-12-16 ~ 2024-12-31			
Ort der Prüfung: *Place of testing*:	See page 5 of main report			
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüfergebnis*: *Test result**:	See main report			



geprüft von:
tested by: Meng Jiang

Datum:
Date: 2025-08-04

Meng Jiang

genehmigt von:
authorized by: Simon Wang

Ausstellungsdatum:
Issue date: 2025-08-04

Stellung / Position:	Project Engineer	**Stellung** / Position:	Authorizer

Sonstiges / *Other*:

The mentioned model listed on above is identical to the original model HR-L630A in the previous section report CN24RUFF 002 except for the model number of the module and unit, factory information and position of HVB etc. The test data refer to the previous section report CN24RUFF 002.
See following pages for details.

Zustand des Prüfgegenstandes bei Anlieferung: Prüfmuster vollständig und unbeschädigt
Condition of the test item at delivery: *Test item complete and undamaged*

* Legende:	P(ass) = entspricht o.g. Prüfgrundlage(n)	F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
** Legend:*	*P(ass) = passed a.m. test specification(s)*	*F(ail) = failed a.m. test specification(s)*	*N/A = not applicable*	*N/T = not tested*

Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht auszugsweise vervielfältigt werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens.
This test report only relates to the above mentioned test sample. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.

Anforderungen
Remarks

1	Alle eingesetzten Prüfmittel waren zum angegebenen Prüfzeitraum gemäß eines festgelegten Kalibrierungsprogramms unseres Prüfhauses kalibriert. Sie entsprechen den in den Prüfprogrammen hinterlegten Anforderungen. Die Rückverfolgbarkeit der eingesetzten Prüfmittel ist durch die Einhaltung der Regelungen unseres Managementsystems gegeben. Detaillierte Informationen bezüglich Prüfkonditionen, Prüfequipment und Messunsicherheiten sind im Prüflabor vorhanden und können auf Wunsch bereitgestellt werden. *The equipment used during the specified testing period was calibrated according to our test laboratory calibration program. The equipment fulfils the requirements included in the relevant standards. The traceability of the test equipment used is ensured by compliance with the regulations of our management system. Detailed information regarding test conditions, equipment and measurement uncertainty is available in the test laboratory and could be provided on request.*
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3	Prüfklausel mit der Note * wurden an qualifizierte Unterauftragnehmer vergeben und sind unter der jeweiligen Prüfklausel des Berichts beschrieben. Abweichungen von Prüfspezifikation(en) oder Kundenanforderungen sind in der jeweiligen Prüfklausel im Bericht aufgeführt. *Test clauses with remark of * are subcontracted to qualified subcontractors and descripted under the respective test clause in the report.* *Deviations of testing specification(s) or customer requirements are listed in specific test clause in the report.*
4	Die Entscheidungsregel für Konformitätserklärungen basierend auf numerischen Messergebnisen in diesem Prüfbericht basiert auf der "Null-Grenzwert-Regel" und der "Einfachen Akzeptanz" gemäß ILAC G8:2019 und IEC Guide 115:2021, es sei denn, in der auf Seite 1 dieses Berichts genannten angewandten Norm ist etwas anderes festgelegt oder vom Kunden gewünscht. Dies bedeutet, dass die Messunsicherheit nicht berücksichtigt wird und daher auch nicht im Prüfbericht angegeben wird. Zu weiteren Informationen bezueglich des Risikos durch diese Entscheidungsregel siehe ILAC G8:2019. *The decision rule for statements of conformity, based on numerical measurement results, in this test report is based on the “Zero Guard Band Rule” and “Simple Acceptance” in accordance with ILAC G8:2019 and IEC Guide 115:2021, unless otherwise specified in the applied standard mentioned on Page 1 of this report or requested by the customer. This means that measurement uncertainty is not taken in account and hence also not declared in the test report. For additional information to the resulting risk based of this decision rule please refer to ILAC G8:2019.*

TEST REPORT

ANSI/CAN/UL 9540A:2025
Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Report Number. .....:	CN25EW8J 001
Date of issue.....:	See cover page
Total number of pages .....:	See cover page
Name of Testing Laboratory preparing the Report.....:	**TÜV Rheinland (Shanghai) Co., Ltd.** No. 177, Lane 777, West Guangzhong Road, Jing'an District, Shanghai 200072, P. R. China
Applicant's name.....:	**AESC Jiangsu Co., Ltd.**
Address .....:	No.66 Shentai Road, Shengang Street, Jiangyin City, Wuxi City, 214400 Jiangsu P.R. China
Test specification:	
Standard .....:	ANSI/CAN/UL 9540A:2025
Test procedure .....:	TÜV Rheinland Test Report
Non-standard test method .....:	N/A
Test Report Form No.....:	UL 9540A-E01
Test Report Form(s) Originator ....:	TÜV Rheinland (Shanghai) Co., Ltd.
Master TRF .....:	Dated 2025-03-21

General disclaimer:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing Testing Laboratory. The authenticity of this Test Report and its contents can be verified by contacting the TÜV Rheinland (Shanghai) Co., Ltd., responsible for this Test Report.

Other / Scope:

This report presents the result of unit level tests of UL 9540A: 2025.

All tests were conducted at TUV Rheinland (Shanghai) Co., Ltd. and TUV Rheinland's partner labs that were under supervision of TÜV Rheinland's engineer.

All tests were under supervision of TÜV Rheinland's engineer.

List of Attachments：

Attachment A: Diagrams of Setup for Unit Level Testing

Attachment B: Module Conditioning (Charge/Discharge) Profiles

Attachment C: Observations and Records

Attachment D: Module and Initiating Cell(s) Temperature Profiles during Testing

Attachment E: Smoke Release Rate, Chemical Heat Release Rate, Convective Heat Release Rate and Heat Flux

Attachment F: Flammable Gas Generation and Composition Data

Attachment G: Sample Photos and Test Photos

Attachment H: List of Test and Measurement Instruments

Attachment I: Revision Information

Summary of testing:

Model No:	HR-L630B
Ratings (Vdc, kWh):	1331.2 Vdc, 838.656kWh
Cells in series/parallel:	(2P52S)8S
BESS dimensions (mm):	2191×902×2679
BESS weight (kg):	5890±80
Maximum Target BESS Temperature (°C):	17.8
Maximum Wall Surface Temperature (°C):	18.1
BESS enclosure material:	No-enclosure provided for BESS unit, racks are directly mounted on the container frames
BESS Intended Installation: **Non-Residential:** outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted, roof top, open garage **Residential:** Outdoor ground mounted, indoor floor mounted, outdoor wall mounted, indoor wall mounted	Non-Residential: indoor floor mounted in a container. For a container system BESS including those intended for outdoor installation only, the unit level test shall be in accordance with the indoor floor mounted unit level test using the battery system racks as the test units and with the test installation set up in accordance with the installation layout within the container. According to 9.1.2.1 from the CRD, it should be treated as indoor floor mounted application
Total number of cell(s) went into thermal runaway:	2
Thermal Runaway and Propagation:	1 initiating cell went into thermal runaway and propagated to 1 adjacent cell
Maximum Smoke Release Rate (m^2/s):	0.3202
Total Smoke Released(m^2):	19.717
Total smoke released duration:	19:27-22:38
Peak Chemical Heat Release Rate (kW):	No flaming occurred
Peak Convective Heat Release Rate (kW):	No flaming occurred

Total Heat Release(kJ):	No flaming occurred
External Flaming:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred
Flying Debris:	No flying debris occurred
Re-ignitions:	No further re-ignitions were observed during post test observation

Summary of Unit level test Gas Analysis Data:

Gas Analysis:

Flame ionization detection	☒
Fourier-Transform infrared Spectrometer	☒
Hydrogen Sensor (palladium-nickel, thin-film solid state sensor)	☒
White light source with photo detector (smoke release rate)	☒

Unit level Gas Composition & Volume for Each Compound (Pre-flaming and After flame):

Gas Compound	Gas Type	Pre-Flaming(L)	Post-Flaming(L)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	43.44	No flaming
Carbon Monoxide	Carbon Containing	176.30	No flaming
Carbon Dioxide	Carbon Containing	226.18	No flaming
Hydrogen	Hydrogen	302.87	No flaming

Note: 1) The collection time is from 19:27-22:38.

2) See Attachment F for detail gas analysis data.

Summary of BESS Unit Test Results

Performance Criteria in accordance with Table 9.1 for Indoor Floor Mounted non-residential unit

Flaming outside the initiating BESS unit was not observed;	☒
Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit did not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8;	☒
For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces did not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15;	☒
Explosion hazards were not observed, including deflagration, detonation; and	☒

Necessity for an Installation level test	
The performance criteria of the unit level test as indicated in Table 9.1 of UL 9540A 4th edition has not been met, therefore an installation level testing in accordance with UL 9540A will need to be conducted on the representative the installation with this unit installed.	☐
The performance criteria of the unit level tests as indicated in Table 9.1 of UL 9540A 4th edition has been met, therefore an installation level testing in accordance with UL 9540A need not be conducted	☒

Tests performed (name of test and test clause): UL 9540A cl 9. Unit Level	**Testing location:** Shanghai Testing & Inspection Institute for Electrical Equipment Co., Ltd. Area A, 1F, Building 1, No.988, Shangxue Road, Malu Town, Jiading District, Shanghai, China

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)

Testing:

Date of receipt of test item.....: See cover page

Date (s) of performance of tests .....: See cover page

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 ☐ comma / ☒ point is used as the decimal separator.

Name and address of factory (ies)..... : Envision Energy Co., Ltd.
No. 3, Shenzhuang Road, Shengang Street, Jiangyin City, 214443, Jiangsu, P.R. China

Other:
N/A

UL 9540A testing information:

Cell level information	
Manufacturer :	AESC Jiangsu Co., LTD
Model number :	HC-L315A
Chemistry :	$LiFePO_4$
Physical configuration :	Prismatic
Electrical rating :	Rated capacity: 315 Ah
	Nominal voltage: 3.2 V
Average cell surface temperature at gas venting:	159 °C
Average cell surface temperature at thermal runaway:	246 °C
Gas Volume:	160.4 L
Lower flammability limit (LFL), % volume in air at the ambient temperature:	7.75%
Lower flammability limits (LFL), % volume in air at the venting temperature:	7.45%
Burning velocity (Su):	83.39 cm/s
Maximum pressure (Pmax):	95.83 psig

Cell level Gas Composition:

Gas component		Concentration % (v/v)
Methane	CH_4	4.980
Acetylene	C_2H_2	0.243
Ethylene	C_2H_4	2.458
Ethane	C_2H_6	0.845
Propadiene	C_3H_4	0.005
Propylene	C_3H_6	1.252
Propane	C_3H_8	0.254
-	C_4 (Total)	0.417
-	C_5 (Total)	0.099
-	C_6 (Total)	0.021
Benzene	C_6H_6	0.012
Dimethyl Carbonate	$C_3H_6O_3$	1.453
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.217

Hydrogen	H_2	51.380
Carbon Monoxide	CO	12.896
Carbon Dioxide	CO_2	23.467
-	Total	100

Module Level Information	
Model No:	HP-L630B
Ratings (Vdc, kWh) :	166.4Vdc
Cells in series/parallel:	52S2P
Module dimensions (W x D x H (mm)) :	2197.7±5 mm*794±5 mm*246.2±5 mm
Module weight (kg) :	670±10kg
Module enclosure material:	Top metal enclosure and Front panel: made of Unsaturated Polyester, minimum thickness 1.6 mm Bottom enclosure: made of aluminum alloy, minimum thickness 2.0 mm
Total number of cell(s) went into thermal runaway:	2
Thermal Runaway and Propagation:	1 initiating cell went into thermal runaway and propagated to 1 adjacent cell
Maximum Smoke Release Rate (m^2/s)	0.21
Total Smoke Released: (m^2)	5.90
Peak Chemical Heat Release Rate: (kW):	No flaming occurred
External Flaming:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred
Flying Debris:	No flying debris occurred
Re-ignitions:	No further re-ignitions were observed during post test observation
UL 9540A module test report	Accepted test report from UL, Report No.: 4791861688

Note:
(1) The module level UL 9540A test report refers to UL 9540A: 2019. Module surface temperature is not measured but will not affect this test.
(2) The model HP-L630B is similar as model HP-L630A with the same Branding Manufacturer AESC Jiangsu Co., LTD.
(3) Battery models HP-L630B have not been conducted test and for reference only.

Gas Composition & Volume for Each Compound (Pre-flaming and After flame):

Gas Compound	Gas Type	Pre-Flaming (L)	Post-Flaming (L)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	34.04	No flaming
Carbon Monoxide	Carbon Containing	46.31	No flaming

Carbon Dioxide	Carbon Containing	21.79	No flaming
Hydrogen	Hydrogen	91.52	No flaming

General product information

Photo of Battery system:

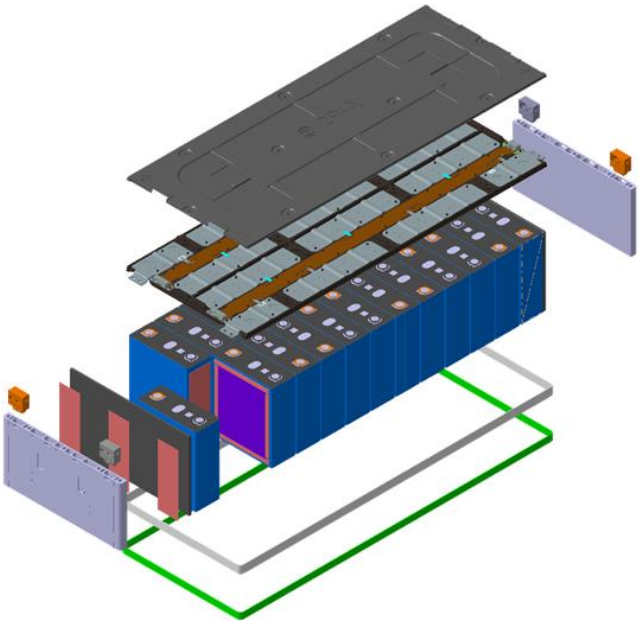


Battery system information

Item	Specifications	Remark
Model number	HR-L630B	
Nominal Energy of Rack	838.656kWh	Fresh cell & standard charge and discharge procedure
Nominal Capacity	630Ah	Fresh cell & standard charge and discharge procedure
Nominal Voltage	1331.2V	
Standard Charge/Discharge Mode	Charge with 0.5P until the maximum voltage is higher than the alarm threshold (3.6V), then charge with 0.1P until the maximum voltage is higher than the alarm threshold (3.62V/1489.28V). Discharge with 0.5P until the minimum voltage is lower than the alarm threshold (2.8V/1164.8V).	
DC Voltage Range	1164.8~1497.6V	
Maximum Charge/Discharge Power	0.5P	
Nominal Charge/Discharge Power	0.5P	
Cooling System	Liquid cooling	inlet temperature in Nidec side would be 19-21°C, flow rate 80 L/min for one Rack Inlet and Outlet at the bottom
Recommended Operating Temperature	25±3°C	Ambient
Altitude	≤4000m	

Module Construction

Figure 1. Layout of the battery system contents



Diagrams of setup for battery system testing

Figure 2. Thermocouples (no. xx) locations of initiating cell

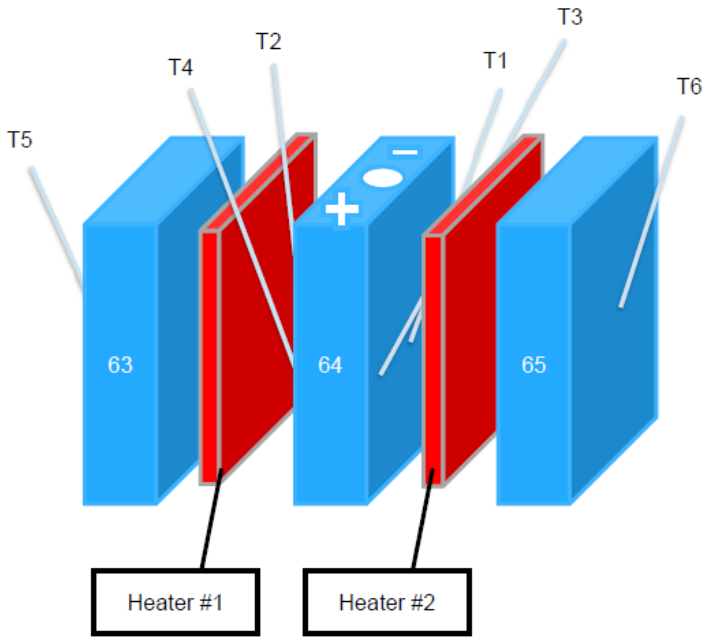


Figure 3. Cell numbering, heater location and thermocouples (no. xx) locations inside the sub-module

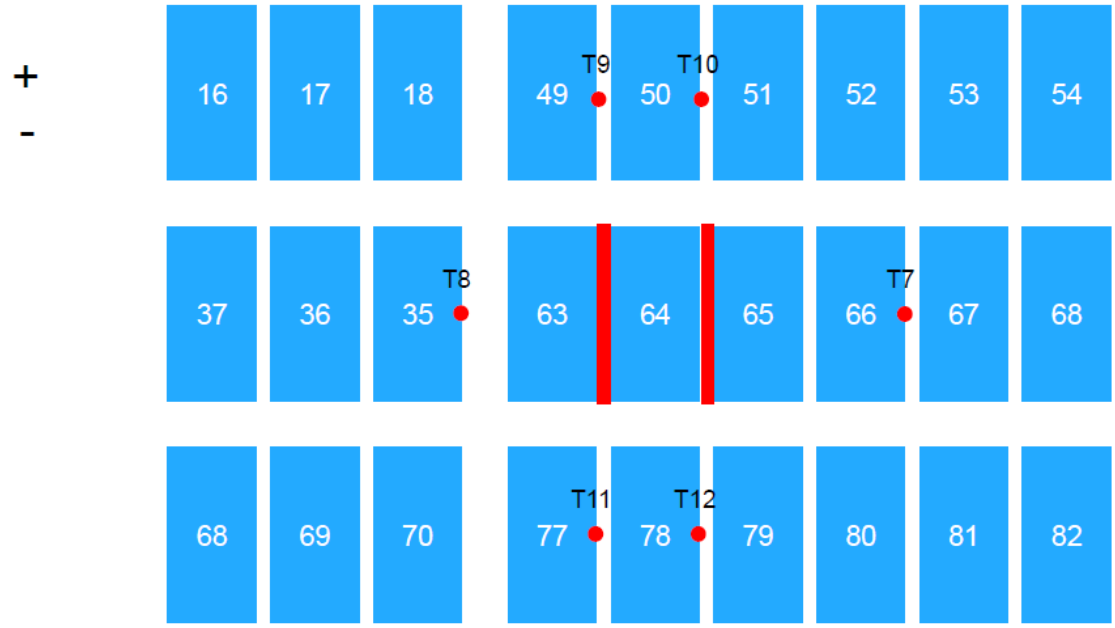
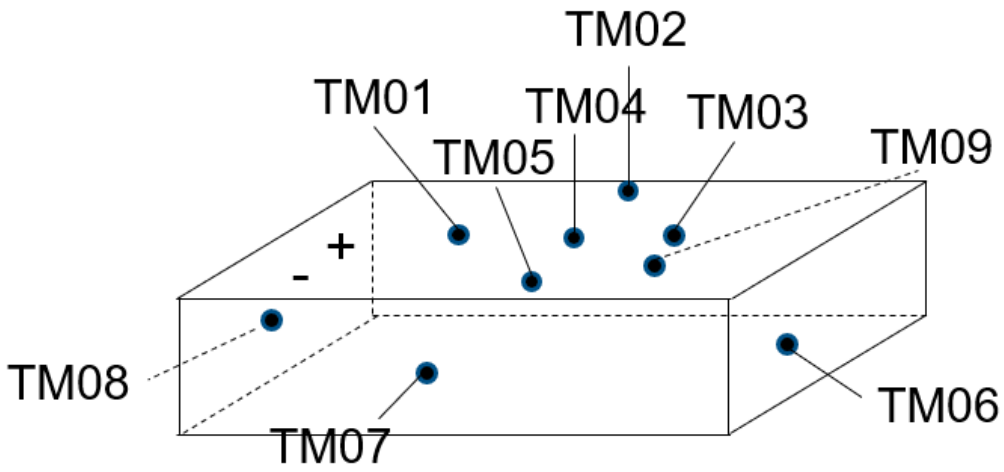


Figure 4. Thermocouples' locations outside module



ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
CONSTRUCTION			--
5	**General**		--
5.1	**Cell**		P
5.1.1	The cells associated with the BESS that were tested shall be documented in the test report.	Accepted test report from UL, Report No.: 4791271040	P
5.1.2	The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973.	Accepted test report and certificate from UL Report No.: MH65212-20240614 Cert. No.: UL-US-2424131-0 UL-CA-2419011-0	P
5.1.3	Refer to 7.7.1 for further details be included in the cell level test report.		N/A
5.2	**Module**		P
5.2.1	The modules associated with the BESS that were tested shall be documented in the test report, including the generic (e.g., metallic or nonmetallic) enclosure material, the general layout of the module contents and the electrical configuration of the cells in the modules and the modules in the BESS.	See Module Level Information	P
5.2.2	The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973.	Test with unit	N/A
5.2.3	Refer to 8.4 for further details to be included in the module level test report.		N/A
5.3	**Battery energy storage system unit**	DUT complied with UL1973	P
5.3.1	The BESS unit documentation included in the test report shall indicate the units that comply with UL 9540 and include the manufacturer, model, electrical ratings, and energy capacity of all BESS.		N/A
5.3.2	For BESS units for which UL 9540 compliance cannot be determined, the documentation included in the test report shall include the number of modules in the BESS, electrical configuration of the module, and physical layout of the modules in the BESS, battery management system (BMS) and other major components of the BESS. It shall be documented as to whether the battery system complies with UL 1973 in addition to the overall BESS compliance to UL 9540.	Accepted test report and certificate from TÜV Rheinland, Report No.: CN25RBLI 001 Cert. No.: CU 72502863_0001	P
5.3.3	If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report.		N/A

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
5.3.4	Refer to 9.7, 10.4 and 10.7 for further details to be included in the unit level and if applicable, installation level test reports.		P
5.4	**Flow Batteries**	Not applicable to Li-ion cell	N/A
PERFORMANCE			--
6	**General**		--
6.1	The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires.		P
6.2	At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications.		P
6.3	Temperatures on parts and surfaces shall be measured continuously, taking the average over every 60 seconds. The maximum of these averages shall be documented for each thermocouple location. Cell surface temperatures shall be measured continuously, but not averaged over every 60 seconds as the other temperature measurements are.		P
6.4	When heat flux measurements are taken, they shall be measured continuously, taking the average over every 60-second interval. The maximum of these averages shall be documented for each gauge location.		P
9	**Unit Level**		--
9.1	**Sample and test configuration**		P
9.1.1	The unit level test shall be conducted with BESS units installed as described in the manufacturer's instructions and this section. Test configurations include the following:	Applied a). Indoor floor mounted non-residential use BESS.	P
	a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS; f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; and i) Rooftop non-residential use BESS; j) Rooftop residential use BESS; and k) Open parking garage non-residential use BESS installations.	For a container system BESS including those intended for outdoor installation only, the unit level test shall be in accordance with the indoor floor mounted unit level test using the battery system racks as the test units and with the test installation set up in accordance with the installation layout within the container.	P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
9.1.2	The unit level test requires one initiating BESS unit in which an internal fire condition in accordance with the module level test is initiated and target adjacent BESS units representative of an installation.	See figure 5-11 for test installations	P
	Tests conducted for indoor floor mounted installations for residential BESS may be considered representative of both indoor floor mounted and outdoor ground mounted installations. Tests shall be conducted indoors with fire propagation hazards and separation distances between initiating and target units representative of the installation.	Non-residential	N/A
	Exception: Testing can be conducted outdoors for outdoor only installations if there are the following controls and environmental conditions in place: a) Wind screens are utilized with a maximum wind speed maintained at ≤ 12 mph; b) The temperature range is within 10°C to 40°C; c) The humidity is < 90% RH; d) There is sufficient light to observe the testing; e) There is no precipitation during the testing; f) There is control of vegetation and combustibles in the test area to prevent any impact on the testing and to prevent inadvertent fire spread from the test area; g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area and to prevent exposure of persons to any hazards as a result of testing.	Indoor floor mounted unit level testing method	N/A
9.1.3	For outdoor non-residential use High Temperature Batteries installed in a container, the unit level test is waived as there is no additional information to be collected at the unit level for this technology when it is utilized for outdoor use only. Instead, the installation level test shall be conducted in accordance with 10.9.	Not applicable to Li-ion cell	N/A
9.1.4	For installations, where the high temperature battery modules are not installed on racks but rather within separate compartments within the container, the module is considered the test unit for the test of 10.9. See 10.2.3 and 10.2.4.	Not applicable to Li-ion cell	N/A
9.1.5	Depending upon the configuration and design of the BESS (e.g. the BESS is composed of multiple separate parts within separate enclosures), this testing to determine fire characterization can be done at the battery system level.	Testing at battery rack level	P
9.1.6	Where the manufacturer's instructions indicate that the BESS can be installed outdoors and in open parking garages less than 3 m (10 feet) from the means of egress or other exposures, testing shall be conducted as described in this Section		N/A

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
9.1.7	The initiating BESS unit shall contain components representative of a BESS unit in a complete installation. Combustible components that interconnect the initiating and target BESS units shall be included.		P
9.1.8	Target BESS units shall include the outer cabinet, racking, module enclosures, and components that retain cells components. The target BESS units may also include one live, populated module at the location of the highest anticipated temperature in the enclosure. The remaining target BESS unit module enclosures do not need to contain cells		P
9.1.9	The initiating BESS unit shall be brought to the maximum operating state of charge in accordance with the manufacturer's specifications and allowed to rest for a minimum of 1 hour at room ambient before the start of the test.		P
9.1.10	Prior to initiating the test, the voltage of the initiating module shall be measured and recorded. If the voltage drop is greater than 0.1 % of the fully charged voltage of the module, then the initiating BESS shall be charged again as noted in 9.1.9 and the voltage of the initiating BESS shall be recorded.		P
9.1.11	If a BESS unit includes an integral fire suppression system, there is an option of providing this with the DUT. If the BESS unit is provided with an optional integral fire suppression system, the system shall not be provided on the DUT.	No integral fire suppression system	N/A
9.1.12	Electronics and software controls such as the battery management system (BMS) in the BESS are not relied upon for this testing. This does not include a fire suppression control in accordance with UL 864 that is external to the BESS, but provided as part of an integral fire suppression system per 9.1.11.		P
9.2	**Test method – Indoor floor mounted BESS units**		P
9.2.1	During an indoor test, the test room environment shall be controlled to prevent drafts that may affect test results. At the start of the test, the room ambient temperature shall not be less than 10 °C (50 °F) nor more than 32 °C (90 °F).	Indoor floor mounted	P
9.2.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units shall be closed, latched and locked at the beginning and duration of the test.		P
9.2.3	The initiating BESS unit shall be positioned adjacent to two instrumented wall sections.	See figure 5	P
9.2.4	Instrumented wall sections shall extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of the target BESS units.		P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
9.2.5	Instrumented wall sections shall be at least 0.61-m (2-ft) taller than the BESS unit height, and not less than 2.13 m (7 feet) in height above the floor		P
9.2.6	The surface of the instrumented wall sections shall be covered with gypsum wall board and painted flat black. An incremental visual reference shall be provided on the instrumented wall sections for scale so that flame extension can be accurately measured if applicable. The gypsum wall board shall be 13-mm (1/2-inch) thick at minimum.		P
9.2.7	The initiating BESS unit shall be centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.		P
9.2.8	The light transmission in the calorimeter's exhaust duct shall be measured using a white light source and photo detector for the duration of the test, and the smoke release rate shall be calculated as described in 8.2.17.		P
9.2.9	The chemical and convective heat release rates shall be measured for the duration of the test, using the methodologies specified in 8.2.13 and 9.2.12, respectively.	See Attachment E	P
9.2.10	With reference to 9.2.9, the heat release rate measurement system shall be calibrated using an atomized heptane diffusion burner.	See Attachment E	P
9.2.11	With reference to 9.2.9, the convective heat release rate shall be measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct.	See Attachment E	P
9.2.12	With reference to 9.2.9, the convective heat release rate shall be calculated using the following equation: $HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p \, dT$		P
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation as noted in 9.1.	The test installation set up in accordance with the installation layout within the container.	P
9.2.14	Separation distances shall be specified by the manufacturer for distance between:		P
	a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units.	See figure 5	P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
9.2.15	Wall surface temperatures shall be measured in vertical array(s) at 152-mm (6-inch) intervals for the full height of the instrumented wall sections. The thermocouples for measuring the temperature on wall surfaces shall be horizontally positioned in the wall locations anticipated to receive the greatest thermal exposure. Temperatures shall be measured continuously, averaging over every 60-second interval per 6.3. The maximum of these averages shall be documented for each thermocouple location		P
9.2.16	Thermocouples shall be secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires. The thermocouple tip shall be depressed into the gypsum and held in thermal contact with the surface at that point.		P
9.2.17	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt Boelter or Gardon gauges at the surface of each instrumented wall as follows in (a)– (c). Heat flux shall be measured continuously, averaging over every 60-second interval per 6.4. The maximum of these averages shall be documented for each gauge location		P
	a) Both are collinear with the vertical thermocouple array;		P
	b) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and		P
	c) One is positioned at the elevation estimated to receive the greatest heat flux during potential propagation of thermal runaway within the initiating BESS unit.		P
9.2.18	Heat flux shall be measured with the sensing element of at least two water-cooled Schmidt Boelter or Gardon gauges at the surface of each adjacent target BESS unit that faces the initiating BESS unit as follows in (a) and (b). Heat flux shall be measured continuously, averaging over every 60-second interval per 6.4. The maximum of these averages shall be documented for each gauge location		P
	a) One is positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating BESS; and		P
	b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating BESS.		P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
9.2.19	For BESS intended for installation outdoors or in open parking garages covered by 9.1.6, heat flux shall be measured with the sensing element of at least one water-cooled Schmidt-Boelter or Gardon gauge positioned at the mid height of the initiating unit at the minimum horizontal distance from the BESS specified by the manufacturer or the point where the majority of off-gas venting is expected from the initiating unit. Heat flux shall be measured continuously, averaging over every 60-second interval per 6.4		P
9.2.20	No. 24-gauge or smaller, Type-K exposed junction thermocouples shall be installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module. Temperatures shall be measured continuously, averaging over every 60-second interval per 6.3. The maximum of these averages shall be documented for each thermocouple location.		P
9.2.21	For residential use BESS, the DUT shall be covered with a single layer of cheese cloth ignition indicator.	Non-residential	N/A
9.2.22	Cell to cell thermal runaway propagation in accordance with the module level test shall be created within a single module in the initiating BESS unit:		P
	a) The position of the module shall be selected to present the greatest thermal exposure to adjacent modules (e.g. above, below, laterally), based on the results from the module level test; and		P
	b) The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module shall be the same as that used to initiate and propagate thermal runaway within the module level test (Section 8).	Same as module level test	P
9.2.23	The composition, velocity and temperature of the initiating BESS unit vent gases shall be measured within the calorimeter's exhaust duct as outlined in 8.2.12. The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with a palladium-nickel thin-film solid state analyser. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation		P
9.2.24	The hydrocarbon content of the vent gas may additionally be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm^{-1} and a path length of at least 2.0 m (6.6 feet), or equivalent gas analyser.		P
9.2.25	The test shall be terminated if:		P

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
	a) There are three consecutive temperature readings measured inside each module within the initiating BESS unit that are determined to be falling over 15-minute intervals;		N/A
	b) The modules return to a temperature less than 60 °C (140 °F);	The module temperature returns to ambient temperature	P
	c) The fire propagates to adjacent units or to adjacent walls;		N/A
	d) A condition hazardous to test staff or the test facility requires mitigation; or		N/A
	e) Flaming outside the test room is observed.		N/A
9.2.26	For residential use systems, the gas collection data gathered in 9.2 shall be compared to the smallest room installation specified by the manufacturer to determine if the flammable gas collected exceeds 25% LFL in air.	Non-residential	N/A
9.3	**Test method – Outdoor ground mounted units**		N/A
9.3.1	Outdoor ground mounted non-residential use BESS being evaluated for installation in close proximity to buildings and structures shall use the test method described in 9.2. If intended for outdoor use only installations, including rooftop installations, the smoke release rate, the convective and chemical heat release rate and content, velocity and temperature of the released vent gases need not be measured.		N/A
9.4	**Test Method – Indoor wall mounted units**		N/A
9.5	**Test Method – Outdoor wall mounted units**		N/A
9.6	**Rooftop and open garage installations**		N/A
9.7	**Unit level test report**		P
9.7.1	The report on the unit level testing shall identify the type of installation being tested, as follows:		P
	a) Indoor floor mounted non-residential use BESS; b) Indoor floor mounted residential use BESS; c) Outdoor ground mounted non-residential use BESS; d) Outdoor ground mounted residential use BESS; e) Indoor wall mounted non-residential use BESS f) Indoor wall mounted residential use BESS; g) Outdoor wall mounted non-residential use BESS; h) Outdoor wall mounted residential use BESS; i) Rooftop installed non-residential use BESS; or j) Open parking garage installed non-residential use BESS.	Indoor floor mounted non-residential use BESS.	P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
9.7.2	With reference to 9.7.1, if testing is intended to represent more than one installation type, this shall be noted in the report.	One installation type	N/A
9.7.3	The report shall include the following, as applicable:		P
	a) Unit manufacturer name and model number (and whether UL 9540 compliant);	See the summary of this report	P
	b) Number of modules in the initiating BESS unit;	See figure 6	P
	c) The construction of the initiating BESS unit per 5.3;	See figure 6	P
	d) Fire protection features/detection/suppression systems within unit;		N/A
	e) Module voltage(s) corresponding to the tested SOC;	See Attachment C	P
	f) The thermal runaway initiation method used;	External heaters	P
	g) Location of the initiating module within the BESS unit;	See figure 6	P
	h) Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, soffits as applicable, and thermocouples;	See figure 5	P
	i) Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	See Attachment C	P
	j) Chemical and convective heat release rate versus time data;	See Attachment E	P
	k) Separation distances from the initiating BESS unit to target walls (e. g. distances A and C in Figure 9.1);	See figure 5	P
	l) Separation distances from the initiating BESS unit to target BESS units (e.g. distances D and H in Figure 9.1);	See figure 5	P
	m) The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	See Attachment D	P
	n) The maximum ceiling or soffit surface temperatures achieved during the indoor or outdoor wall mounted test and the location of the measuring thermocouple;		N/A
	o) The maximum incident heat flux on target wall surfaces and target BESS units;	See Attachment E	P
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;		N/A
	q) Gas generation and composition data if conducted indoors;	See Attachment F	P
	r) Peak smoke release rate and total smoke release data if conducted indoors;	See Attachment E	P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
	s) Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;		N/A
	t) Observation of flying debris or explosive discharge of gases unless mitigated by an engineered deflagration protection system;	See Attachment C	P
	u) Observation of re-ignition(s) from thermal runaway events;	See Attachment C	P
	v) Observation(s) of sparks, electrical arcs, or other electrical events;	See Attachment C	P
	w) Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits;	See Attachment C	P
	x) Photos and video of the test.	Recorded	P
	y) If the test is terminated in accordance with 9.2.25, the circumstances of the termination; and		P
	z) Module level test report summary and cell level test report summary.		P
9.8	**Performance at unit level testing**		P
9.8.1	Installation level testing in Section 10 is not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.	Installation level testing is not required according to the performance conditions.	P
	a) Flaming outside the initiating BESS unit is not observed;	No flaming observed	P
	b) Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.10;	Max. Temperature during the test: 17.8°C Criteria Temperature: 159.0°C	P
	c) Surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient	Max. Temperature during the test: 18.1°C Criteria Temperature: 114.4°C	P
	d) Explosion hazards are not observed, including deflagration or detonation	No explosion observed	P
9.9	**Flow battery unit tests**	Not applicable to Li-ion cell	N/A
9.10	**Flow battery unit level test report**	Not applicable to Li-ion cell	N/A
9.11	**Flow battery unit level performance criteria**	Not applicable to Li-ion cell	N/A

--End of report--

Attachment A: Diagrams of Setup for Unit Level Testing

Diagrams of setup for unit level testing

Figure 5. Test site setup diagram with separation distance. (Top view)

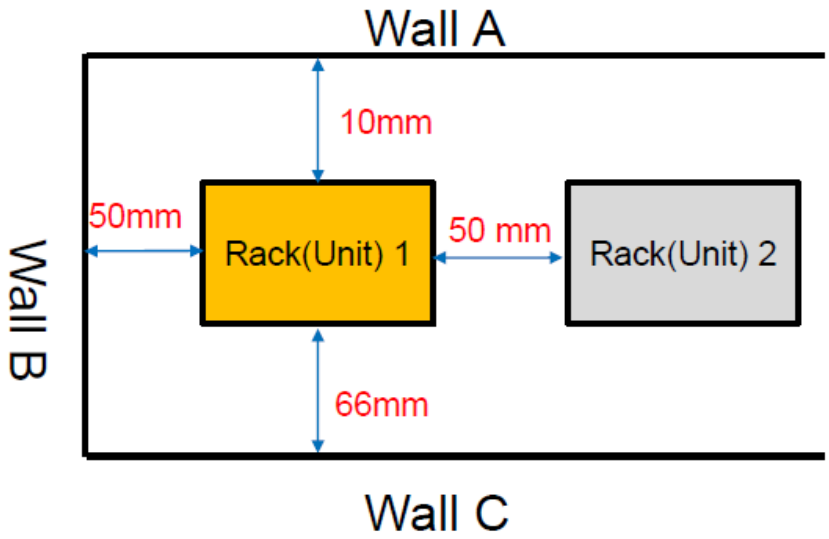


Figure 6. Module numbering in units

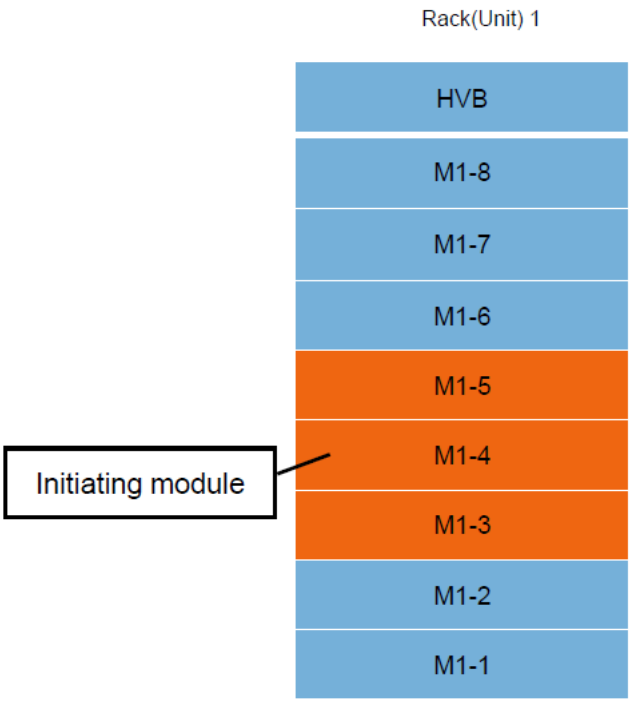
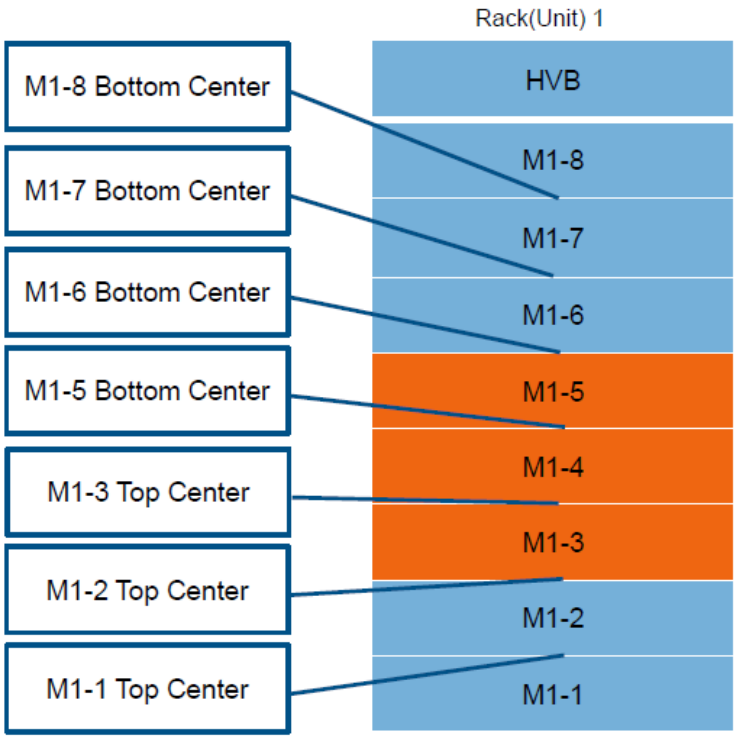
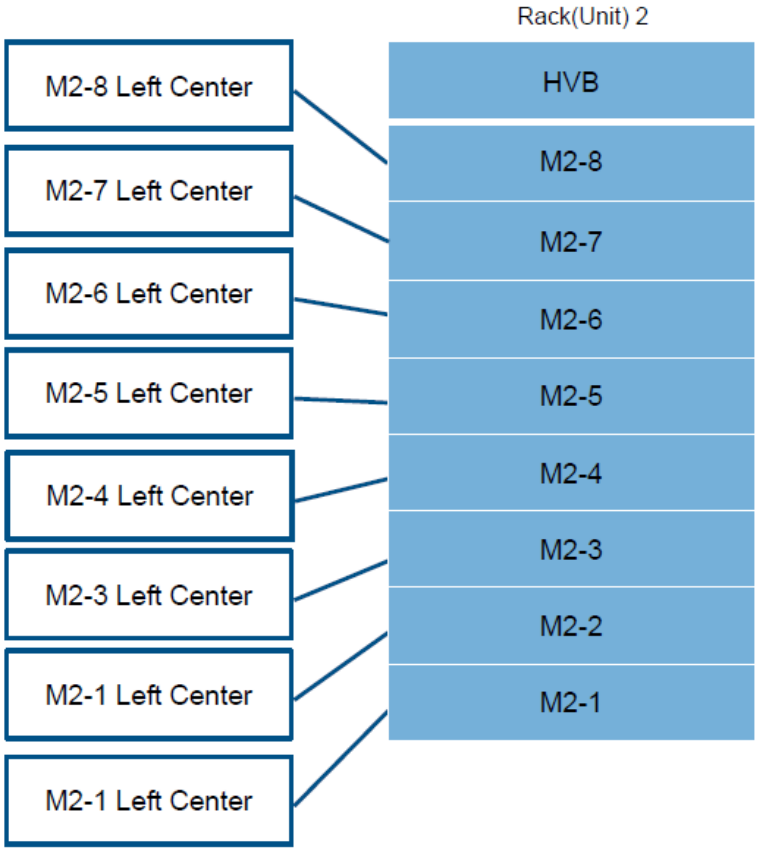


Figure 7. Thermocouple location on modules in initial unit 1



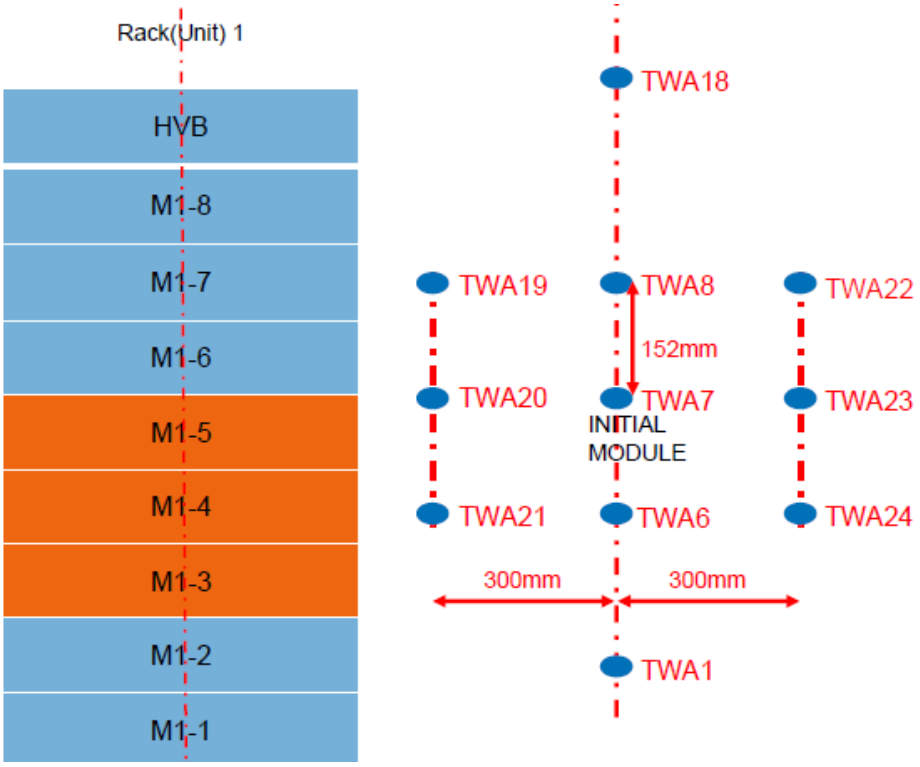
View direction: towards instrument wall A with reference to Figure 5

Figure 8. Thermocouple location on modules in target unit 2



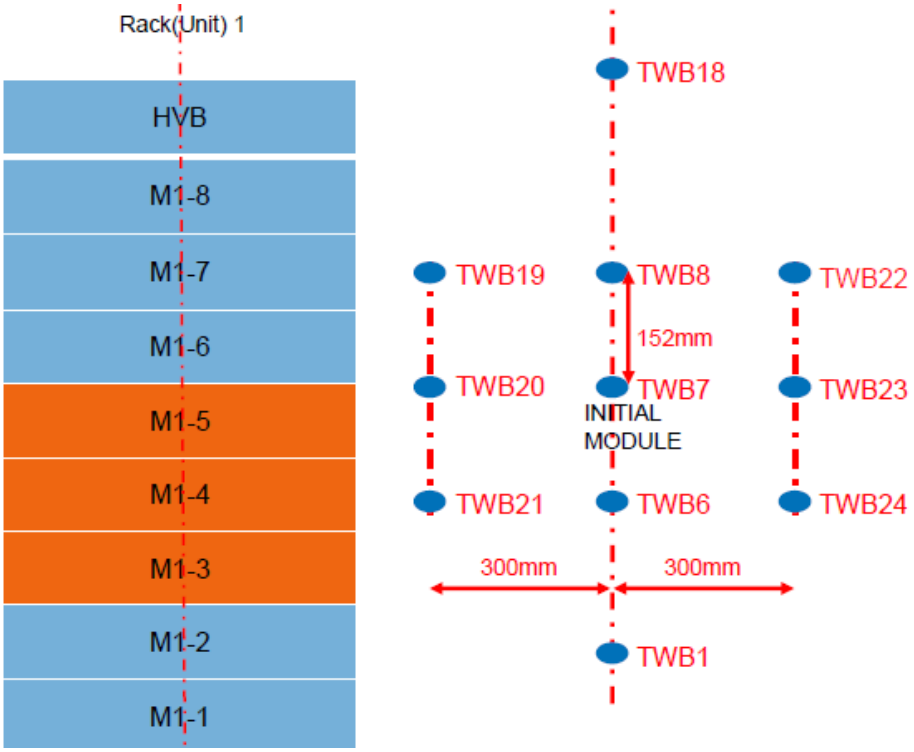
View direction: backward instrument wall A with reference to Figure 5

Figure 9. Vertical position of the thermocouples on the wall A



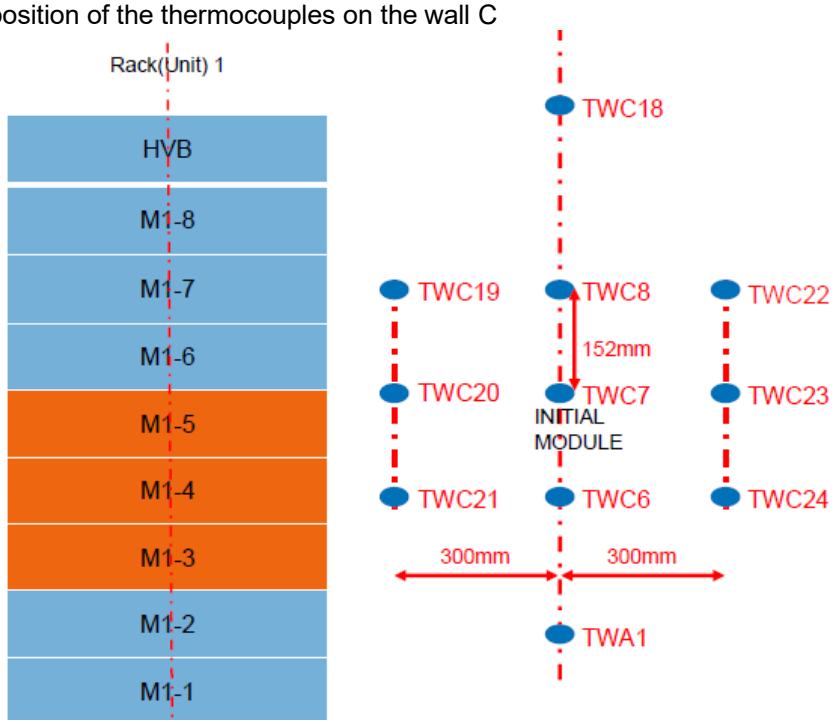
View direction: towards instrument wall A with reference to Figure 5

Figure 10. Vertical position of the thermocouples on the wall B



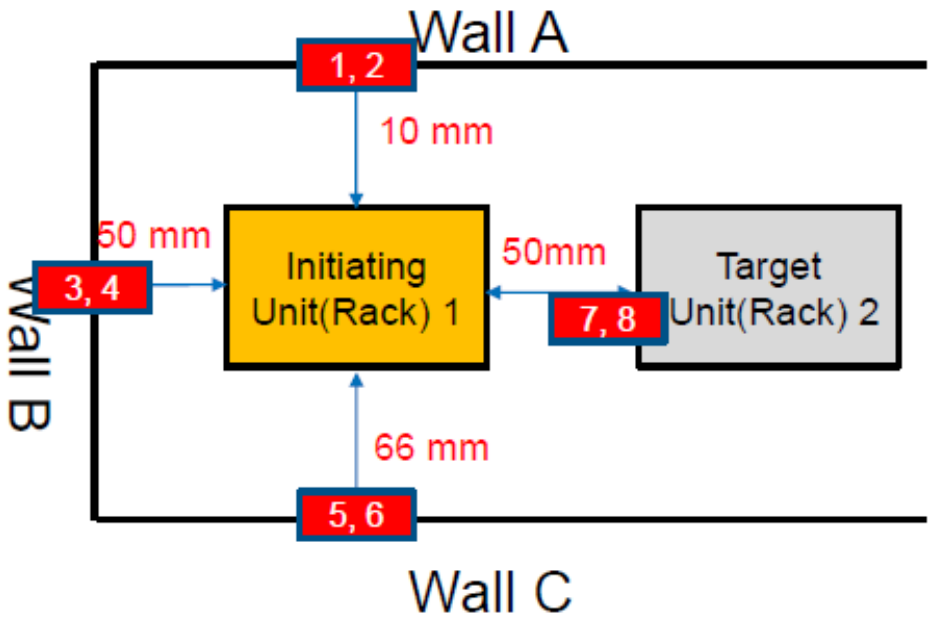
View direction: towards instrument wall B with reference to Figure 5

Figure 11. Vertical position of the thermocouples on the wall C



View direction: towards instrument wall C with reference to Figure 5

Figure 12. Heat flux sensor locations on instrument wall



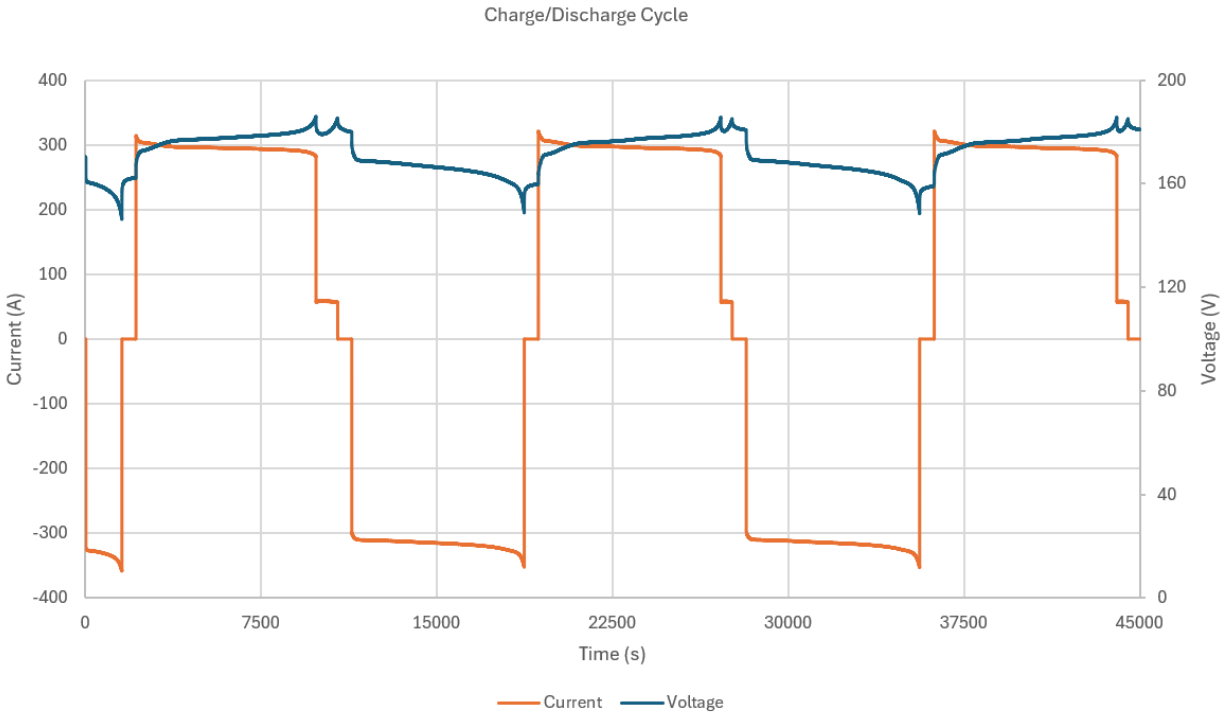
Attachment B: Module Conditioning (Charge/Discharge) Profiles

Module sample was conditioned, prior to testing, through charge and discharge cycles of 3 cycles to verify that the module was functional.

Each cycle was defined as a charge to 100% SOC and allowed to rest several minutes and then discharged to an end of discharge voltage (EODV) determined by the manufacturer. Refer to 2.1 for charge and discharge profile.

The module sample was put in a climate chamber during charge and discharge. The ambient is kept at 25°C±2°C and 50%± 5% R.H.

Figure 13. Module charge and discharge voltage/current profiles



Attachment C: Observations and Records

Ambient conditions at the initiation of the test. :	17.4°C, 67.8% R.H.
Sample number ..... :	#2024121501
Open circuit voltage before test (V)..... :	178.2
Weight before test (kg) ..... :	673.5 (with thermocouples)
Time initiating the test..... :	19:27 start to heat the cells
Weight after test (kg) ..... :	672.5 (with thermocouples)
Open circuit voltage after test (V)..... :	174.6
Weight loss (kg)..... :	1.0

Observations during test:

Location (Cell#)	Event	Time
/	Test start	19:27
Cell 64	Vent	20:02
Cell 64	Thermal runaway	20:27
Cell 63	Vent	20:28
Cell 63	Thermal runaway	20:32

Note:
1) No flying debris or explosive discharge of gases during test.
2) No sparks, electrical arcs, or other electrical events during test.
3) No flaming observed.

Attachment D: Module and Initiating Cell(s) Temperature Profiles during Testing

Figure 14. Temperatures of cell #63~#65

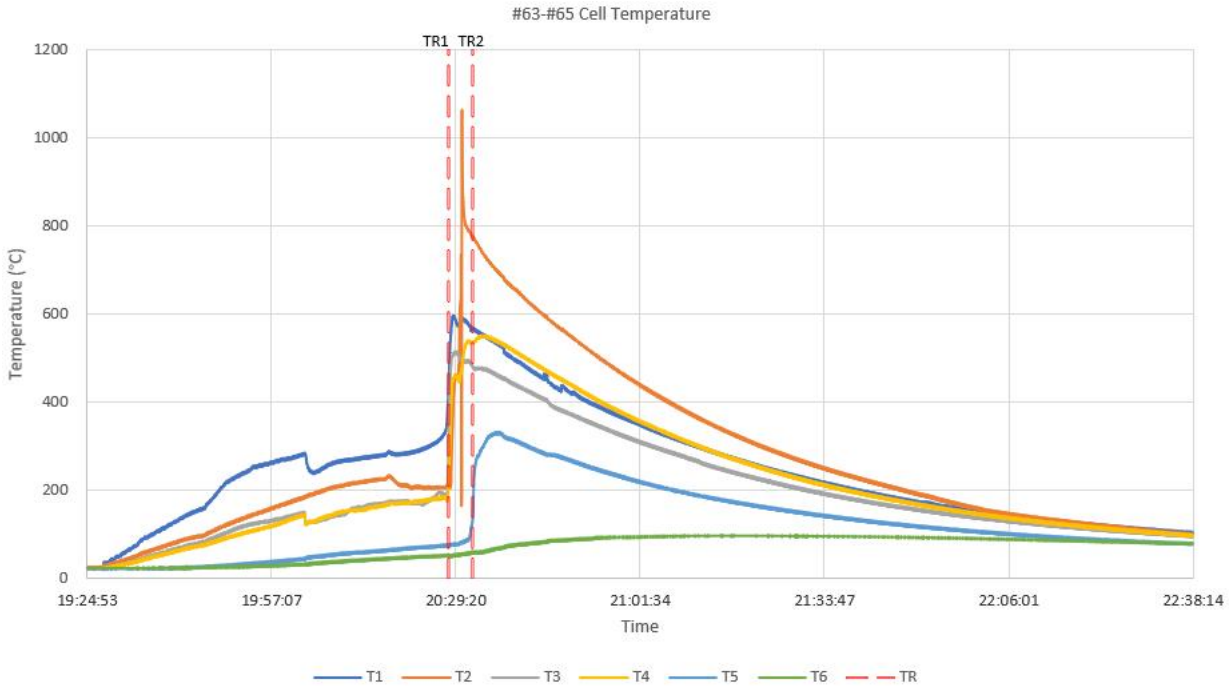


Figure 15. Temperatures of cell #35 and #66

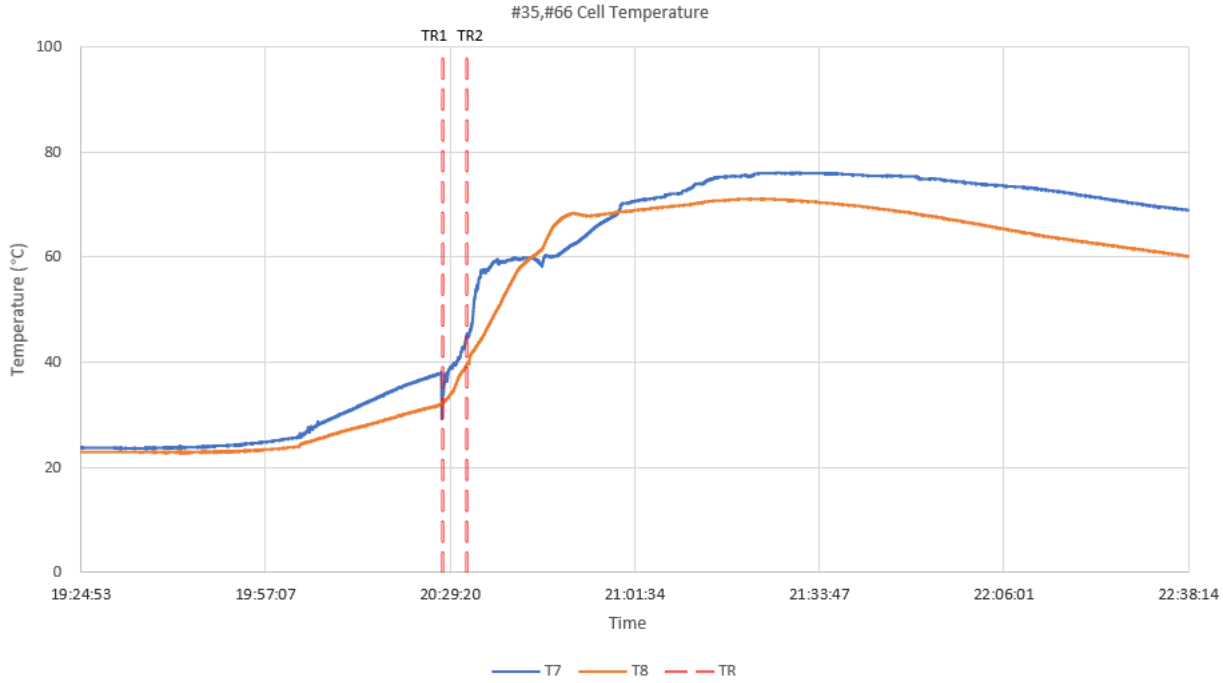


Figure 16. Temperatures of cell #49~#50

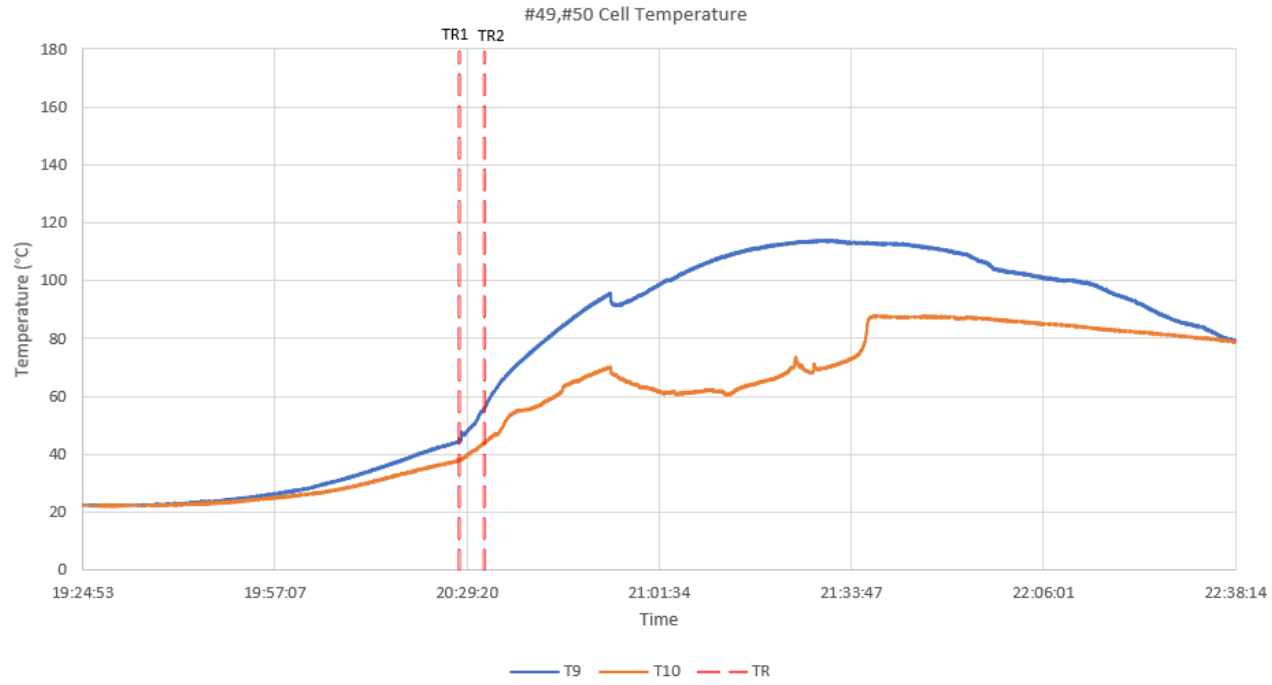


Figure 17. Temperatures of cell #77~#78

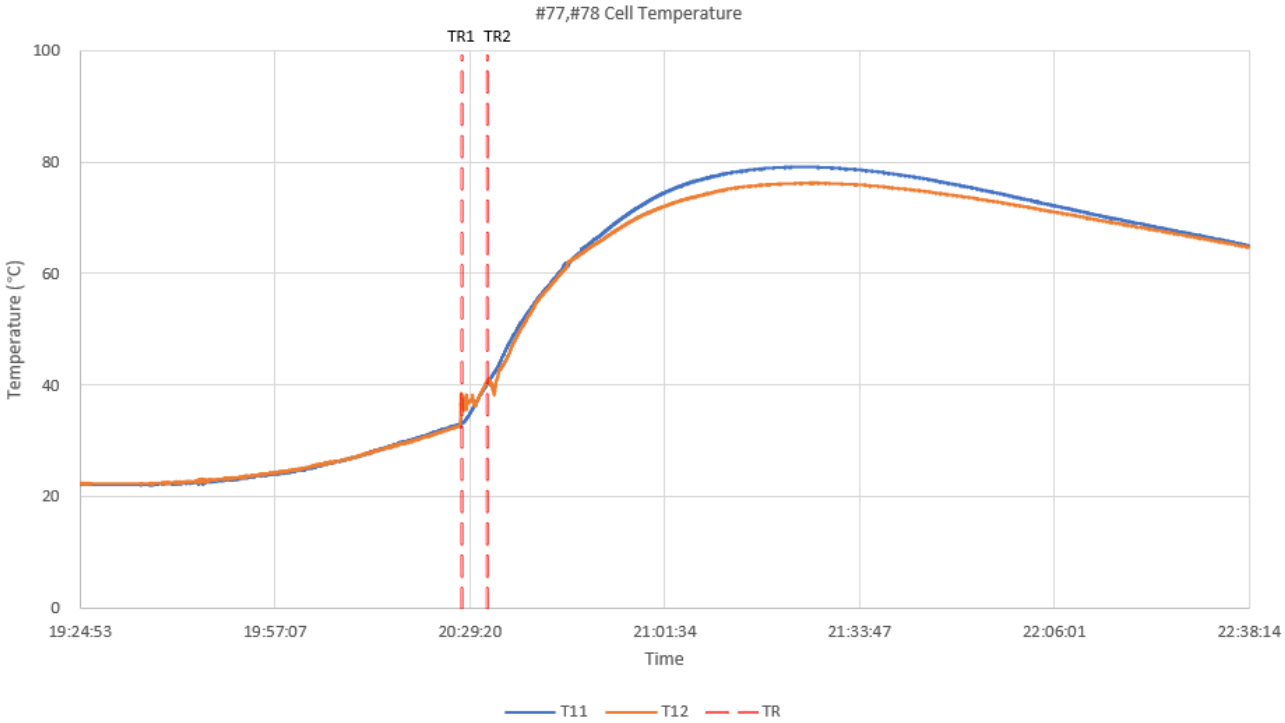


Figure 18. Temperatures of module surface

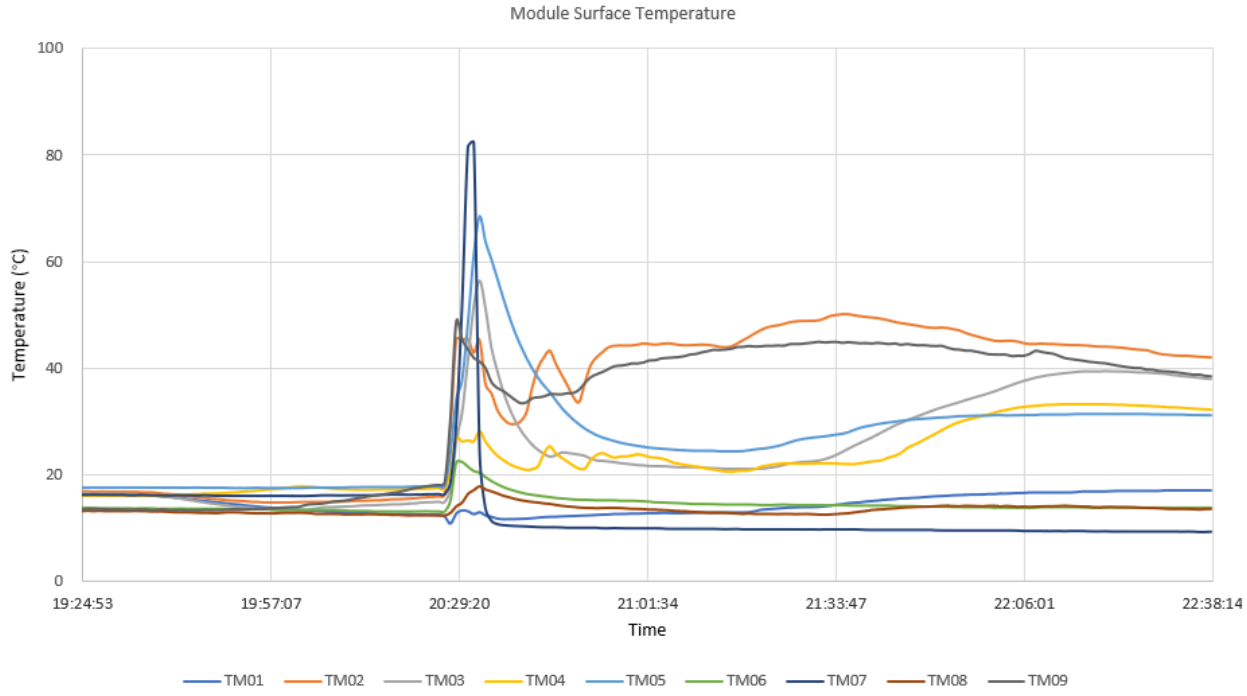


Figure 19. Surface temperatures of modules in initial unit 1 (refer to Figure 6)

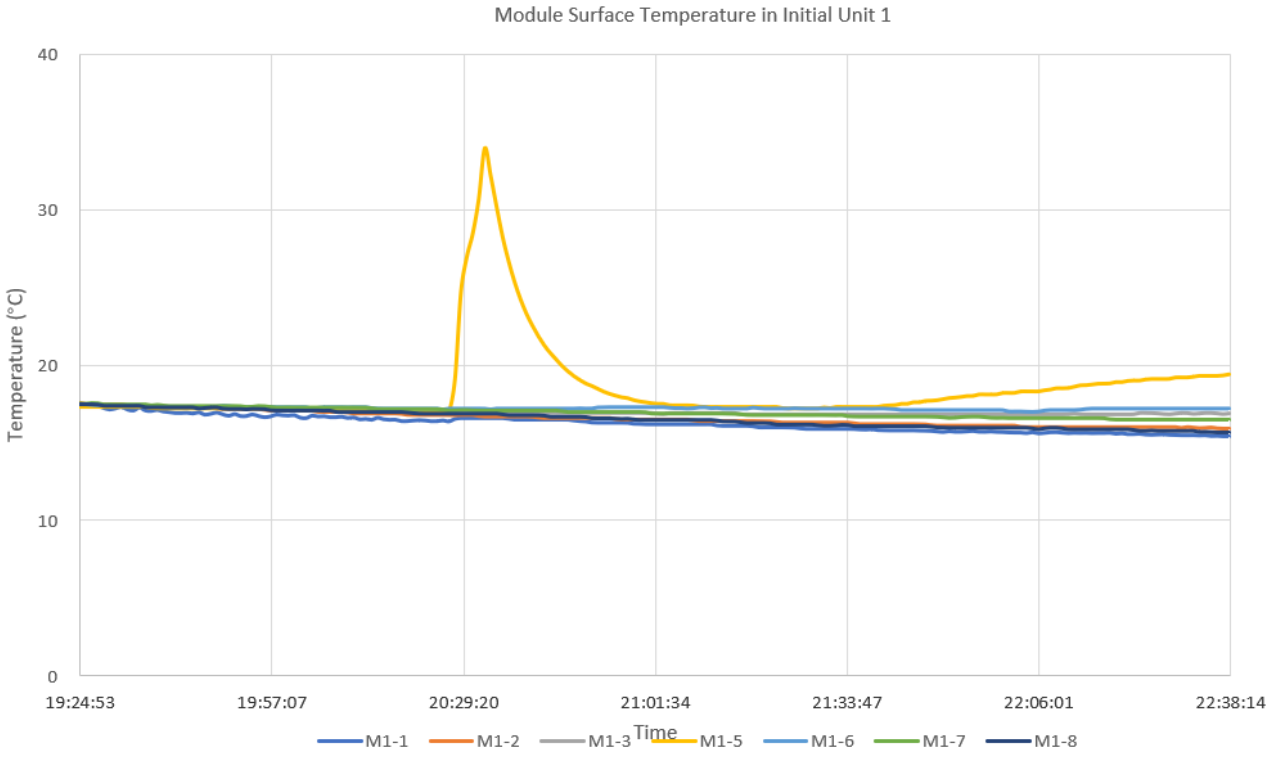
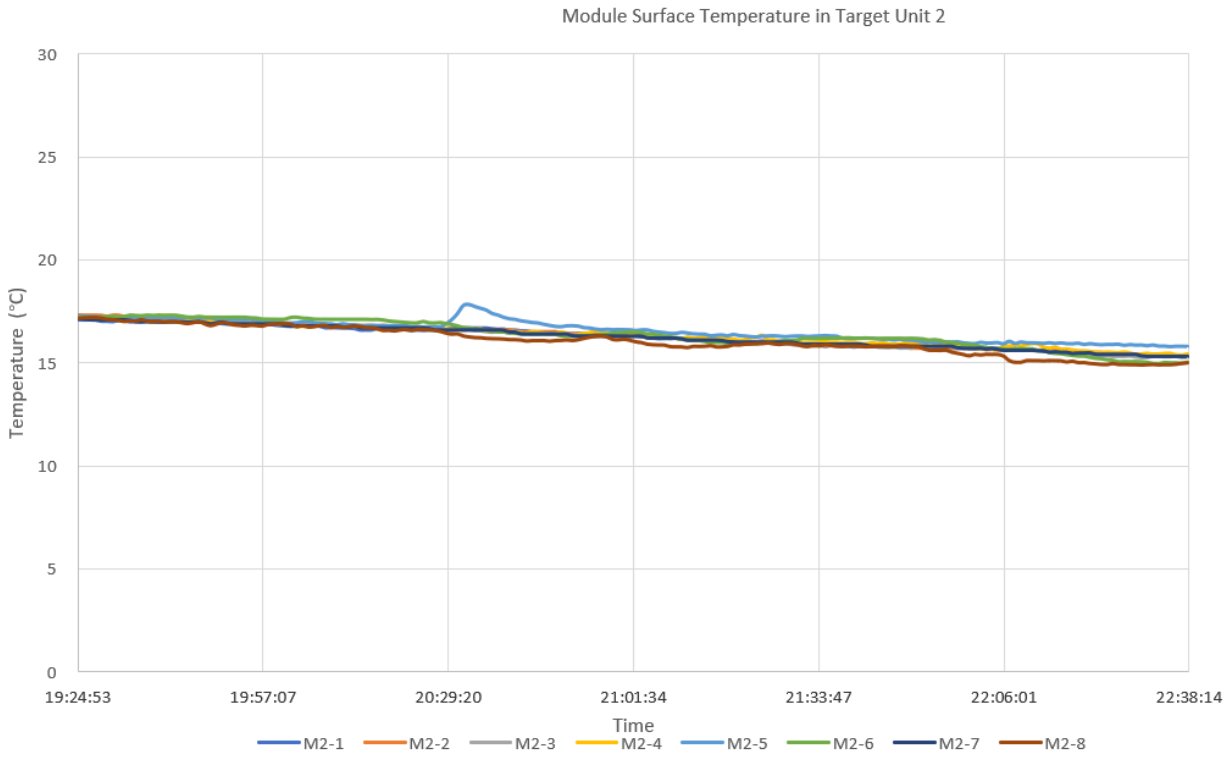


Figure 20. Surface temperatures of modules in target unit 2 (refer to Figure 6)



Maximum Temperatures in Target Units		
UL 9540A performance criteria, Cell Surface Temperature at Gas venting: 159.0 °C		
Location		Maximum Module Temperature (°C)
Surface temperatures of modules in target unit 2	M2-5	17.8

Figure 21. Temperatures on instrument wall A

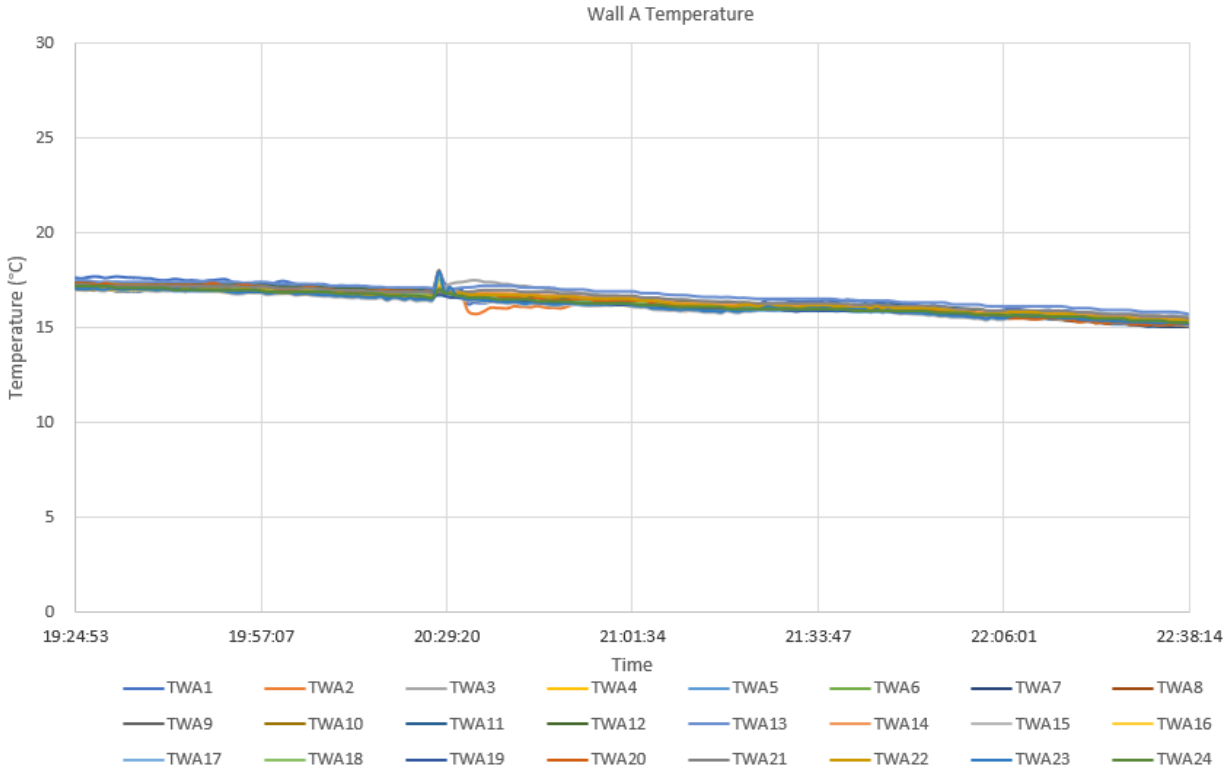


Figure 22. Temperatures on instrument wall B

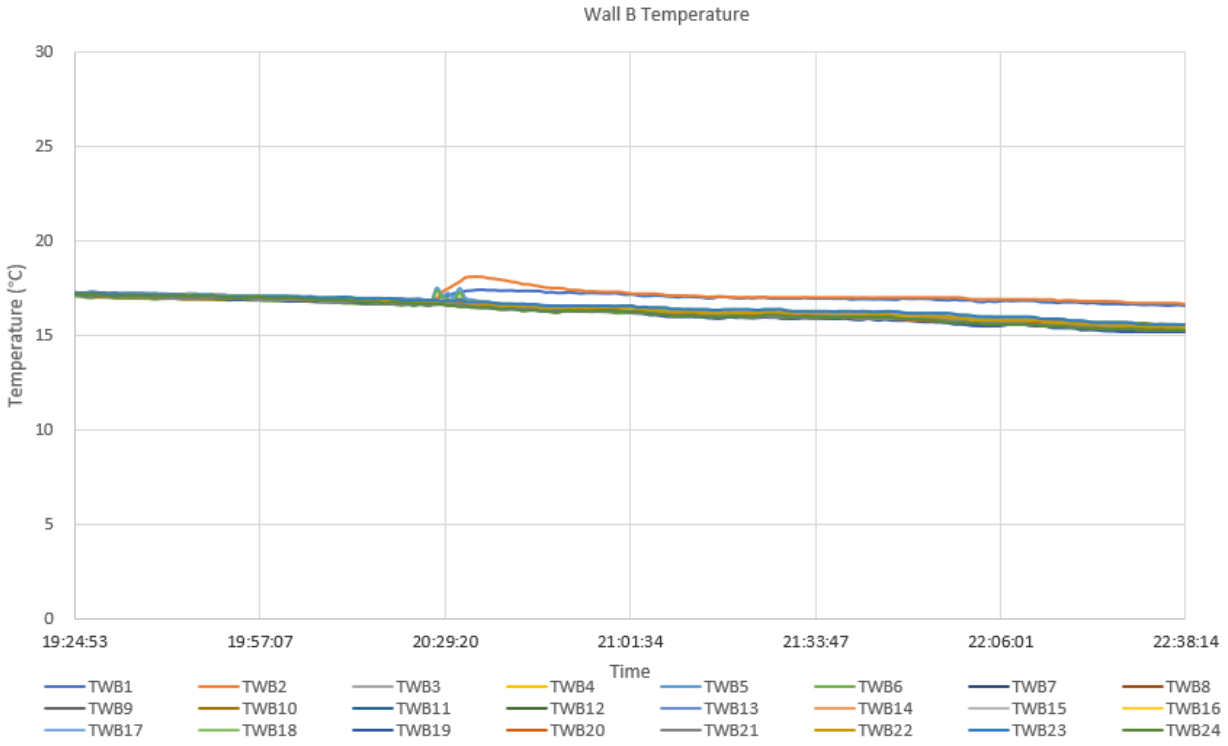
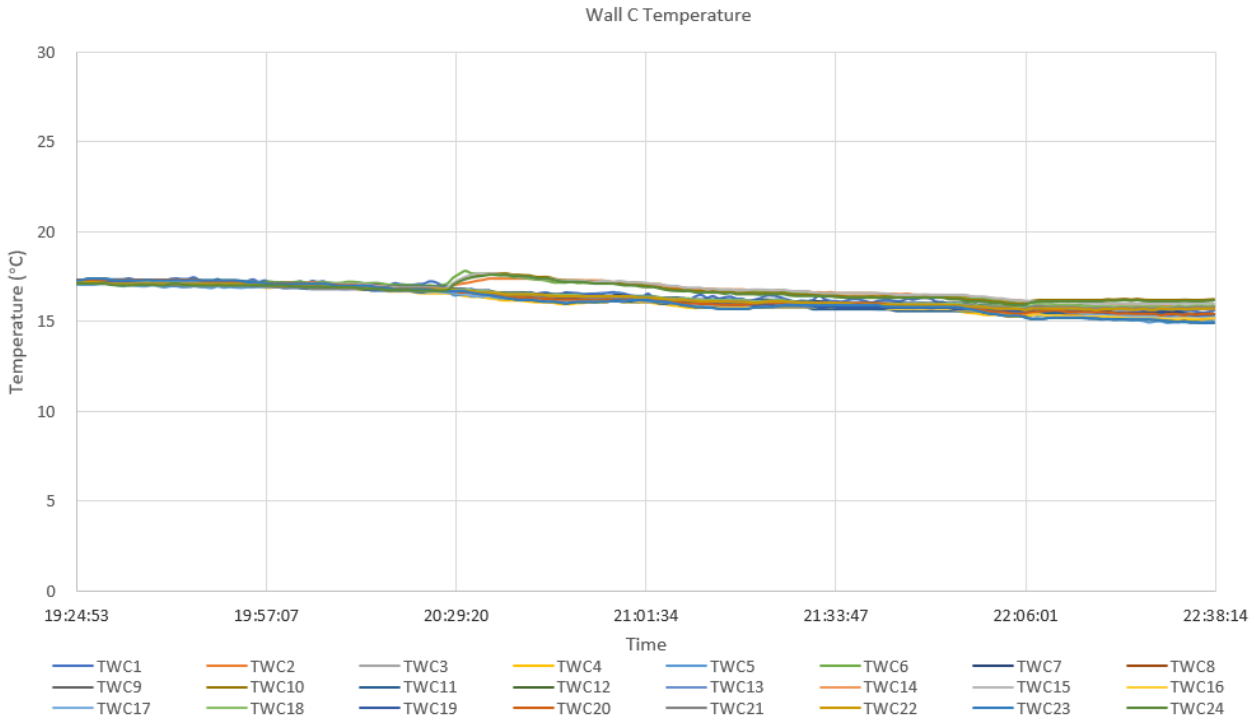
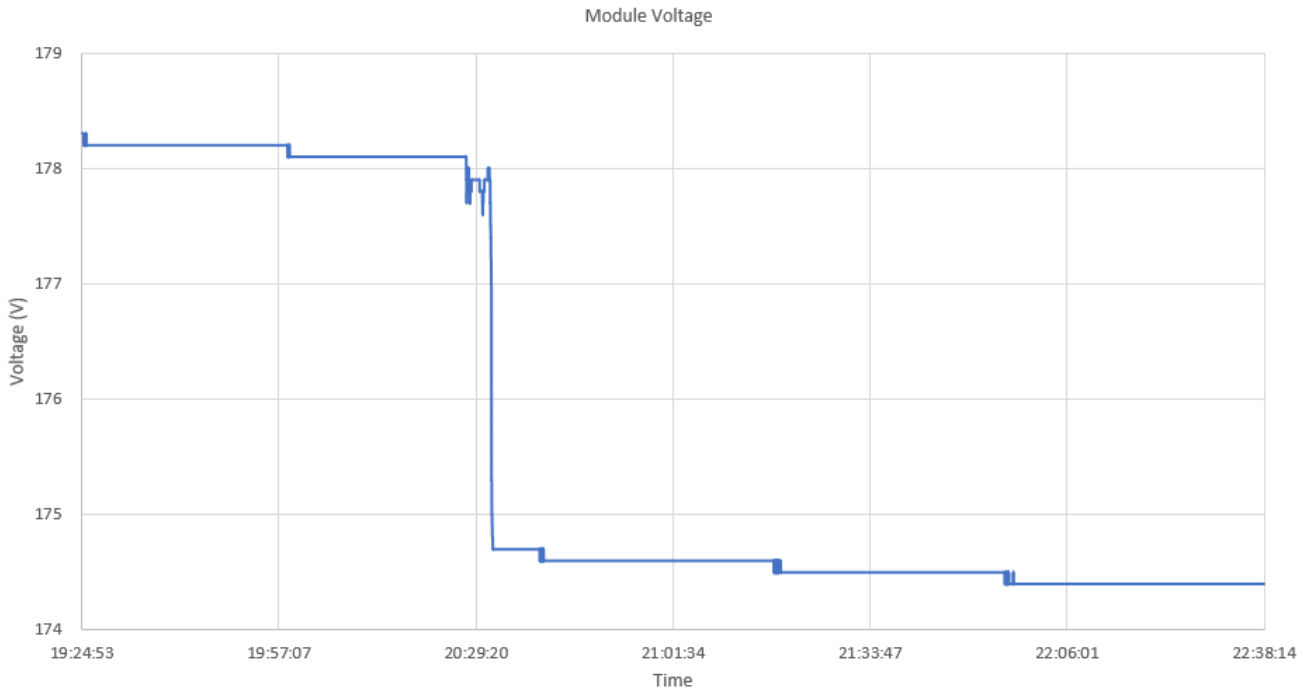


Figure 23. Temperatures on instrument wall C



Maximum Temperatures on Wall		
Ambient Temperature: 17.4°C		
UL 9540A performance criteria, Ambient + 97°C: 114.4°C		
Location		Maximum Wall Temperature (°C)
Wall A	TWA15	18.0
Wall B	TWB2	18.1
Wall C	TWC2	17.7

Figure 24. Module Voltage



Attachment E: Smoke Release Rate, Chemical Heat Release Rate, Convective Heat Release Rate and Heat Flux

Smoke and heat release rate		
Smoke Release Rate(SRR)	Maximum SRR(m^2/s)	0.3202
	Total Smoke Released(m^2)	19.717
Heat Release Rate(HRR)	Peak Chemical HRR(kW)	No flaming observed
	Peak Convective HRR(kW)	No flaming observed
	Total Heat Release(MJ)	No flaming observed

Figure 25. Smoke Release Rate

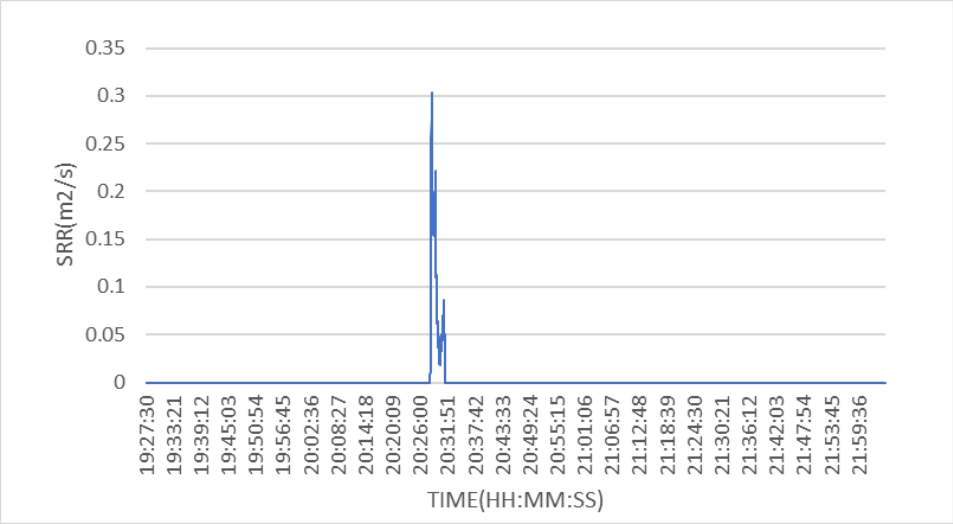


Figure 26. Total Smoke Released

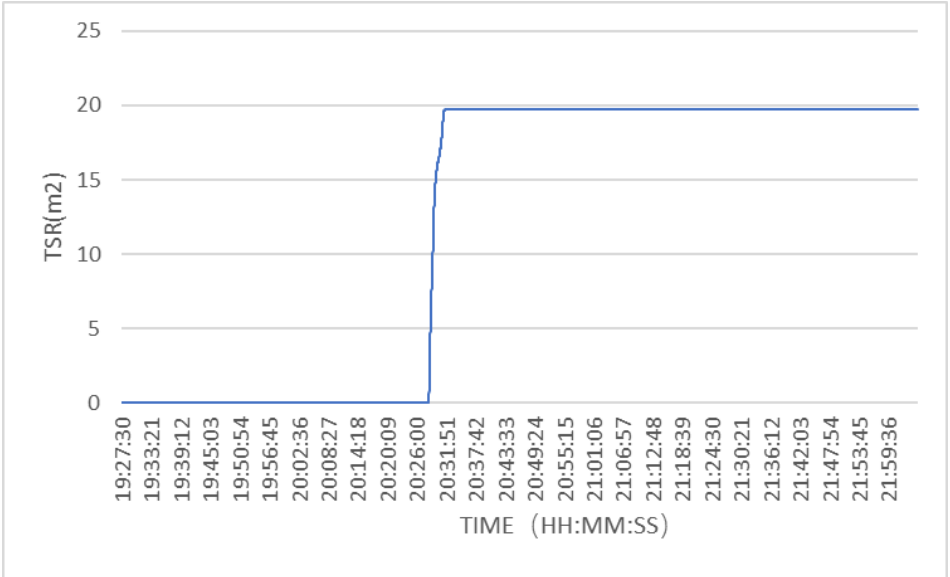
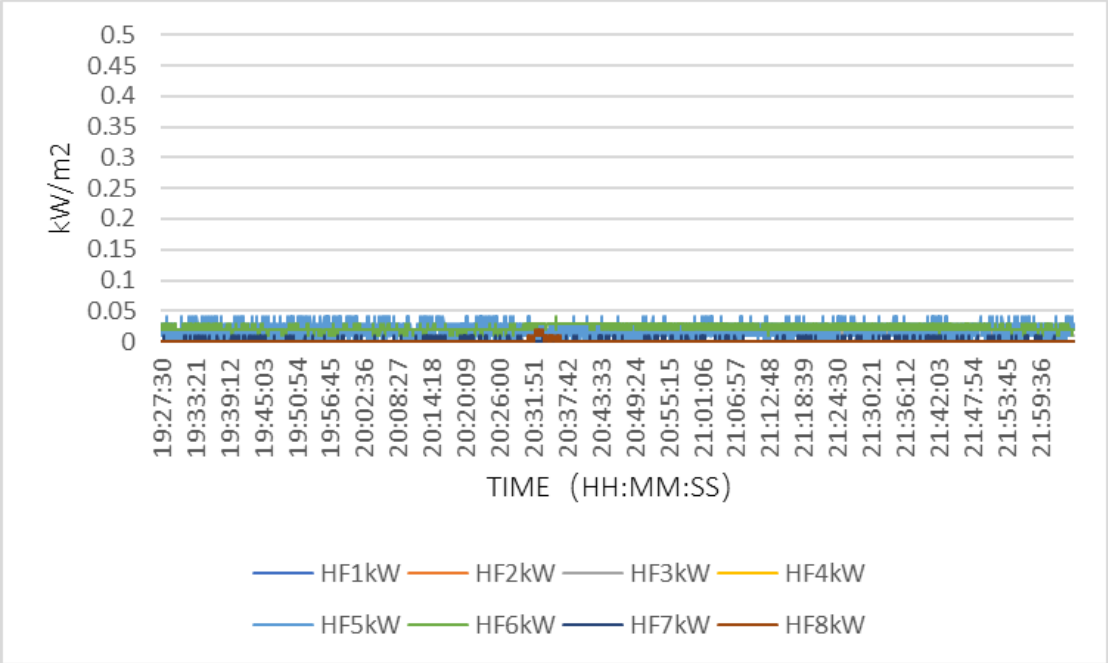


Figure 27. Heat Flux

Location of heat flux see figure 12.



Attachment F: Flammable Gas Generation and Composition Data

Measurement Method	Gas Compound	Gas Type	Pre-Flaming(L)	Post-Flaming(L)
Flame ionization detection	Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	43.44	No flaming
Fourier-Transform infrared Spectrometer	Carbon Monoxide	Carbon Containing	176.30	No flaming
	Carbon Dioxide	Carbon Containing	226.18	No flaming
Solid-state Hydrogen Sensor	Hydrogen	Hydrogen	302.87	No flaming
Note: The collection time is from 19:27 to 22:38.				

Measurement Method	Gas type	Gas components		Total volume of gas (L)	
				Pre-Flaming(L)	Post-Flaming(L)
Fourier-Transform infrared Spectrometer	Hydrocarbon species	Methane	CH_4	55.27	No flaming
		Ethylene	C_2H_4	26.94	No flaming
		Ethane	C_2H_6	4.33	No flaming
Note: The collection time is from 19:27 to 22:38.					

Figure 28. Total Hydrocarbons

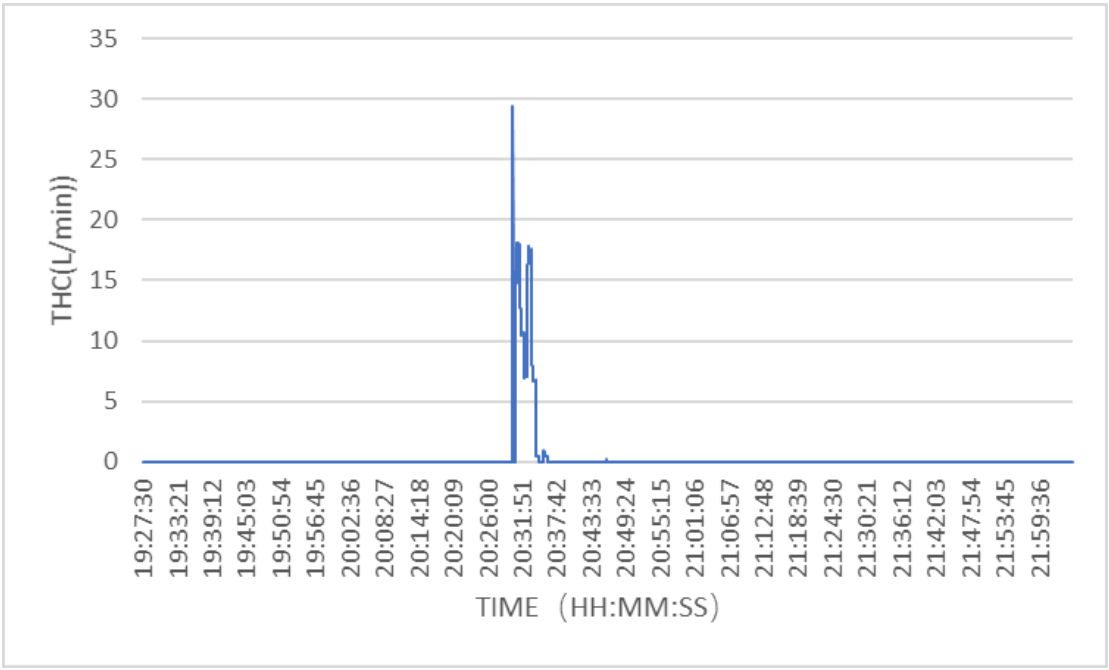
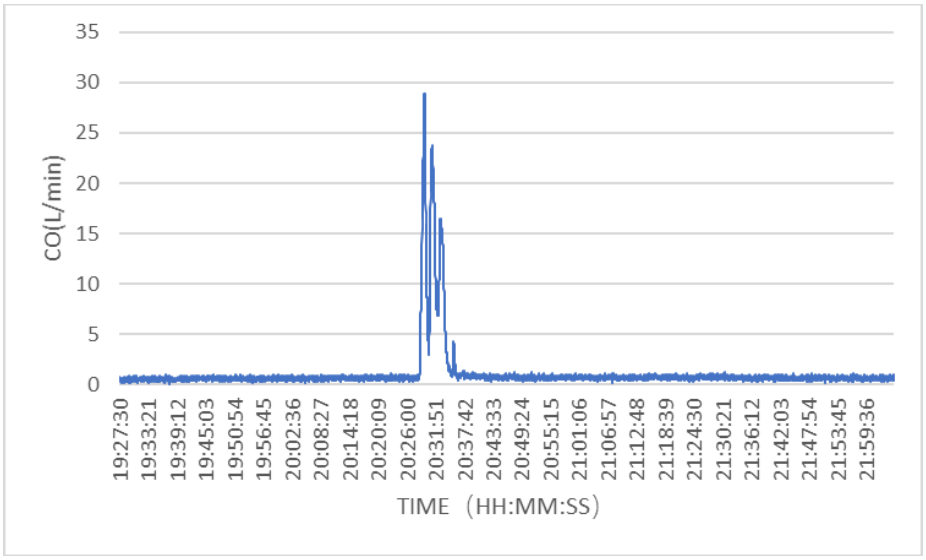


Figure 29. CO, CO_2



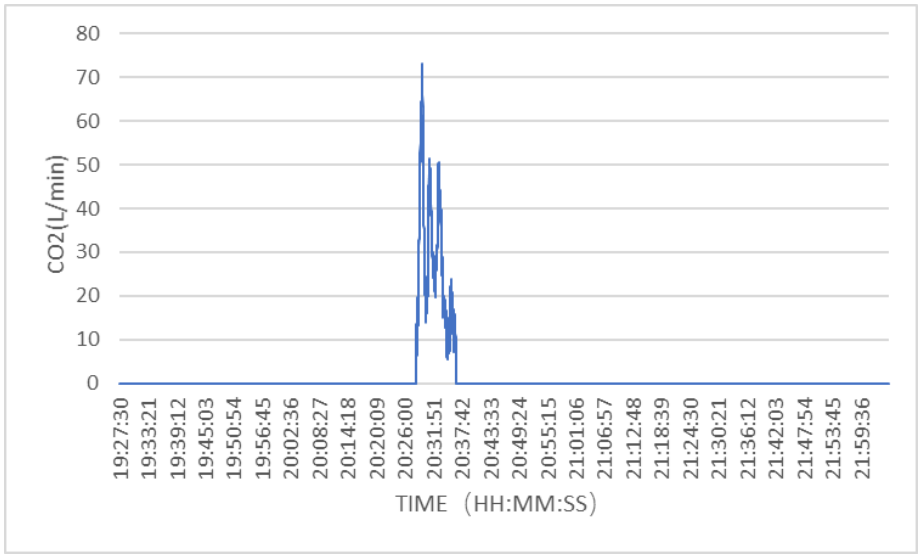


Figure 30. Hydrogen

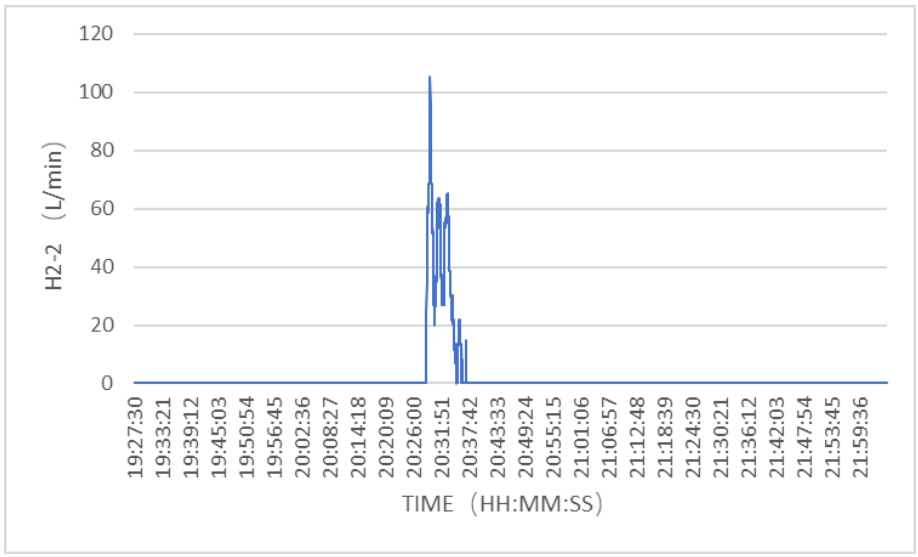
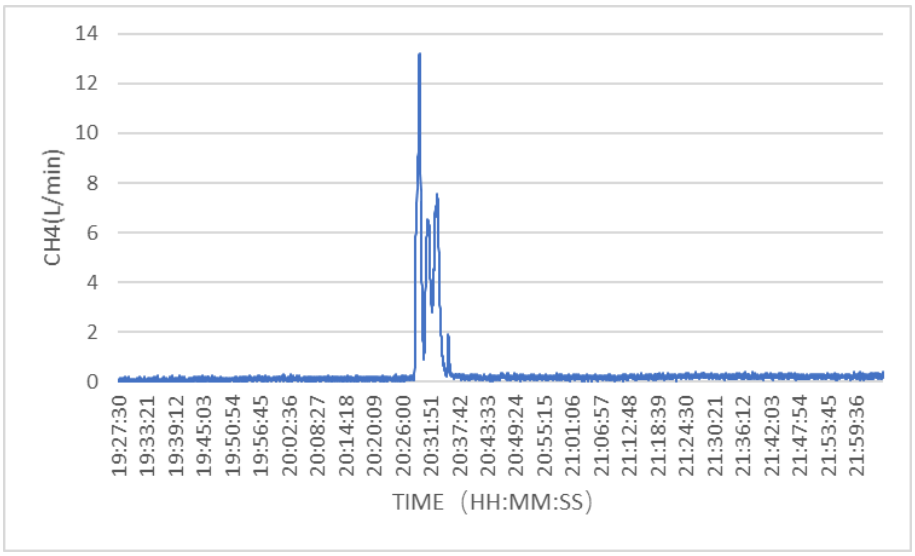
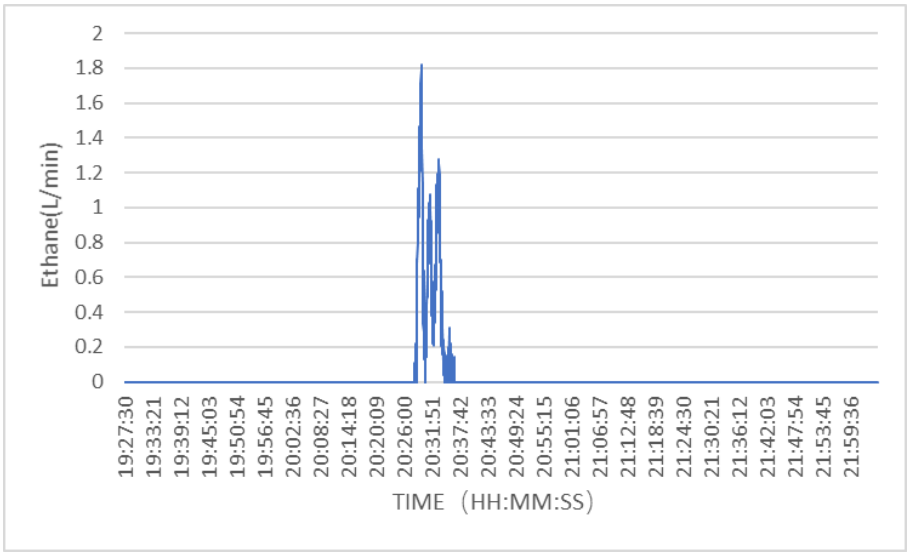
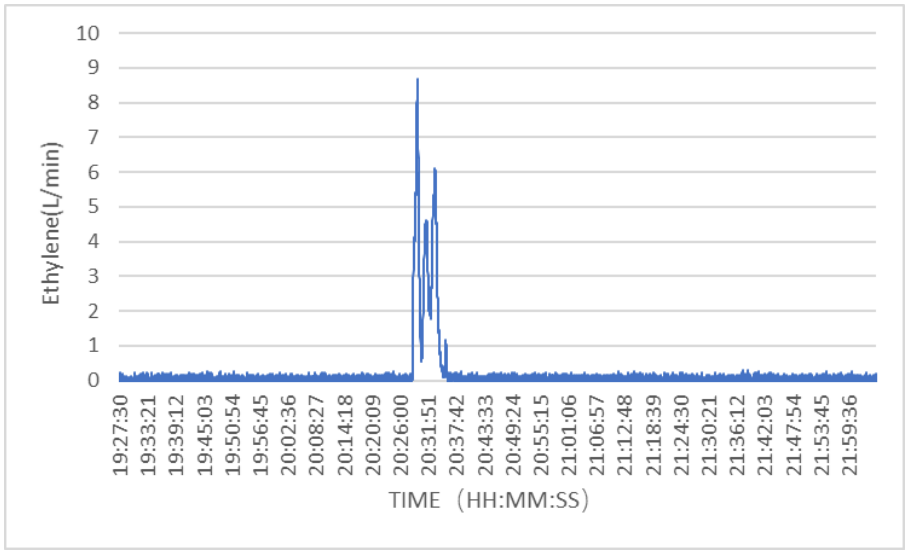


Figure 31. Hydrocarbon species







Attachment G: Sample Photos and Test Photos

Figure 32. Sample before test





Figure 33. Test setup





Figure 34. Smoke release during test





Figure 35. Photos after test









Attachment H: List of Test and Measurement Instruments

No.	Equipment	Model	Rating	Inventory no.	Cal. expire date
1	Ambient temperature and humidity	HWP01-10S	-30°C ~50°C, 20%RH~100%RH	12005577	2025.2.2
2	Data acquisition equipment	DAQ970A	3-slot cardcage with 6½ digit (22 bit) internal DMM 0.004%, accuracy 0.06% Vac	TY2020000138	2025.2.2
3	Data acquisition equipment	TP700	Measuring range-60 °C to 1372 °C Measurement accuracy ± (0.05% rdg.+0.5°C) Display resolution0.01°C	TY2211000716-2	2025.2.2
4	Data acquisition equipment	TP700	Measuring range-60 °C to 1372 °C Measurement accuracy ± (0.05% rdg.+0.5°C) Display resolution0.01°C	TY2020000217	2025.2.2
5	Electronic scale	CHAOOUC1	0-500KG	65960494169	2025.2.2
6	Paramagnetic oxygen analyser	SERVOMEX 4100	O2: paramagnetic sensor, range 0-25%, accuracy 0.02%, response time T90 < 7S	ZY2020000018-1	2025.2.6
7	Velocity probe	2671-25L-D-11-G2-E-N	4-20mA output, range 0-250pa, accuracy ± 1% F.S	ZY2020000018-2	2025.2.6
8	Photo detector	PDA36A2	Thorlabs optical receiver, wavelength range (350-1000) mm, gain adjustable, voltage output (0-10) V, instability < 0.1%	ZY2020000018-3	2025.2.2
9	Fourier-Transform Infrared Spectrometer	atmosFIR	Spectral scanning range: 485 - 7500cm-1; Spectral repeatability: < 0.1cm-1	ZY2020000018-5	2025.3.9
10	Non-dispersive infrared carbon dioxide and carbon monoxide sensor	SERVOMEX 4100	CO2: infrared sensor, measuring range 0-10%, accuracy 1% F.S, response time T90 < 7S Co: infrared sensor, measuring range 0-1%, accuracy 1% F.S, response time T90 < 8s	ZY2020000018-4	2025.2.6

11	Palladium-nickel thin-film solid state sensor	MODEL 2000	Range: 0-2000ppm, temperature less than 100 C, -90~110kPa	ZY2021000210	2025.2.2
12	Flame ionization detector	3010	Accuracy: 2.0%	19937	2025.3.9
13	Heat flux measurement equipment	MW88-JTC08C	0 ~ ± 99999 w / m2, - 250 ~ 980 °C, accuracy 5%, response time less than 0.1s,	ZY2020000010	2025.2.2
14	Thermopile	RS-WD-HW-1	0-200 °C, 4-20mA, response speed < 0.15s	28348141942	2025.2.2

Attachment H: Revision Information

New report, no revision information.

Appendix C

LSFT REPORTS

This Appendix is protected under a confidentiality agreement and has been redacted from this version of the report.

Appendix D

AESC USER MANUAL

This Appendix is protected under a confidentiality agreement and has been redacted from this version of the report.

Appendix E

SAFETY DATA SHEETS

DONGYUE FEDERATION 山东东岳绿冷科技有限公司
Shandong Dongyue Refrigerants Co.,Ltd. Tangshan Town, Huantai County
E-mail: zhao@dongyuechem.com Zibo city,shandong,China
Fax:0086-533-8220509 Tel: 0086-5333142515

R32 Material Safety Data Sheet

1. PRODUCT AND COMPANY IDENTIFICATION

Product Name: DIFLUOROMETHANE
Company: Shandong Dongyue Chemical Co.,Ltd
Street Address: Huantai County,
City, Province,Zip,Country: Zibo City,Shandong Province,China, 256401
Chem-tract: +86-533-8222579
MEDICAL: +86-533-8222259

2. Composition/Information on Ingredient

Substance Name	CAS Registry Number
DIFLUOROMETHANE	75-10-5

Formula: CH2F2
Synonyms: Carbon fluoride hydride * Difluoromethane * Methylene Difluoride

3, Hazards Identification

EMERGENCY OVERVIEW
Flammable Highly Flammable, Extremely Flammable Liquefied Gas.
For additional information on toxicity, please refer to Section 11

4, FIRST AID MEASURES

ORAL EXPOSURE
If swallowed, wash out mouth with water provided person is conscious. Call a physician
INHALATION EXPOSURE
If inhaled, remove to fresh air. If not breathing give artificial respiration. If breathing is difficult, give oxygen.
DERMAL EXPOSURE
In case of skin contact, flush with copious amounts of water for at least 15 minutes. Remove contaminated clothing and shoes. Call a physician.
EYE EXPOSURE
In case of contact with eyes, flush with copious amounts of water for at least 15 minutes. Assure adequate flushing by separating the eyelids with fingers. Call a physician.

5, Fire Fighting Measure

FLASH POINT N/A
AUTOIGNITION TEMP N/A

Shandong Dongyue Refrigerants Co.,Ltd. Tangshan Town, Huantai County
E–mail: zhao@dongyuechem.com Zibo city,shandong,China
Fax:0086-533-8220509 Tel: 0086-5333142515

FLAMMABILITY N/A

FIREFIGHTING

Protective Equipment: Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes. Specific Hazards: Emits toxic fumes under fire conditions

6, Accidental Release Measure

PROEDURE TO BE FOLLOWED IN CASE OF LEAK OR SPILL

Evacuate area and keep personal upwind. Shut off all sources of ignition. Shut off leak if there is no risk.

METHODS FOR CLEANING UP

Ventilate area and wash spill site after material pickup is complete.

7, Handling and Storage

HANDLING

User Exposure: Do not breathe gas. Do not get in eyes, on skin, on clothing. Avoid prolonged or repeated exposure.

STORAGE

Suitable: Keep tightly closed. Keep away from heat, sparks, and open flame. Store in a cool dry place. Cylinder temperature should not exceed 125 F (52℃)

SPECIAL REQUIREMENTS

Contents under pressure.

8, Exposure Controls

ENGINEERING CONTROLS

Mechanical exhaust required .Safety shower and eye bath.

WORK PRACTICES

Store and use with adequate ventilation

PERSONAL PROTECTIVE EQUIPMENT

Respiratory: Government approved respirator in nonventation. Areas and/or for exposure above the TLV or PEL.

Hand: Compatible chemical-resistant gloves.

Eye: Chemical safety goggles.

GENERAL HYGIENE MEASURES

Wash thoroughly after handling.

9, Physical/Chemical Properties

Appearance;	N/A
Molecular Weight	52.02 AMU
pH	N/A

BP/BP Range	-51.6℃
MP/MP Range	-136℃
Freezing Point	N/A
Vapor Pressure:	N/A
Vapor Density	N/A
Saturated Vapor Conc,	N/A
SG/Density:	1.1 g/cm3
Bulk Density:	N/A
Odor Threshold	N/A
Volatile %	N/A
VOC Content	N/A
Water Content	N/A
Solvent Content	N/A
Evaporation Rete	N/A
Viscosity	N/A
Surface Tension	N/A
Partition Coefficient	N/A
Decomposition Temp	N/A
Flash Point	N/A
Explosion Limits	N/A
Flammability	N/A
Autoignition Temp	N/A
Refractive Index	N/A
Optical Rotation	N/A
Miscellaneous Data	N/A
Solubility	N/A

N/A= not available

10, Stability and Reactivity

STABILITY

Reactions to Avoid: Reacts violently with:

Materials to Avoid: Sodium, Potassium, Calcium, Alkali metals.

HAZARDOUS DECOMPOSITION PRODUCTS

Hazardous Decomposition products: Carbon monoxide, Carbon dioxide, Hydrogen fluoride.

11, Toxicological Information

ROUTE OF EXPOSURE

Skin Contact: Can cause severe frostbite. Prolonged or repeated exposure to skin causes defeating and dermatitis. May cause skin irritation.

Eye Contact: May cause eye eye irritation.

Inhalation: Material may be irritating to mucous membranes and upper respiratory tract.

Multiple Routes: May be harmful by inhalation, ingestion, or skin absorption.

TARGET ORGEN OR SYSTEM

Damage to the heart. Heart.

SIGNS AND SYMPTOMS OF EXPOSURE

Exposure can cause: Narcotic effect. Exposure to large amounts can cause: Damage to the heart.

Inhalation

Mouse Rat

1,810,000 mg/m3 1,890,000 mg/m3

LC 50 LC50

Remarks: Behavioral: Change in motor activity.

Behavioral: Ataxia. Lungs, Thorax, or Respiration: Respiratoty depression.

CHRONIC EXPOSURE – TERATOGEN

Species: Rat

Dose: 50000 PPM/6H 50000 PPM/6H

Route of Application: Inhalation

Exposure Time: (6-15 PREG)

Result: Effects on Embryo or Fetus: Fetotoxicity (except death, e, g,. stunted fetus)

Effects on Embryo or Fetus; Fetotoxicity (except death, e, g, stunted fetus)

12, Ecological Information

No data available.

13, Disposal Considerations

APPROPRIATE METHOD OF DISPOSAL OF SUBSTANCE OR PREPARATION

Observe all federal, state, and local environmental regulations.

APPROPRIATE METHOD OF DISPOSAL OF CONTAMINATED PACKAGING

Caution: No-return cylinder. Do not reuse. Empty cylinder will contain hazardous residue.

Follow proper disposal techniques.

14, Transport Information

Proper Shipping Name: Difluoromethane

Class: 2 Hazard labels: 2.1 UN Number:3252

Not Allowed – Aircraft; Cargo aircraft only. Not permitted on passenger aircraft.

15 Regulatory Information

EU ADDITIONAL CLASSIFICATION

Symbol of Danger: F

Shandong Dongyue Refrigerants Co.,Ltd. Tangshan Town, Huantai County
E–mail: zhao@dongyuechem.com Zibo city,shandong,China
Fax:0086-533-8220509 Tel: 0086-5333142515

Indication of Danger: Highly Flammable.
R:11
Risk Statements: Highly Flammable.
S: 9 16 33
Safety Statements: Keep container in well-ventilated place. Keep away from sources of ignition – no smoking , Take precautionary measures against static discharges.

US CLASSIFICATION AND LABEL TEXT

Indication of Danger: Flammable (USA) Highly Flammable (EU).
Risk Statements: Extremely flammable liquefied gas.
Safety Statements: keep container in a well-ventilated place. Keep away from sources of ignition – no smoking. Take precautionary measures against static discharges.
US Statements: Target organ: Heart

UNITED STATES REGULATORY INFRORMATION

SARA LISTED; No
TSCA INVENTORY ITEM: Yes

CANADA REGULATORY INFROMATION

WHMIS Classification: This product has been classified in accordance with the hazard criteria of the CPR, and the MSDS contains all the information required by the CPR.

DSL: No
NDSL: Yes

16, OTHER INFORMATON

Revision Information
Revision Date 03 JAN 2024
Key
N/E= Not Established N/A=Not Applicable (R)=Registered Trademark

The end of MSDS

Appendix F

NFPA 69 TEST REPORT

Prüfbericht-Nr.: *Test report no.:*	**CN25XMAG 001**	**Auftrags-Nr.:** *Order no.:*	**326103326**	Seite 1 von 20 *Page 1 of 20*
Kunden-Referenz-Nr.: *Client reference no.:*	**2526542**	**Auftragsdatum:** *Order date:*	2025-04-07	
Auftraggeber: *Client:*	AESC jiangsu Co., Ltd. No.66 Shentai Road, Shengang Sub-District, Jiangyin City, Wuxi, Jiangsu Province, P.R. China			
Prüfgegenstand: *Test item:*	Energy Storage System			
Bezeichnung / Typ-Nr.: *Identification / Type no.:*	HE-L5030A			
Auftrags-Inhalt: *Order content*:	Assessment report			
Prüfgrundlage: *Test specification:*	This report provides evaluation and CFD analysis of the ventilation system in energy storage system referring to Chapter 8 in NFPA69:2024.			
Wareneingangsdatum: *Date of sample receipt:*	2025-03-20			
Prüfmuster-Nr.: *Test sample no:*	Engineering sample			
Prüfzeitraum: *Testing period:*	2025-03-21 - 2025-03-31			
Ort der Prüfung: *Place of testing:*	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüfergebnis*: *Test result*:*	See main report			



geprüft von: *tested by:*	Yichen Zhao	**genehmigt von:** *authorized by:*	Simon Wang
Datum: *Date:* 2025.08.04		**Ausstellungsdatum:** *Issue date:* 2025.08.04	
Stellung */ Position:*	**Project Engineer**	**Stellung** */ Position:*	**Authorizer**

Sonstiges */ Other:*	The mentioned models listed above are identical to the original model ENS-LC5030-11, ENS-LC5030-12 in the previous section report CN25DGS8 001 except for model name, trademark, license holder, adding MSD which leads to a slight increase in total size, and changing the fuse type to meet the new MSD. The test data refers to previous section report CN25DGS8 001. See following pages for details.
Zustand des Prüfgegenstandes bei Anlieferung: *Condition of the test item at delivery:*	Prüfmuster vollständig und unbeschädigt *Test item complete and undamaged*

* Legende:	P(ass) = entspricht o.g. Prüfgrundlage(n)	F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
** Legend:*	*P(ass) = passed a.m. test specification(s)*	*F(ail) = failed a.m. test specification(s)*	*N/A = not applicable*	*N/T = not tested*

Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht auszugsweise vervielfältigt werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens.
This test report only relates to the above mentioned test sample as. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.
V05

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1. General Production Information:

1.1. Cell

The product information and parameters are provided by the client as below.

Manufacturer .....:	AESC jiangsu Co., Ltd.	
Model number.....:	HC-L315A	
Chemistry .....:	LiFePO4	
Physical configuration .....:	Prismatic	
Electrical rating .....:	Rated capacity:	315 Ah
	Nominal voltage:	3.2 V
Standard charge method .....:	Charge power:	504 W
	End of charge voltage:	3.65 V
Standard discharge method .....:	Discharge power:	504 W
	End of discharge voltage:	2.5 V

1.2. Module

The product information and parameters are provided by the client as below.

Manufacturer name :		AESC jiangsu Co., Ltd.
Model number :		HP-L630B
Physical configuration :		Nonmetallic enclosure
		Weight: 670±10 kg
		Cells in series/parallel: 2P52S
Cooling method :		Liquid cooling
Electrical rating :		Rated capacity: 630 Ah
		Nominal voltage: 166.4V
Standard charge method.....:	Charge current :	315 A
	End of charge voltage :	189.8 V
	Charge temperature range:	0~55 °C
Standard discharge method.....:	Discharge current :	315 A
	End of discharge voltage :	130 V
	Discharge temperature range:	-30~55 °C
External dimensions (mm) :		2214.6±5*794±5*246.2±5mm

1.3. Energy Storage System

The product information and parameters are provided by the client as below.

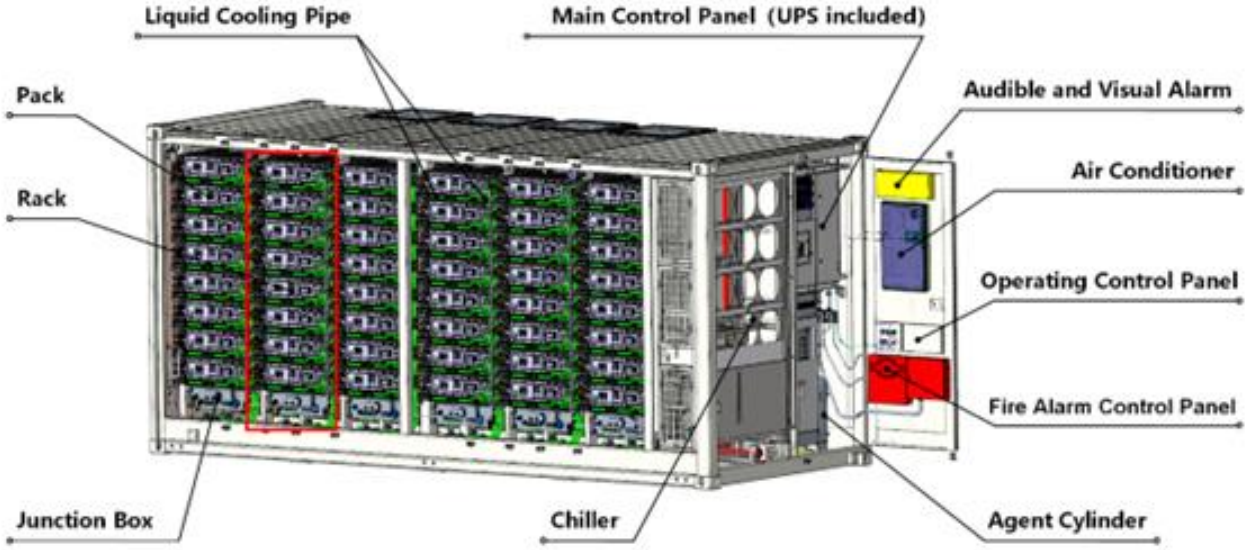
	Lithium Ion Battery System
Type/model	HE-L5030A
Structure	((2P52S)8S)6P
Rated Energy [kWh]	5030
Battery Type	$LiFePO_4$
Rated Capacity [Ah]	3780
Maximum continuous charging/discharging power [kW]	2515.968
Peak current in charge [A]	2130
Peak current in discharge [A]	2400
Nominal Voltage [Vdc]	1331.2
Upper limit charging voltage [Vdc]	1497.6
Discharging cut-off voltage [Vdc]	1123.2
Charge range of ambient temperature [°C]	-30 to 55*
Discharge range of ambient temperature [°C]	-30 to 55*
AC auxiliary power input	277/480Vac，3W+N+PE, 65A, 60Hz
Weight [kg]	Max 43000
Overall size: (L*W*H) [mm]:	6058*2438*2896
Enclosure Protection (IP)	IP55
Cooling Type	Liquid cooling and heating for battery Forced air cooling for distribution room
Protective class	I
Altitude [m]	Below 2000

Note*: The system will not start charging until cell min temperature > 0°C heating by liquid chiller which controlled by LEMS.

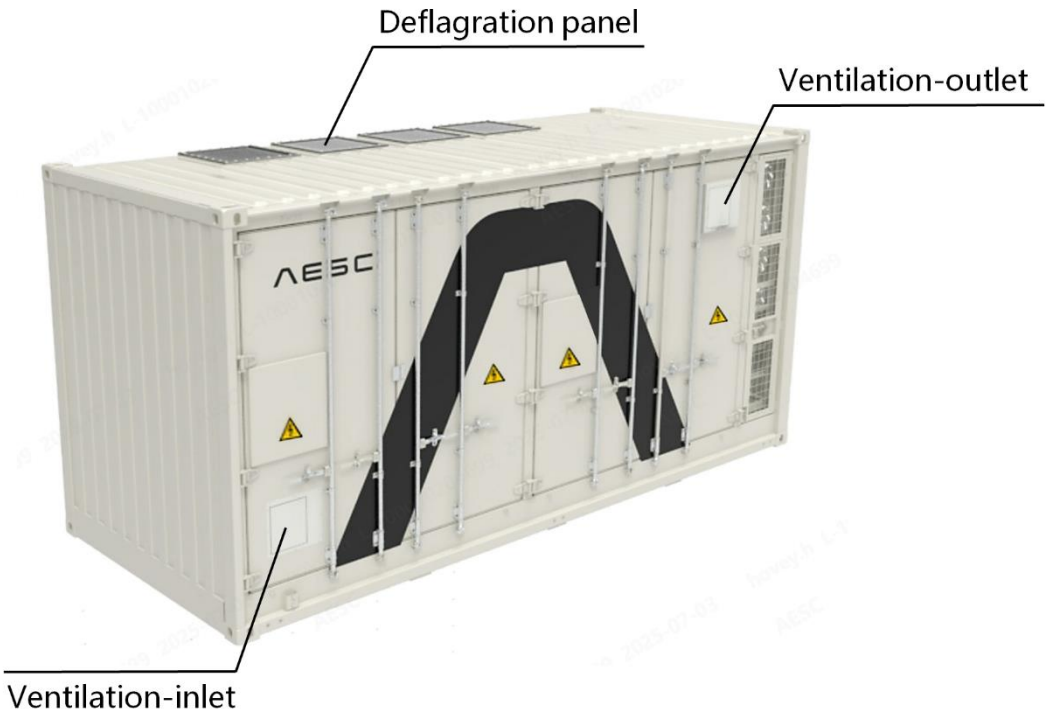
2. Product Description:

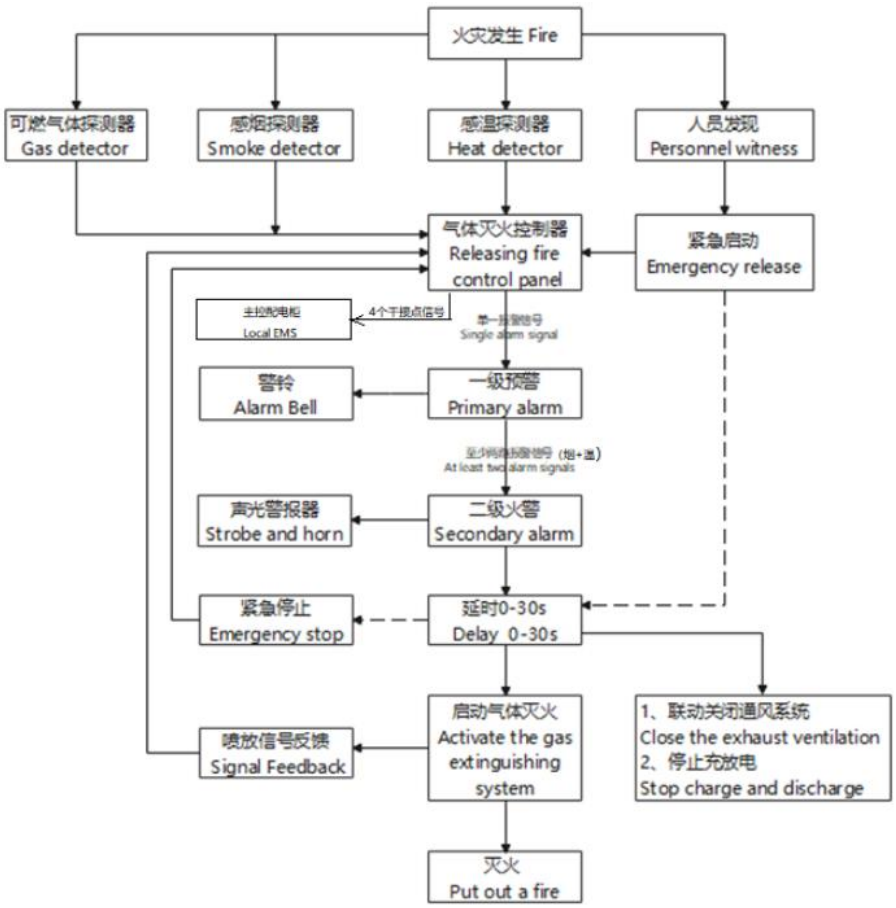
2.1. General Description

1- The EUT covered by this report is DC system for energy storage, which mainly consists of 6 battery racks in parallel connection, 1 liquid chiller, 1 air conditioning, fire protection, communication device and some auxiliary power supply components integrated in 1 container.
2- The battery rack is liquid cooling type, each rack consists of 8 battery packs and 1 control box in series connection. Each battery pack mainly consists of 104 cells structured with 52S2P, 1 MSD, 1 slave BMU and related connection parts. The slave BMU is used for measuring and collecting the cell parameters of each pack and uploading to BCU in control box. The control box mainly consists of protective devices such as relay, hall, fuse, circuit breaker and master BCU function as the control unit for the battery system.
3- The input auxiliary power source system should be an TN-C-S type in end-installation specifed by the manufacture.
4- Suitable external overcurrent device and manual disconnect switch should be provided for both positive and negative of main battery circuit in end-installation.
5- The insulation between the hazardous voltage circuit and the grounded metal enclosure is basic insulation. And the insulation between the hazardous voltage circuit and communication circuit is reinforced insulation.
6- The battery system has overcharge, over-discharge, over current and short-circuits proof circuit. The electronic circuits and software controls for the battery system replied upon protective functions of the battery management system have been evaluated in accordance with IEC 60730-1 Annex H.
7- The EUT is an outdoor type with IP55 degree, PD2 was evaluated for inside and PD3 for outside.
8- Overvoltage Category II was evaluated for the battery system, the battery system should isolate from an Overvoltage category III supply source to prevent transient overvoltage conditions in end-installation.
9- Suitable fire barriers or enclosures which comply with NFPA 855 should be provided and evaluated in the end-installation.
10- See below layout for detail structure.



2.2. Venting System Layout





3. Ventilation system evaluation referring to Chapter 8 in NFPA69:2024

Clause	Requirement – Test	Result – Remark	Verdict
Chapter 8	**Deflagration Prevention by Combustible Concentration Reduction**		--
8.1	**Application.** The technique for combustible concentration reduction shall be permitted to be considered where a mixture of a combustible material and an oxidant is confined to an enclosure and where the concentration of the combustible can be maintained below the lower flammable limit (LFL).	Specified in detail in "CFD analysis of the ventilation system"	P
8.2	**Basic Design Considerations**		--
8.2.1	All of the following factors shall be considered in the design of a system intended to reduce the combustible concentration below the LFL:	Specified in detail in "CFD analysis of the ventilation system"	P
	1) Required reduction in combustible concentration		P
	2) Variations in the process, process temperature and pressure, and materials being processed		P
	3) Operating controls		P
	4) Maintenance, inspection, and testing		P
	5) Concentration variation with time and location within the protected enclosure		P
8.2.2	The LFLs of the combustible components shall be determined at all operating conditions, including startup and shutdown.		P
8.2.3	**Protection System Design and Operation**		--
8.2.3.1	The owner or operator shall be responsible for a thorough analysis of the process to determine the type and degree of deflagration hazards inherent in the process		P
8.2.3.2	Information required for the monitoring and control of the concentration of combustible components shall be compiled and documented. This information shall include, but not be limited to, the following:		--
	(1) Monitoring and control objectives		P
	(2) Monitored and controlled areas of the process		P
	(3) Dimensioned drawings of the process with the following: (a) Equipment make and model if available, including volumes and diameters and design strengths (b) Plan and elevation views with flows indicated		P

3. Ventilation system evaluation referring to Chapter 8 in NFPA69:2024

Clause	Requirement – Test	Result – Remark	Verdict
	(4) Startup, normal, shutdown, temporary operations, and emergency shutdown process conditions and ranges for the following: (a) Flow (b) Temperature (c) Pressure (d) Oxidant concentration (e) Fuel concentration		P
	(5) Process flow diagram and description		N/A
	(6) Ambient temperature in process area		P
	(7) Process interlocks		N/A
8.2.3.3	The owner or operator shall disclose any and all process information required for the protection system design.		P
8.2.3.4	The protection system design shall be subject to a documented review by a qualified person.		P
8.2.3.5	The owner or operator shall be responsible for the maintenance of the system after installation and acceptance based on procedures provided by the vendor. Maintenance records shall be retained for inspection by the authority having jurisdiction.		P
8.2.3.6	The owner or operator shall be responsible for periodic inspection of the system by personnel trained by the system manufacturer. The inspection frequency shall be in accordance with Section 15.7.		N/A
8.2.3.7	Management of Change. The effect of any process change shall be addressed as specified in Section 15.11.		N/A
8.2.3.8	All documentation relevant to the protection system shall be retained in accordance with Chapter 15.		N/A
8.3	**Design and Operating Requirements**		--
8.3.1	**Combustible Concentration Limit.** The combustible concentration shall be maintained at or below 25 percent of the LFL for all foreseeable variations in operating conditions and material loadings, unless the following conditions apply:	Specified in detail in “CFD analysis of the ventilation system”	P
	(1) Where continuously monitored and controlled with safety interlocks, the combustible concentration shall be permitted to be maintained at or below 60 percent of the LFL.	Specified in detail in “CFD analysis of the ventilation system”	N/A

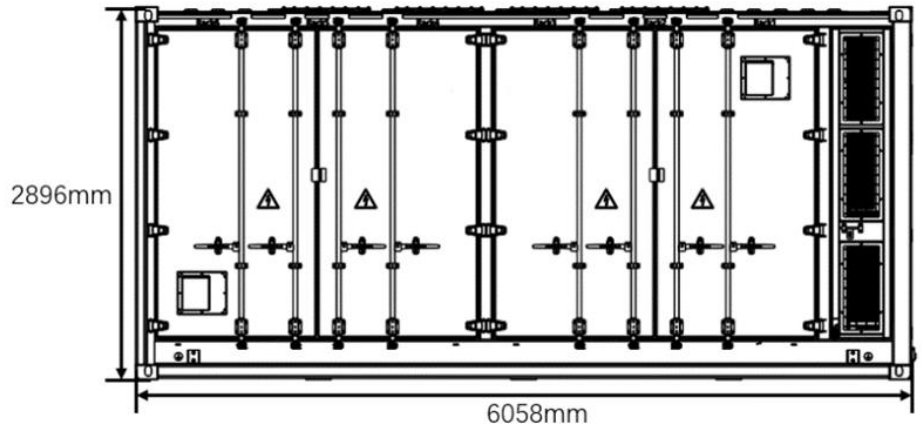
3. Ventilation system evaluation referring to Chapter 8 in NFPA69:2024

Clause	Requirement – Test	Result – Remark	Verdict
	(2) Aluminium powder production systems designed and operated in accordance with NFPA 484 shall be permitted to be maintained at or below 50 percent of the LFL.		N/A
8.3.2	**Catalytic Oxidation.** Where catalytic oxidation is used for combustible concentration reduction, the following shall apply:		N/A
	(1) Isolation systems shall be provided in all inlets to the catalytic oxidation unit.		N/A
	(2) Unless the combustible concentration is monitored continuously, the effectiveness of the catalytic oxidation system shall be verified periodically in accordance with the manufacturer's recommendations.		N/A
8.3.3	**Ventilation or Air Dilution**		N/A
8.3.3.1	If ventilation is used, the outlets from the protected enclosures shall be located so that hazardous concentrations of the exhausted air cannot enter or be drawn into the fresh air intakes of environmental air‐handling systems.		N/A
8.3.3.2	Air intakes shall meet one of the following requirements:		N/A
	(1) They shall be located so that combustible material cannot enter the air-handling system, even in the event of spills or leaks.		N/A
	(2) They shall be provided with gas detectors that automatically interlock to stop air intake.		N/A
8.3.3.3	Filters, dryers, or precipitators in the air intakes shall be located such that they are accessible for cleaning and maintenance.		N/A
8.4	**Instrumentation**		N/A
8.4.1	Instrumentation shall be provided to monitor and control the process flows.		N/A
8.4.2	Instrumentation shall be calibrated according to the requirements of Chapter 15.		N/A
8.4.3	Where the enclosure being protected presents a personnel hazard, alarms shall be provided to indicate abnormal operation of the system.		N/A

4. CFD analysis of the ventilation system

4.1. Basic Information of the system

The interior and exterior drawings provided by AESC were verified between TUV and AESC before running any calculation.
Figure 4-1 shows an external view of the container and the dimensions from a front and left view. The container measures 6.058*2.438*2.896 m including one battery cabinet, liquid cooling system and AC Auxiliary Interface. The cabinet contains 6 racks, 8 modules in each rack and 104 cells in each module. The overall internal volume of battery cabinet is approximately 31.715 m^3. Subtracting the space filled by racks, modules, and the support structure, the actual open internal volume (efficient volume) is 12.48 m^3.



Front view

Figure 4-1: Geometry of AESC energy storage system

4.2. Principles and Assumptions

The following safety systems and CFD analysis have been acknowledged for the basis of the study's assumptions. Note that the scenarios and assumptions are run in unit levels, module levels and cell levels to show progressively worse-case scenarios based on the information available and are considered to be conservative.

4.2.1. Thermal runaway and propagation

(1) Propagation between cells:

The UL 9540A test report of module level and unit level indicate that cell-to-cell propagation could happen within a submodule which contains 13 cells. According to the test report, total 2 cells were failed in both module and unit level tests. It indicates that cell-to-cell thermal runaway propagation would occur in the battery pack.

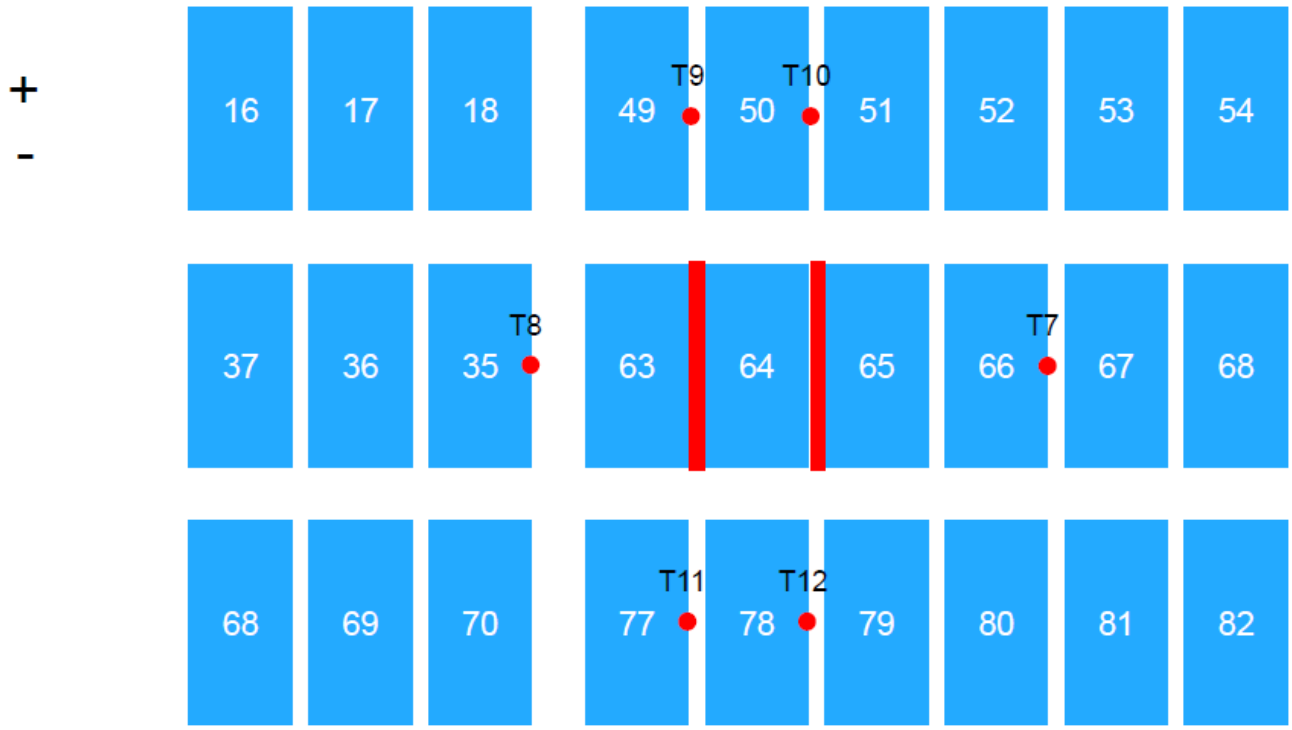


Figure 4-2: Initiating module set up in unit level UL9540A test report

(2) Propagation between modules:

The UL 9540A test report of unit level does not indicate that it is possible to have propagation between modules.

Assumption 1: There is no module-to-module propagation.

4.2.2. Leakage profile and gas composition

(1) Leakage profile:

The data and test phenomenon in cell level, module level and unit level UL 9540A test report provide gas release rate and total amount. The gas release rate profile in this study is the worst scenario that considered the raw data from unit level UL 9540A test. (See Figure 4-3).



Figure 4-3: Unit level gas generation and composition data

For conservative consideration, it is assumed that the gas release rate is set to be a constant value which is the maximum release rate throughout the test. Based on module level and unit level test, the gas release is 238.11 LPM according to the test raw data of CO, CO_2, hydrogen and THC release rate in unit level test. (See Figure 4-4).

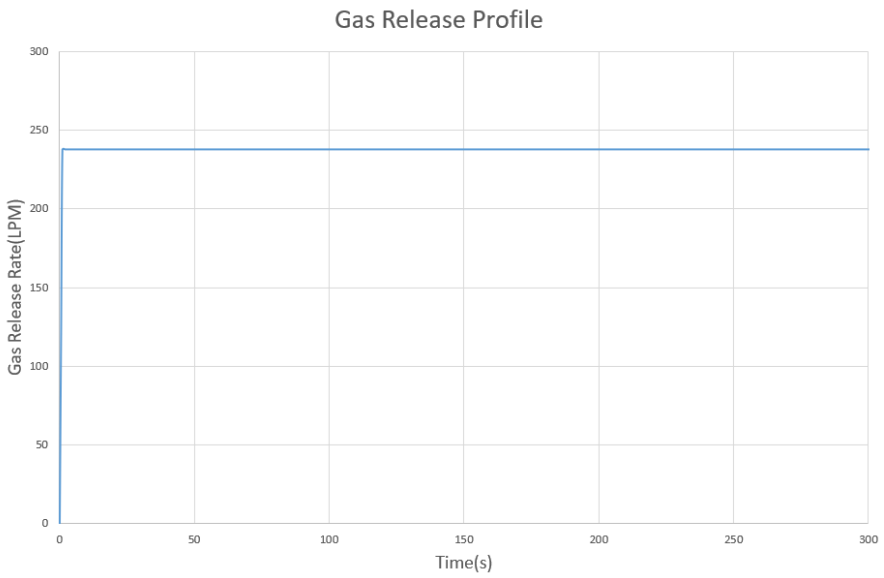


Figure 4-4: Gas release rate profile

Assumption 3: The offgas release profile is set as above for each scenario.

(2) Position of the leak:

According to the configuration of the battery rack inside the battery compartment, consider the battery packs located at the bottom of the air inlet, the middle position, and the air outlet as initiating modules, and name them 001, 002, and 003 respectively.



Figure 4-5: Location of gas leakage position (front view)

Assumption 4: Three offgas release positions on the racks are considered in this study. (See Figure 4-5)

(3) Gas detector:

Regarding the construction of the container, there are two gas detectors equipped on the edge of the roof in battery compartment. Gas detector 1 detects H_2, and Gas detector 2 detects CO, the locations are shown in figure 4-6.



Figure 4-6: Location of gas detectors (front view).

Assumption 5: The positions of the gas detectors as described above are used to monitor the concentrations of hydrogen and carbon monoxide to trigger ventilation fans.

(4) Gas composition and LFL:

Gas composition was provided in the test data of cell level UL 9540A report. Table 4-1 lists the release gas composition by volume.

Table 4-1: Gas composition by volume

Gas component		Concentration % (v/v)
Methane	CH_4	4.980
Acetylene	C_2H_2	0.243
Ethylene	C_2H_4	2.458
Ethane	C_2H_6	0.845
Propylene	C_3H_6	1.252
Propane	C_3H_8	0.254
-	C_4 (Total)	0.417
-	C_5 (Total)	0.099
-	C_6 (Total)	0.021
Benzene	C_6H_6	0.012
Dimethyl Carbonate	$C_3H_6O_3$	1.453
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.217
Hydrogen	H_2	51.380
Carbon Monoxide	CO	12.896
Carbon Dioxide	CO_2	23.467
-	Total	100

The LFL of offgas is provided as 7.45%vol by cell level UL 9540A test report.

Assumption 6: Gas composition is as above, LFL of gas is set to be 7.45%vol in this study.

4.2.3.System safety

(1) Ventilation system:

The container is equipped with one exhaust fan, which activates when 4000ppm H_2 or 500ppm CO is detected. The rated flow rate of exhaust fan is 1411 m^3/h (833 CFM), consider flow rate attenuation in actual container, the exhaust fan operates at a flow rate of 967.07 m^3/h (568.86 CFM) for a conservative consideration. (see figure 4-7).

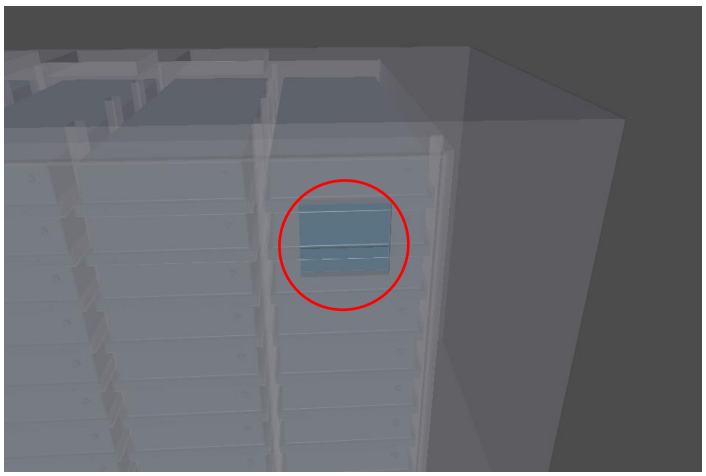


Figure 4-7: Exhaust fans in the container.

Manufacturer name	Type number	Dimension	Flow Rate (Max)
Zeiss Aerodynamics Co., Ltd.	NEO-400-350	400×360mm	833 CFM

Assumption 7: The dispersion simulations are run with the exhaust fans working. The exhaust fan operates at a flow rate of 967.07 m^3/h (568.86 CFM). The activation time will be calculated from the CFD simulations.

(2) Thermal runaway control:

No thermal runaway prevention system is installed.

Assumption 8: Thermal runaway occurs in the module.

(3) Deflagration panels:

No deflagration panel installed on the container.

Assumption 9: No deflagration panel acts in this report.

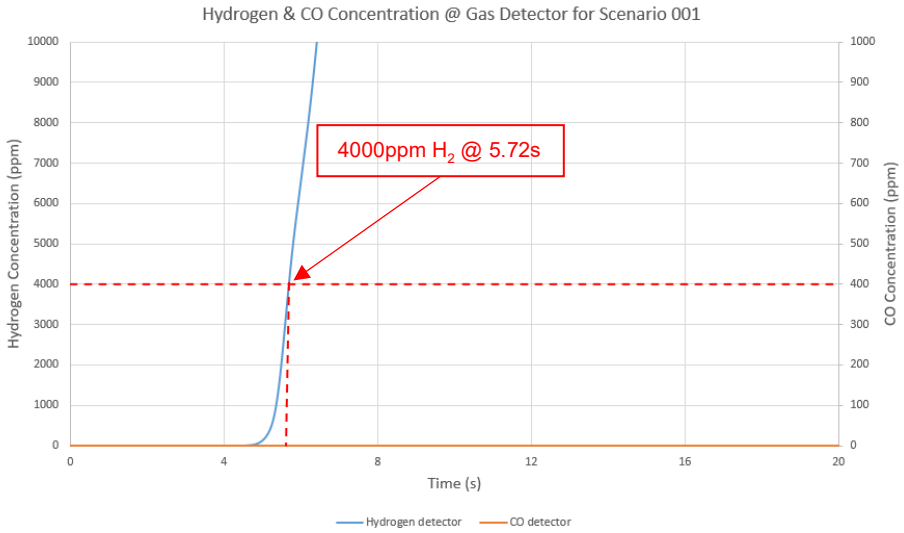
4.3. Simulation Results

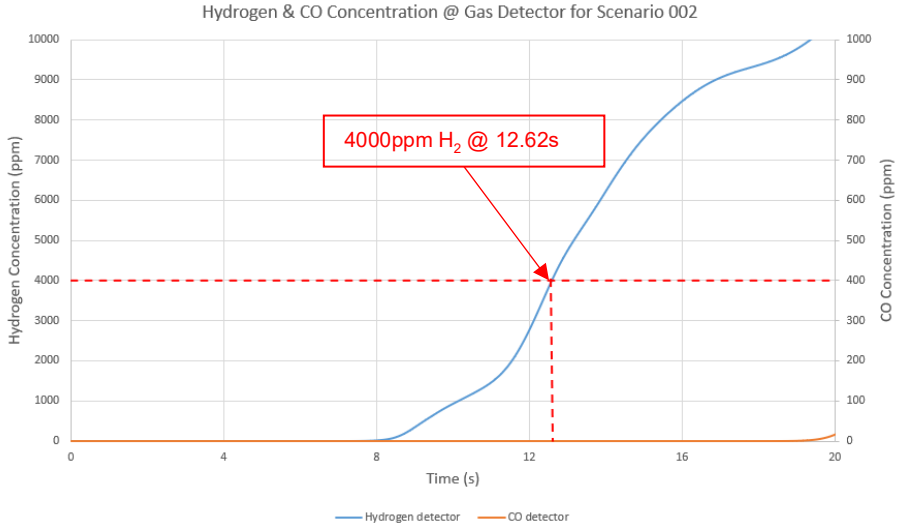
A total of 3 dispersion scenarios were run representing progressively worse-case scenarios based on the assumptions made in the previous sections. The modelling covers 3 leakage positions.

According to the strategy of the ventilation system provided by AESC, the fan will be activated when the detection reaches 4000 ppm of hydrogen or 500 ppm of carbon monoxide. Considering the actual time lag that takes for exhausting fan to reach maximum flow rate, 5s time lag for fan start was added to each scenario after detector activated. Table 4-2 shows the activating time for each scenario. Figure 4-8 shows the hydrogen and carbon monoxide concentrations at the location of the gas detector in each scenario.

Table 4-2: Fan activating time.

Scenario	Leakage Point	Activating time (s)
001	1	10.72
002	2	17.62
003	3	9.90





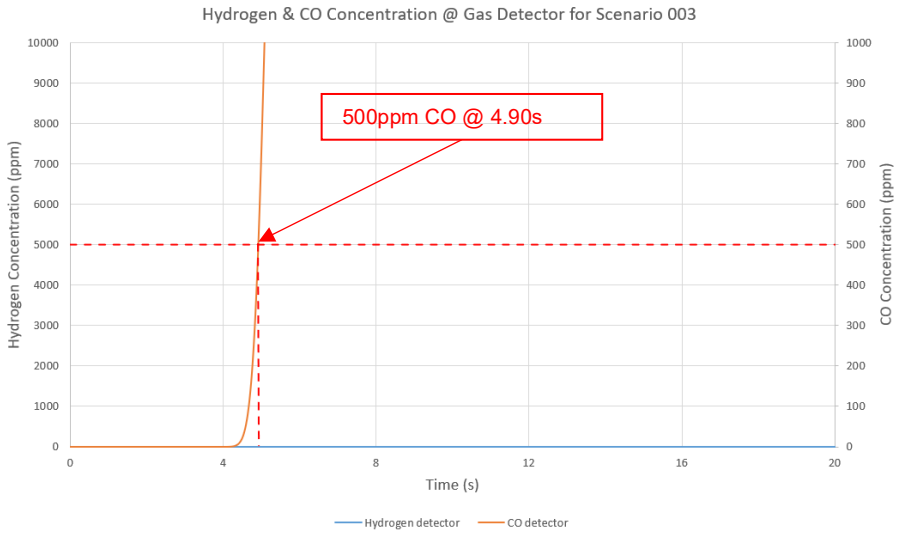


Figure 4-8: Hydrogen & CO concentration at detectors.

Table 4-3 presents a summary of the scenarios and the results from the simulation. The maximum average concentration inside enclosure is presented as the combustible concentration limit according to NFPA 69 Chapter 8.

Table 4-3: Average gas concentration

Scenario	Maximum average gas concentration	
	Vol%	%LFL
001	1.06%	14.23%LFL
002	0.66%	8.86%LFL
003	0.30%	4.03%LFL

Figure 4-9 shows the average gas concentration for each scenario and with the extraction fans activated.

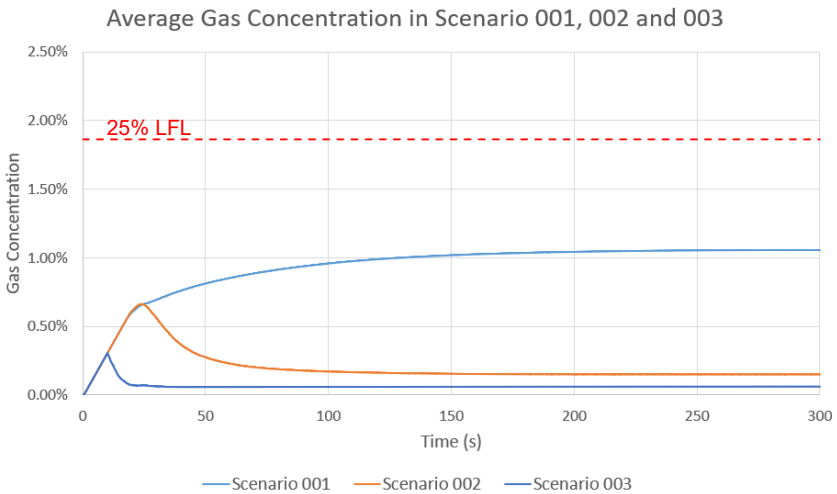
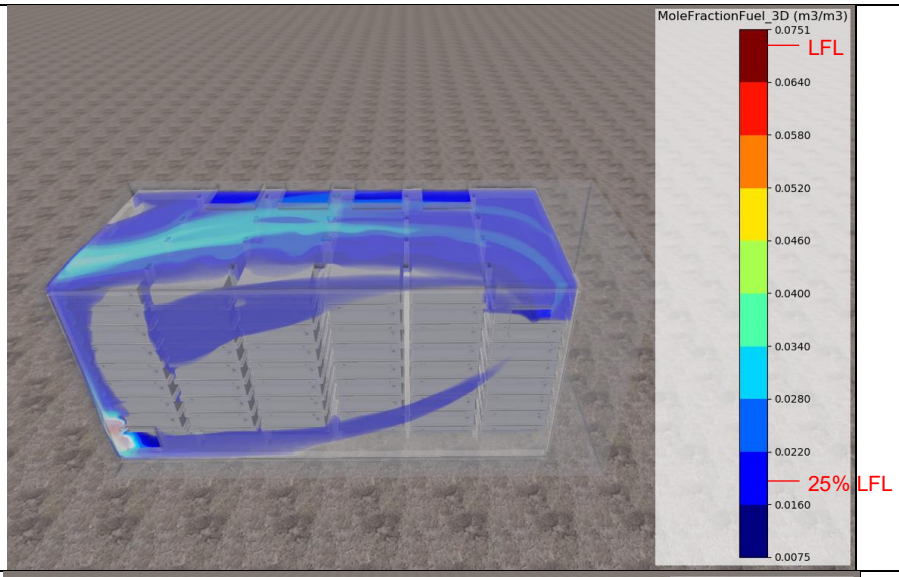
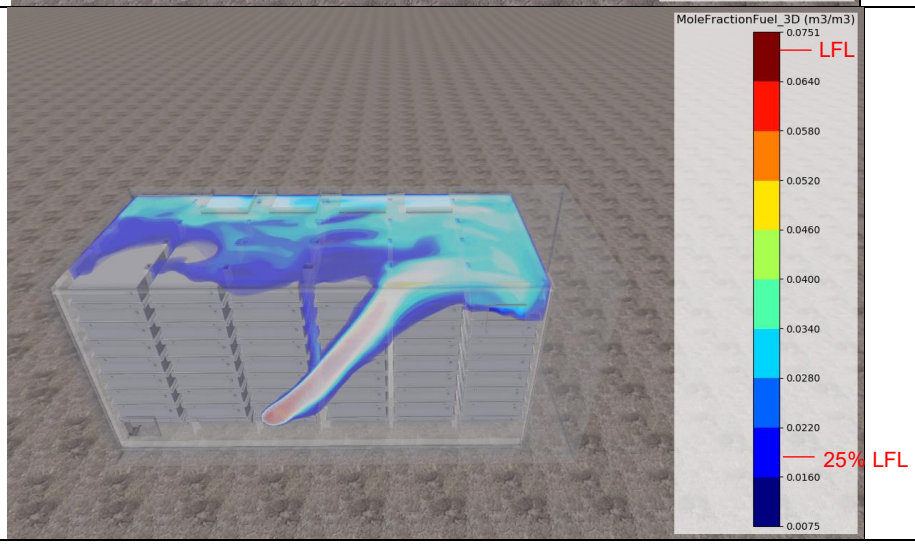


Figure 4-9: Average gas concentration plot.

From the simulations we observe:

a) All scenarios with extraction fans activated can reduce flammable volume of gas;
b) All scenarios with extraction fans activated can remain gas average concentration below 25% LFL in the container;
c) There is a small pocket of gas above 25%LFL throughout the process (see Figure 4-10).

Figure 4-10 shows the gas cloud inside container at the time step that the gas average concentration is the maximum for each scenario.

Scenario	Gas cloud @ maximum average concentration
001	
002	

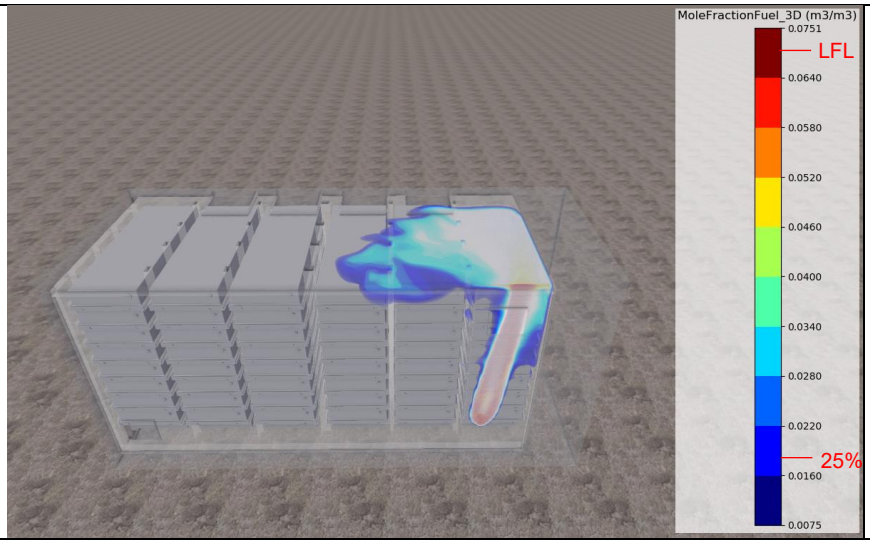
003		

Figure 4-10: Gas cloud at maximum average concentration

4.4. NFPA 69 Analysis

Chapter 8 of NFPA 69 is a section of the standard that discusses deflagration prevention by combustible concentration reduction, which applies to the flammable gas extraction system (via fans and gas detection). Chapter 8 states that the following design and operating requirements must be met to comply with NFPA 69:

The combustible concentration shall be maintained at or below 25 percent of the LFL for all foreseeable variations in operating conditions and material loadings, unless the following conditions apply:

(1) Where continuously monitored and controlled with safety interlocks, the combustible concentration shall be permitted to be maintained at or below 60 percent of the LFL.

(2) Aluminum powder production systems designed and operated in accordance with NFPA 484 shall be permitted to be maintained at or below 50 percent of the LFL.

As shown in Figure 4-7 and 4-8, the extraction fans keep the average concentration of gas in the container below 25% LFL in all scenarios. It is noted that small pockets of gas are seen to exceed 25% LFL during the extraction of the gases.

5. Conclusions

Conclusions for AESC Energy Storage System NFPA 69 CFD Analysis are:

a) Extraction fans could reduce flammable volume of gas;
b) The average gas concentration could be maintained below 25%LFL for each compartment.
c) The combustible concentration of all compartments is within the limit of NFPA 69.

The scenarios in this report follow the situation of cells failure and gas release from test observations outlined in the UL 9540A test report and considered conservative by keeping the gas release rate at constant value for the whole process. The exhausting fan activates when gas concentration at detector reaches 4000 ppm of hydrogen or 500 ppm of carbon monoxide, consider the actual time lag that takes for exhausting fan to reach maximum flow rate, 5s time lag for fan start was added to the scenario.

6. References

(1) NFPA69:2024 Standard on Explosion Prevention Systems

(2) Cell Level UL9540A Report: UL 4791271040

(3) Module Level UL9540A Report: UL 4791861688

(4) Unit Level UL9540A Report: CN25EW8J 001

End of Report

Appendix G

NFPA 68 TEST REPORT

Prüfbericht-Nr.: *Test report no.:*	**CN25WYUH 001**	**Auftrags-Nr.:** *Order no.:*	**326103326**	
Kunden-Referenz-Nr.: *Client reference no.:*	**2526542**	**Auftragsdatum:** *Order date:*	2025-04-07	

Auftraggeber: *Client:*	AESC jiangsu Co., Ltd. No.66 Shentai Road, Shengang Sub-District, Jiangyin City, Wuxi, Jiangsu Province, P.R. China
Prüfgegenstand: *Test item:*	LFP Lithium Iron Phosphate Energy Storage System
Bezeichnung / Typ-Nr.: *Identification / Type no.:*	HE-L5030A
Auftrags-Inhalt: *Order content*:	Assessment report
Prüfgrundlage: *Test specification:*	This report provides evaluation and CFD analysis of the deflagration venting system in energy storage system referring to NFPA68:2023.
Wareneingangsdatum: *Date of sample receipt:*	2025-03-20
Prüfmuster-Nr.: *Test sample no:*	Engineering sample
Prüfzeitraum: *Testing period:*	2025-03-21 - 2025-03-31
Ort der Prüfung: *Place of testing:*	TÜV Rheinland (Shanghai) Co., Ltd.
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.
Prüfergebnis*: *Test result*:*	See main report



geprüft von: *tested by:*	Yichen Zhao	**genehmigt von:** *authorized by:*	Simon Wang
Datum: *Date:* 2025.08.04		**Ausstellungsdatum:** *Issue date:* 2025.08.04	
Stellung */ Position:*	**Project Engineer**	**Stellung** */ Position:*	**Authorizer**

Sonstiges */ Other:*

The mentioned models listed above are identical to the original model ENS-LC5030-11, ENS-LC5030-12 in the previous section report CN252P40 001 except for model name, trademark, license holder, adding MSD which leads to a slight increase in total size, and changing the fuse type to meet the new MSD. The test data refers to previous section report CN252P40 001. See following pages for details.

Zustand des Prüfgegenstandes bei Anlieferung: Prüfmuster vollständig und unbeschädigt
Condition of the test item at delivery: *Test item complete and undamaged*

* Legende:	P(ass) = entspricht o.g. Prüfgrundlage(n)	F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
* *Legend:*	*P(ass) = passed a.m. test specification(s)*	*F(ail) = failed a.m. test specification(s)*	*N/A = not applicable*	*N/T = not tested*

Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht auszugsweise vervielfältigt werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens.
This test report only relates to the above mentioned test sample as. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.
V05

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1. General Production Information:

1.1. Cell

The product information and parameters are provided by the client as below.

Manufacturer .....:	AESC jiangsu Co., Ltd.	
Model number.....:	HC-L315A	
Chemistry .....:	LiFePO4	
Physical configuration .....:	Prismatic	
Electrical rating .....:	Rated capacity:	315 Ah
	Nominal voltage:	3.2 V
Standard charge method .....:	Charge power:	504 W
	End of charge voltage:	3.65 V
Standard discharge method .....:	Discharge power:	504 W
	End of discharge voltage:	2.5 V

1.2. Module

The product information and parameters are provided by the client as below.

Manufacturer name :		AESC jiangsu Co., Ltd.
Model number :		HP-L630B
Physical configuration :		Nonmetallic enclosure
		Weight: 670±10 kg
		Cells in series/parallel: 2P52S
Cooling method :		Liquid cooling
Electrical rating :		Rated capacity: 630 Ah
		Nominal voltage: 166.4V
Standard charge method.....:	Charge current :	315 A
	End of charge voltage :	189.8 V
	Charge temperature range:	0~55 °C
Standard discharge method.....:	Discharge current :	315 A
	End of discharge voltage :	130 V
	Discharge temperature range:	-30~55 °C
External dimensions (mm) :		2214.6±5*794±5*246.2±5mm

1.3. Energy Storage System

The product information and parameters are provided by the client as below.

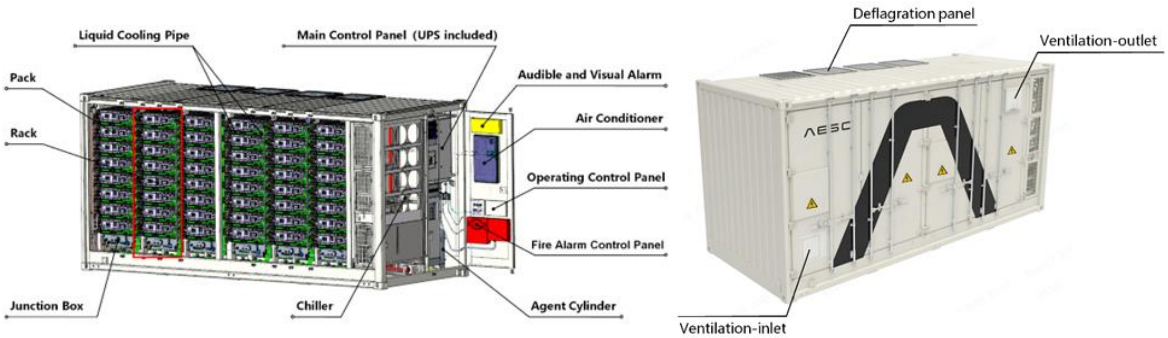
	Lithium Ion Battery System
Type/model	HE-L5030A
Structure	((2P52S)8S)6P
Rated Energy [kWh]	5030
Battery Type	$LiFePO_4$
Rated Capacity [Ah]	3780
Maximum continuous charging/discharging power [kW]	2515.968
Peak current in charge [A]	2130
Peak current in discharge [A]	2400
Nominal Voltage [Vdc]	1331.2
Upper limit charging voltage [Vdc]	1497.6
Discharging cut-off voltage [Vdc]	1123.2
Charge range of ambient temperature [°C]	-30 to 55*
Discharge range of ambient temperature [°C]	-30 to 55*
AC auxiliary power input	277/480Vac，3W+N+PE, 65A, 60Hz
Weight [kg]	Max 43000
Overall size: (L*W*H) [mm]:	6058*2438*2896
Enclosure Protection (IP)	IP55
Cooling Type	Liquid cooling and heating for battery Forced air cooling for distribution room
Protective class	I
Altitude [m]	Below 2000

Note*: The system will not start charging until cell min temperature > 0°C heating by liquid chiller which controlled by LEMS.

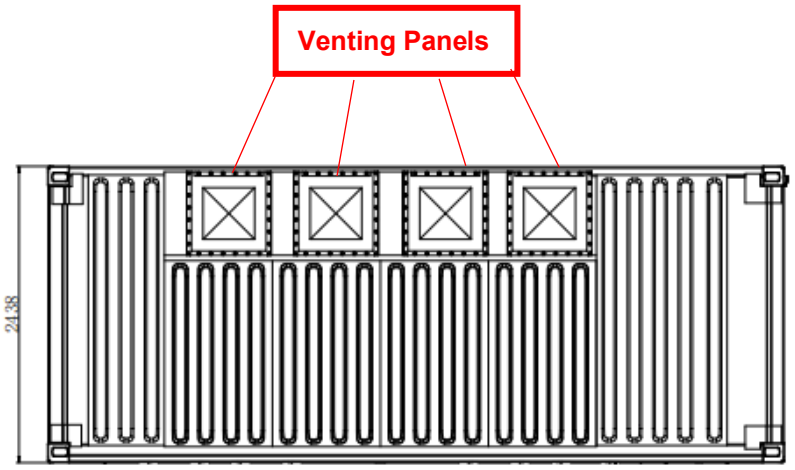
2. Product Description:

2.1. General Description

1- The EUT covered by this report is DC system for energy storage, which mainly consists of 6 battery racks in parallel connection, 1 liquid chiller, 1 air conditioning, fire protection, communication device and some auxiliary power supply components integrated in 1 container.
2- The battery rack is liquid cooling type, each rack consists of 8 battery packs and 1 control box in series connection. Each battery pack mainly consists of 104 cells structured with 52S2P, 1 MSD, 1 slave BMU and related connection parts. The slave BMU used for measuring and collecting the cell parameters of each pack and uploading to BCU in control box. The control box mainly consists of protective device such as relay, hall, fuse, circuit breaker and master BCU function as the control unit for the battery system.
3- The input auxiliary power source system should be an TN-C-S type in end-installation specifed by the manufacture.
4- Suitable external overcurrent device and manual disconnect switch should be provided for both positive and negative of main battery circuit in end-installation.
5- The insulation between the hazardous voltage circuit and the grounded metal enclosure is basic insulation. And the insulation between the hazardous voltage circuit and communication circuit is reinforced insulation.
6- The battery system has overcharge, over-discharge, over current and short-circuits proof circuit. The electronic circuits and software controls for the battery system replied upon protective functions of the battery management system have been evaluated in accordance with IEC 60730-1 Annex H.
7- The EUT is outdoor type with IP55 degree, PD2 was evaluated for inside and PD3 for outside.
8- Overvoltage Category II was evaluated for the battery system, the battery system should isolate from an Overvoltage category III supply source to prevents transient overvoltage conditions in end-installation.
9- Suitable fire barriers or enclosure which comply with NFPA 855 should be provided and evaluated in the end-installation.
10- See below layout for detail structure.



2.2. Deflagration Venting Layout



3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

Clause	Requirement – Test	Result – Remark	Verdict
Chapter 6	**Fundamentals of Venting of Deflagrations**		--
6.1	**Basic Concepts.**		--
6.1.1	The deflagration index, K, shall be computed from the maximum rate of pressure rise attained by combustion in a closed vessel with volume, V, and shall be defined by the following equation [6.1.1]		N/A
6.1.2	For dusts, K_{St} and P_{max} shall be determined in approximately spherical calibrated test vessels of at least 20 L capacity per ASTM E1226, Standard Test Method for Explosibility of Dust Clouds.		N/A
6.1.2.1	It shall be permitted to determine K_{St} and P_{max} per ISO 6184-1, Explosion Protection Systems — Part 1: Determination of Explosion Indices of Combustible Dusts in Air.		N/A
6.1.2.2	The owner/user shall be permitted to test the dust with moisture content and particle size that deviates from the recommended conditions established by the method described in 6.1.2 or 6.1.2.1, provided a documented assessment acceptable to the authority having jurisdiction has been performed prior to using these K_{St} and P_{max} values to determine vent sizing.		N/A
6.1.2.3	For aluminum, hafnium, magnesium, tantalum, titanium, zirconium, and similar alloys or mixtures with adiabatic flame temperature higher than 3300°C, unless K_{St} and P_{max} are determined in nominal 1 m3 or larger calibrated test vessels, the K_{St} value shall be multiplied by a factor of 2 for application of the design methods.		N/A
6.1.3	For gases, P_{max} shall be determined in approximately spherical calibrated test vessels of at least 5 L (1.3 gal) capacity with initially quiescent mixture with low energy ignition source (i.e., less than 100 J).	See cell level UL9540A test report.	P
6.2	**Mixtures.**		--
6.2.1	Gas Mixtures.		P
6.2.1.1	Where the hazard consists of a flammable gas mixture, the vent size shall be based on the fundamental burning velocity of the mixture.	See clause 4 and cell level UL9540A test report.	P
6.2.1.2	Where the gas mixture composition is not certain, the vent size shall be based on the component having the highest fundamental burning velocity.		N/A
6.2.2	Dust Mixtures		N/A
6.2.2.1	Where the hazard consists of a dust mixture, the vent size shall be based on the K_{St} and P_{max} of the mixture.		N/A

3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

Clause	Requirement – Test	Result – Remark	Verdict
6.2.2.2	Where the dust mixture composition is not certain, the vent size shall be based on the highest K_{St} of all components and the highest P_{max} of all components.		N/A
6.2.3	Hybrid Mixtures		N/A
6.2.3.1	For hybrid mixtures, the vent size shall be based on the equivalent mixture K_{St} as determined by test.		N/A
6.2.3.2	Where test data are not available for hybrid mixtures with gases that have combustion characteristics similar to those of propane (fundamental burning velocity ≤1.3 times that of propane) and St-1 and St-2 dusts, the design shall be permitted to be based upon P_{max} = 10 bar-g and K_{St} = 500 bar-m/s.		N/A
6.2.4	Foams of Combustible Liquids. Design of deflagration venting for foams of combustible liquids shall be based on tests performed on the specific foam.		N/A
6.3	**Enclosure Design and Support.**		--
6.3.1	Enclosure Design Pressure Selection Criteria.		P
6.3.1.1	P_{red} shall not exceed two-thirds of the ultimate strength for the vented enclosure, provided deformation of the equipment can be tolerated.		N/A
6.3.1.2	Where deformation cannot be tolerated, P_{red} shall not exceed two-thirds of the yield strength for the vented enclosure.		N/A
6.3.1.3	For enclosures designed using the ASME Boiler and Pressure Vessel Code or similar codes, the maximum allowable working pressure, herein designated as P_{mawp}, shall be determined by calculation.		N/A
6.3.1.4	Ductile design considerations shall be used for materials subject to brittle failure, such as cast iron.		N/A
6.3.2	Venting shall be sufficient to prevent the maximum pressure that develops within the enclosure, P_{red}, from exceeding the enclosure strength, Pes, including the dynamic effect of the rate of pressure rise, as expressed by a dynamic load factor (DLF) [6.3.2]	See clause 4.	P
6.3.2.1	In the absence of detailed structural response analysis, it shall be permitted to assume a worst-case value of DLF = 1.5 and design based on the weakest structural element of the enclosure.		N/A
6.3.2.2	It shall be permitted to modify the value of DLF based on a documented analysis of the vented explosion pressure profile and enclosure structural response.	AESC has provided dynamic structural analysis based on modeling, see Reference (5)	P
6.3.3	All structural elements and supports shall be included in the design calculations.		P

3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

Clause	Requirement – Test	Result – Remark	Verdict
6.3.3.1	The weakest structural element, as well as any equipment or other devices that can be supported by structural elements, shall be identified.		P
6.3.3.2	Where designing an enclosure to prevent catastrophic failure while still allowing permanent deformation, the normal dead and live loads shall not be relied on to provide restraint.		P
6.3.3.3	Structural members shall be designed to support the total load.		P
6.3.3.4	Doors, windows, ducts, or other openings in walls that are intended to be pressure resistant shall also be designed to withstand P_{red}.		P
6.3.4	Relieving Walls or Roof.		N/A
6.3.5	Enclosure Support Criteria.	Eliminated according to 6.3.5.4.1	P
6.3.5.4.1	The calculation of reaction forces on the enclosure shall be permitted to be eliminated when all of the following conditions are satisfied: (1) Vent panels are of the rupture diaphragm type. (2) Vent panels are located at opposing positions on the enclosure. (3) The P_{stat} of each vent panel is equal and less than or equal to 0.1 bar-g. (4) Vent panels are of equal area.		P
6.4	**Enclosure Length-to-Diameter Ratio and Vent Variables.**		--
6.4.1	The L/D of an elongated enclosure shall be determined based upon the general shape of the enclosure, the location of the vent, the shape of any hopper extensions, and the farthest distance from the vent at which the deflagration could be initiated.		N/A
6.4.2	For enclosures that can be vented at more than one point along the major axis, the vents shall be permitted to be distributed along the major axis and sized based on the length to diameter (L/D) between vents.		N/A
6.4.2.1	The maximum effective vent area at any point along the major axis shall be the enclosure cross section.		N/A
6.4.3	L/D of Elongated Enclosures.		N/A
6.4.3.1	The L/D of an elongated enclosure shall be determined based upon the general shape of the enclosure, the location of the vent, the shape of any hopper extensions, and the farthest distance from the vent at which the deflagration could be initiated.		N/A

3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

Clause	Requirement – Test	Result – Remark	Verdict
6.4.3.2	The maximum flame length along which the flame can travel, H, shall be determined based on the maximum distance, taken along the central axis, from the farthest end of the enclosure to the opposite end of the vent.		N/A
6.4.3.2.1	When multiple vents are provided, a single value of H, and L/D, shall be permitted to be determined for the enclosure based on the farthest vent.		N/A
6.4.3.2.2	When multiple vents are located along the central axis, the value of H, and L/D, shall be permitted to be determined for each section using the maximum distance from the closest end of one vent to the opposite end of the next vent.		N/A
6.4.3.3	The effective volume of the enclosure, V_{eff}, shall be determined based on the volume of that part of the enclosure through which the flame can pass as it travels along the maximum flame length, H.		N/A
6.4.3.3.1	Partial volume (see Section 8.4) shall not be considered in the determination of effective volume per this section.		N/A
6.4.3.3.2	When multiple vents are provided, a single value of V_{eff} shall be permitted to be determined for the enclosure based upon the farthest vent.		N/A
6.4.3.3.3	When multiple vents are located along the central axis, V_{eff} shall be permitted to be determined for each section using the maximum distance from the closest end of one vent to the opposite end of the next vent.		N/A
6.4.3.3.4	When V_{eff} is less than the total volume of the enclosure, only those vents located within the effective volume shall be considered as providing venting for the event.		N/A
6.4.3.4	It shall be permitted to conservatively determine both H and V_{eff}, or H alone, but not V_{eff} alone, based on the total enclosure, irrespective of vent location.		N/A
6.4.3.5	The effective area, A_{eff}, shall be determined by dividing V_{eff} by H		N/A
6.4.3.6	The effective hydraulic diameter, D_{he}, for the enclosure shall be determined based on the general shape of the enclosure taken normal to the central axis [6.4.3.6]		N/A
6.4.3.6.1	Where the enclosure and any hopper extension are generally cylindrical, the perimeter, p, shall be permitted to be determined based on a circular cross section, given the following [6.4.3.6.1]		N/A
6.4.3.6.2	Where the enclosure and any hopper extension are generally rectangular or square, and the aspect ratio of the largest cross section is between 1 and 1.2, the perimeter shall be permitted to be determined based on a square cross section, given the following [6.4.3.6.2]		N/A

3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

Clause	Requirement – Test	Result – Remark	Verdict
6.4.3.6.3	Where the enclosure and any hopper extension are generally rectangular, and the aspect ratio, R, of the largest cross section is greater than or equal to 1.2, the perimeter shall be permitted to be determined based on the aspect ratio of the largest cross section, given the following [6.4.3.6.3]		N/A
6.4.3.7	L/D for use in this standard shall be set equal to H/D_{he}.		N/A
6.4.4	The vent areas shall be permitted to be reduced from those specified in Chapters 7 and 8 if large-scale tests show that the resulting damage is acceptable to the user and the authority having jurisdiction.		N/A
6.4.5	The owner/user shall be permitted to install vents that are larger in area, are lower in density, or relieve at lower pressure than the minimum requirements determined from application of Chapter 7 or Chapter 8, as appropriate.		N/A
6.5	**Vent Closure Operation.**		--
6.5.1	The vent opening shall be free and clear.		N/A
6.5.2	Vent closure operation shall not be hindered by deposits of snow, ice, paint, corrosion, or debris, or by the buildup of deposits on their inside surfaces.		N/A
6.5.2.1	The materials that are used shall be chosen to minimize corrosion from process conditions within the enclosure and from ambient conditions on the nonprocess side.		N/A
6.5.2.2	Clear space shall be maintained on both sides of a vent to enable operation without restriction and without impeding a free flow through the vent.		N/A
6.5.2.3	To prevent snow and ice accumulation, where the potential exists, and to prevent entry of rainwater and debris, the vent or vent duct exit shall not be installed in the horizontal position, unless any of the alternative methods in 6.5.2.3.1 are followed.		N/A
6.5.2.3.1	Any of the following alternative methods of protection for horizontal vent or vent duct exits shall be permitted: (1) Fixed rain hats where Pred effects on vent area are included in accordance with Section 8.5 and restraint design includes maximum force from Pred applied over the area (2) Weather covers mounted at an angle sufficient to shed snow, with restraints designed and tested to prevent the cover from becoming a free projectile, where inertia effects of the additional weather cover mass and P_{stat} of the cover are included (3) Deicing provisions such as a heated vent closure		N/A

3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

Clause	Requirement – Test	Result – Remark	Verdict
6.5.3	Restraining devices shall not impede the operation of the vent or vent closure device. (See Chapter 10.)		N/A
6.5.4	A vent closure shall release at its P_{stat} or within a pressure range specified by the vent closure manufacturer.		P
6.5.5	A vent closure shall reliably withstand pressure fluctuations that are below $P_{stat.}$		P
6.5.6	A vent closure shall withstand vibration or other mechanical forces to which it can be subjected.		P
6.5.7	P_{stat}, including the manufacturer's negative tolerance, shall be greater than the anticipated loading equivalent to the local design wind speed such that wind load will not cause the vent to open.		N/A
6.5.7.1	The area calculation shall be performed using the nominal value of P_{stat}.		P
6.5.8	P_{stat}, including the manufacturer's positive tolerance, shall be less than the intended P_{red}.		P
6.5.8.1	The area calculation shall be performed using the nominal value of P_{stat}.		P
6.5.9	Vent closures shall be maintained in accordance with Chapter 11		N/A
6.6	**Consequences of a Deflagration.**		--
6.6.1	The material discharged from an enclosure during the venting of a deflagration shall be directed outside to a safe location.		P
6.6.2	Property damage and injury to personnel due to material ejection during venting shall be minimized or avoided by locating vented equipment outside of buildings and away from normally occupied areas. (See Sections 7.6 and 8.9 for gases and dusts, respectively.)		N/A
6.6.2.1	Deflagration vents shall not be located in positions closer to air intakes than the distances prescribed by the fireball length (see Sections 7.6 and 8.9).	See clause 4.	P
6.6.2.2	Deflagration vents shall be permitted to be located closer to buildings and normally occupied areas than the distances determined by Section 7.6 or Section 8.9, provided a documented risk assessment acceptable to the authority having jurisdiction has been performed.		N/A
6.6.2.3	Where a deflector is provided in accordance with 6.6.2.4 and 6.6.2.5, it shall be permitted to reduce the axial (front-centerline) hazard distance to 50 percent of the value calculated in 7.6.1 or 8.9.2. This method shall not be used to reduce the radial hazard distance as defined in 7.6.2 and 8.9.2.2.		N/A

3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

Clause	Requirement – Test	Result – Remark	Verdict
6.6.2.4	A deflector design shall meet all of the following criteria: (1) The deflector for a rectangular vent shall be geometrically similar to the vent and sized with a linear scale factor of at least 1.75. For a round vent, the deflector shall be square shaped and at least 1.75 times the vent diameter. (2) The deflector shall be inclined 45 degrees to 60 degrees from the vent axis, as shown in Figure 6.6.2.4. (3) The centerline of the deflector shall be coincident with the vent axis. (4) The distance from the vent opening to the deflector on the vent axis shall be 1.5D, where D is the equivalent diameter of the vent. (5) The deflector plate shall be mounted so as to withstand the force exerted by the vented explosion, calculated as P_{red} times the deflector area. (6) The deflector location shall not interfere with the operation of hinged vent closures.		N/A
6.6.2.5	A deflector to limit flame length shall not be used as follows: (1) For enclosure volume greater than 20 m^3 (706 ft^3) (2) With a tethered or translating vent closure		N/A
6.6.3	Warning signs shall be posted to indicate the location of a vent.		P
6.7	**Effects of Vent Inertia.**		--
6.7.1	Counterweights and insulation added to panels shall be included in the total mass.		P
6.7.2	A vent closure shall have low mass to minimize inertia, thereby reducing opening time.		N/A
6.7.3	If the total mass of a closure divided by the area of the vent opening does not exceed the panel densities calculated by Equation 7.3.2 and Equation 8.3.2 (for gas and dust, respectively), all vent area correlations presented in this standard shall be permitted to be used without correction.		N/A
6.7.4	Hinged closures shall be permitted to be used, provided the following conditions are met: (1) There are no obstructions in the path of the closure that prevent it from opening. (2) Operation of the closure is not restrained by corrosion, sticky process materials, or paint.		P
6.8	**Fireball Dimensions.**		P

3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

Clause	Requirement – Test	Result – Remark	Verdict
	Measures shall be taken to reduce the risk to personnel and equipment from the effects of fireball temperature and pressure.		
6.8.1	A documented risk assessment shall be permitted to be used to reduce the hazard distances calculated in 6.8.2, 6.8.3, and 6.8.7.		P
6.8.2	Gas Deflagration Fireball Dimensions.		P
	In the case of gas deflagration venting, L_F, the maximum axial length, width, and height of the fireball hazard zone distributed around the centerline of each vent discharge (see Figure 6.8.2) shall be expressed by Equation 6.8.2:		
6.8.3	Dust Deflagration Fireball Dimensions.		N/A
	In the case of dust deflagration venting, L_F, the maximum axial length, width, and height of the fireball hazard zone distributed around the centerline of each vent discharge (see Figure 6.8.2) shall be expressed by Equation 6.8.3		
6.8.4	Definition of Independent Vents.		N/A
	Independent vents shall meet the requirements in 6.8.4.		
6.8.4.1	For vents located at a single elevation and spaced around the circumference of a cylindrical vessel, the normal to the adjacent vents shall be separated by at least 60 degrees or 4 hydraulic diameters of the largest vent.		N/A
6.8.4.2	Vents located on different sides of a rectangular enclosure shall be considered independent.		N/A
6.8.4.3	For vents located along the axis of a cylindrical vessel or on the same side of a rectangular enclosure, the center of the vents shall be separated by at least four times the hydraulic diameter of the largest vent.		N/A
6.8.4.4	Vents that do not meet the requirements of 6.8.4 are allowed but shall not be counted separately to calculate n in 6.8.2 or 6.8.3.		N/A
6.8.5	Axial distance, calculated by Equation 6.8.3, shall be limited to 60 m [104].		N/A
6.8.6	Axial distance calculated by Equation 6.8.2 shall not be limited for gases.		N/A
6.8.7	Where venting is from a cubic vessel, the $P_{max,a}$ value shall be indicated approximately by Equation 6.8.7 [108]		N/A
6.8.8	For distances longer than $\alpha \times L_F$, the maximum external pressure, $P_{max,r}$, shall be indicated approximately by Equation 6.8.8		N/A

3. Deflagration venting design evaluation referring to Chapter 6 in NFPA68: 2023

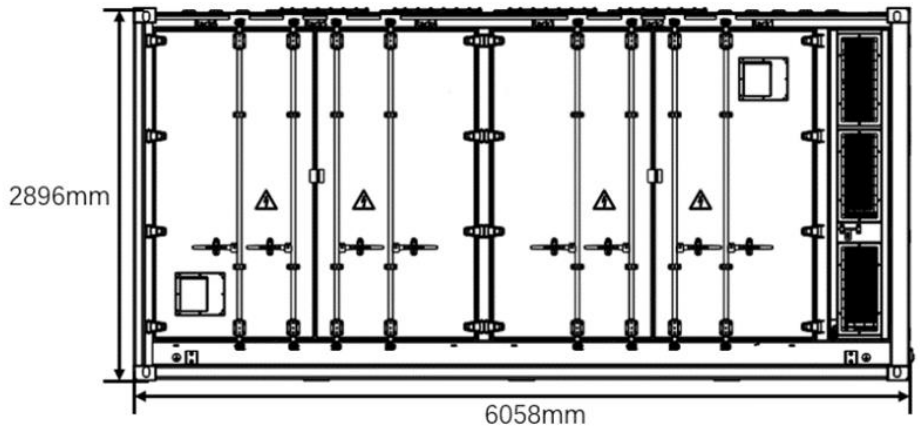
Clause	Requirement – Test	Result – Remark	Verdict
6.8.9	Equation 6.8.3, Equation 6.8.7, and Equation 6.8.8 shall be valid for the following conditions: (1) Enclosure volume: 0.3 $m^3 \leqslant V \leqslant$ 10,000 m^3 (2) Reduced pressure: $P_{red} \leqslant$ 1 bar-g (3) Static activation pressure: $P_{stat} \leqslant$ 0.1 bar-g (4) Deflagration index: $K_{St} \leqslant$ 300 bar-m/s for Equation 6.8.3, $K_{St} \leqslant$ 200 bar-m/s for Equation 6.8.7 and Equation 6.8.8 (5) $P_{max} \leqslant$ 9 bar-g		N/A
6.9	**Effects of Vent Discharge Ducts.**		N/A
6.10	**Venting with Flame Arresting and Particulate Retention.**		N/A

4. CFD analysis of the ventilation system

4.1. Basic Information of the system

The interior and exterior drawings provided by AESC were verified between TUV and AESC before running any calculation.

Figure 4-1 shows an external view of the container and the dimensions from a front and left view. The container measures 6.058*2.438*2.896 m including one battery cabinet, liquid cooling system and AC Auxiliary Interface. The cabinet contains 6 racks, 8 modules in each rack and 104 cells in each module. The overall internal volume of battery cabinet is approximately 31.715 m^3. Subtracting the space filled by racks, modules, and the support structure, the actual open internal volume (efficient volume) is 12.48 m^3.



Front view

Figure 4-1: Geometry of AESC storage system

4.2. Principles and Assumptions

The following safety systems and CFD analysis have been acknowledged for the basis of the study's assumptions. Note that the scenarios and assumptions are run according to cell level, module level and unit level UL9540A test to show progressively worse-case scenarios based on the information available and are considered to be conservative.

4.2.1. Thermal runaway and propagation

(1) Propagation between cells:

The UL 9540A test report of module level and unit level indicate that cell-to-cell propagation could happen within a submodule which contains 13 cells. According to the test report, total 2 cells were failed in both module and unit level test. The test phenomena observed in the UL 9540A report suggest that thermal runaway could potentially involve 4 cells. Therefore, 4 cells failure is considered as the scenario in this study.

Assumption 1: There are 4 cells failure within submodule is considered in this study.

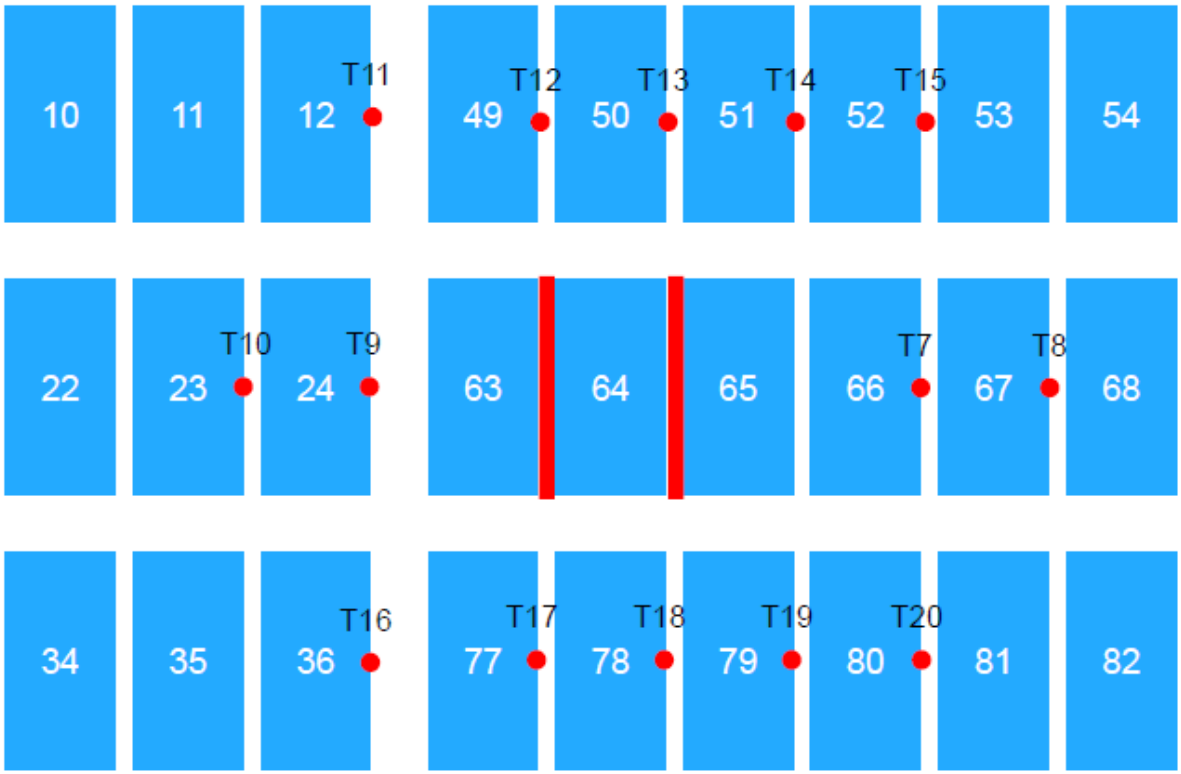


Figure 4-2: Initiating module set up in unit level UL9540A test report.

(2) Propagation between modules:

The UL 9540A test report of unit level did not indicate that it is possible to have propagation between modules.

Assumption 2: There is no module-to-module propagation.

4.2.2. Gas composition and ignition location

(1) Gas cloud:

The data and test phenomenon in cell level, module level and unit level UL 9540A test report provide total amount of released gas. The total volume of flammable gas is calculated to be 641.6 L from cell level test.

In order to perform actual gas cloud explosion, 641.6 L flammable gas would be released into the container in 60s with a constant release rate of 10.693 L/s. While the gas is releasing, concentration and distribution of gas keep changing at different time step, which would generate different explosion pressure inside the container. Q8 is defined as 'the closed volume equivalent cloud at concentration for maximum expansion' and is the recommended variable for determining explosion hazard in enclosed situations. For conservative consideration, the worst explosion hazard would be performed with the gas cloud at highest value of Q8. (See Figure 4-3)

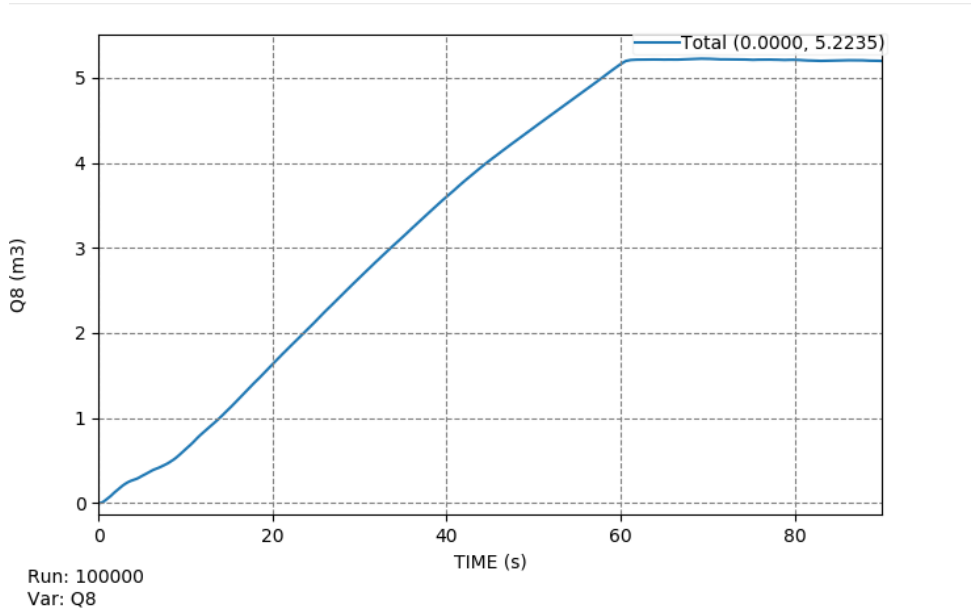


Figure 4-3: Q8 value throughout the dispersion scenario.

It is assumed that gas inside the container forms a gas cloud with stoichiometric concentration and accumulates in the top of the container because of the lower density than air.

Assumption 3: There is 5.22 m^3 flammable gas inside the container and forms a gas cloud with stoichiometry concentration.

(2) Gas composition:

Gas composition was provided in the test data of cell level UL 9540A report. Table 4-1 lists the release gas composition by volume.

Table 4-1: Gas composition by volume

Gas component		Concentration % (v/v)
Methane	CH_4	4.980
Acetylene	C_2H_2	0.243
Ethylene	C_2H_4	2.458
Ethane	C_2H_6	0.845
Propylene	C_3H_6	1.252
Propane	C_3H_8	0.254
n-Butane	C_4 (Total)	0.417
n-Pentane	C_5 (Total)	0.099
n-Hexane	C_6 (Total)	0.021
Benzene	C_6H_6	0.012
Dimethyl Carbonate	$C_3H_6O_3$	1.453
Ethyl Methyl Carbonate	$C_4H_8O_3$	0.217
Hydrogen	H_2	51.380
Carbon Monoxide	CO	12.896
Carbon Dioxide	CO_2	23.467
-	Total	100

Assumption 5: Gas composition is as above.

(3) Ignition location:

The ignition location was selected to be a single point in front of the modules and towards the top. The fire and pressure wave travel further when gas cloud ignited near corner, so top corner ignition was chosen. Since all the wiring and openings to the modules are on the front, it is assumed that the ignition sources are most likely to occur in front of the modules. However, we set another ignition point in the top center of the gas cloud for comparation where the local concentration is the highest in the cabinet (See figure 4-3).

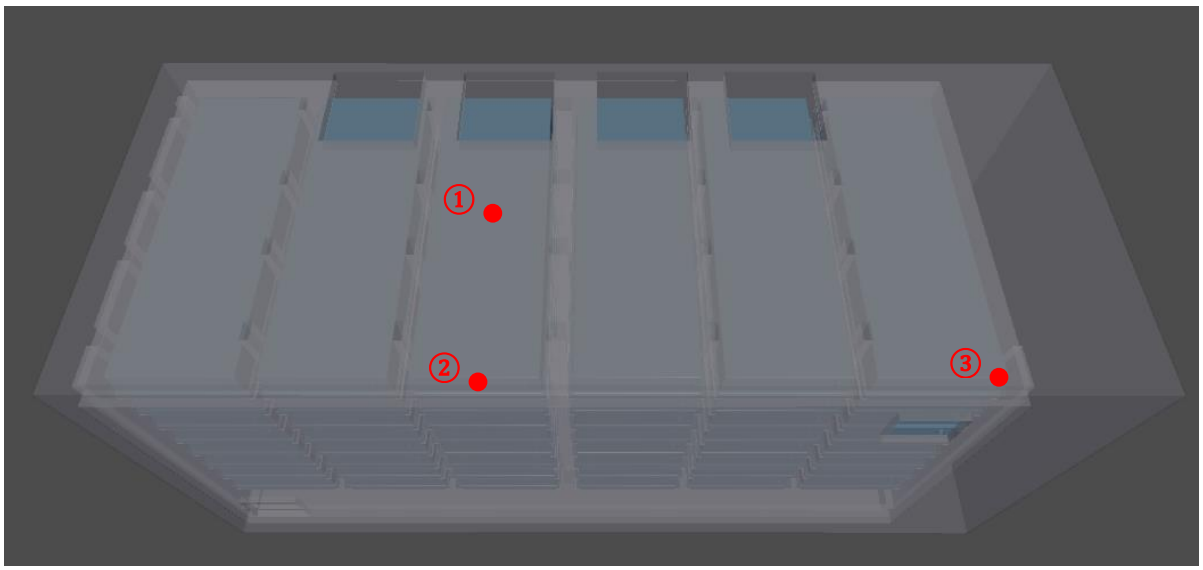


Figure 4-3: Ignition positions

4.2.3.System safety

(1) Ventilation system:

The container is fitted with 1 exhaust fan and passive air inlet louver.

Assumption 6: No ventilation system acts in this report.

(2) Thermal runaway control:

No thermal runaway prevention system is installed.

Assumption 7: Thermal runaway occurs in the module.

(3) Deflagration panels:

Four deflagration panels are installed on the container, 0.610*0.610 m effective area for each panel and act at 0.1 bar pressure difference.

Manufacturer name	Type number	Dimension	Trigger pressure
STIF (Suzhou) Components Co., Ltd	ARC-VENT INS-20 610×610	610*610mm	0.1 bar

Assumption 8: Deflagration panels act as above.

4.3. Simulation Results

A total of three gas explosion scenarios were run representing progressively worse-case scenarios based on the assumptions made in the previous sections. The modelling covered the failure of 4 cells with different ignition position.

Table 4-2 presents a summary of the scenarios and the results from the simulation. The maximum over pressure inside enclosure is presented according to NFPA 68.

Table 4-2: Maximum wall pressure inside enclosure

Scenario	Ignite location	Maximum pressure (bar-g)
001	bottom	0.417
002	bottom	0.230
003	bottom	0.307

(1) Pressure curve

Figure 4-4 to 4-6 shows the wall pressure for each scenario.

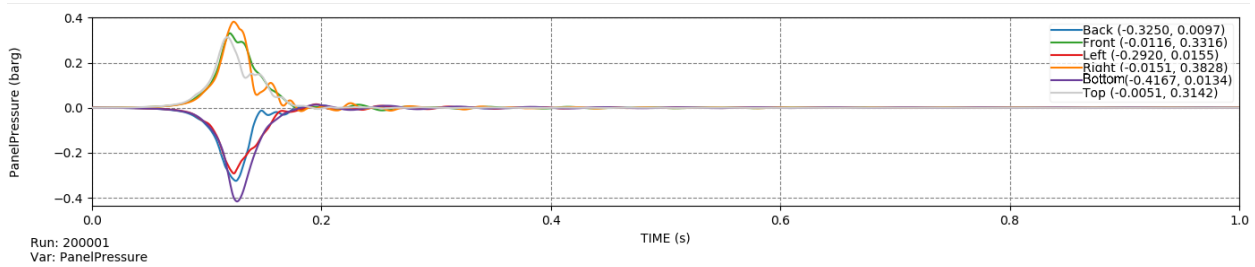


Figure 4-4: Top center ignition pressure curve.

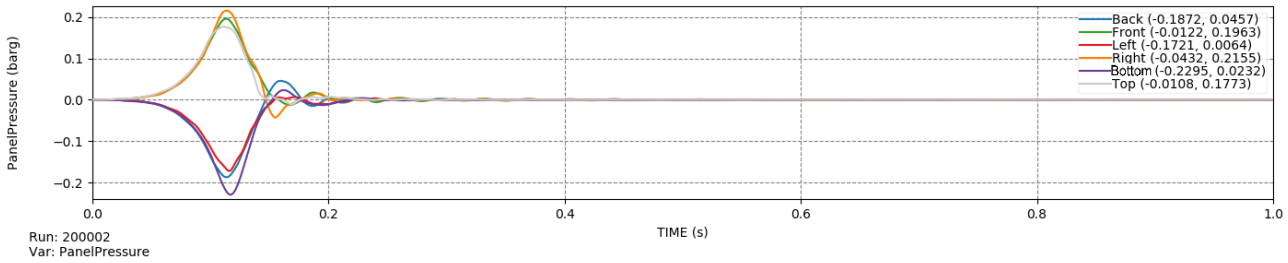


Figure 4-5: Top front center ignition pressure curve.

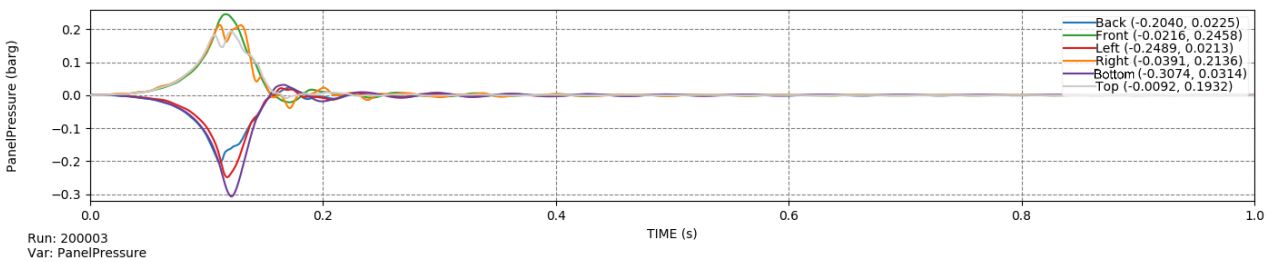


Figure 4-6: Top front corner ignition pressure curve.

Figure 4-7 and 4-9 shows the maximum pressure outside cabinet.

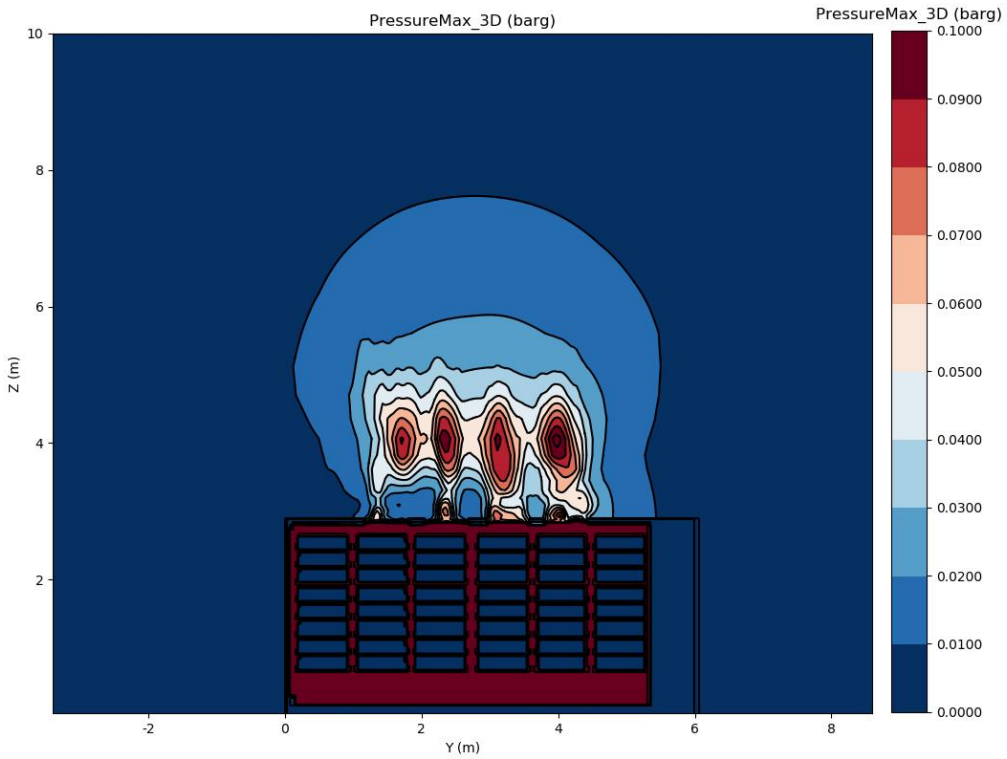


Figure 4-7: Top center ignition pressure map (outside).

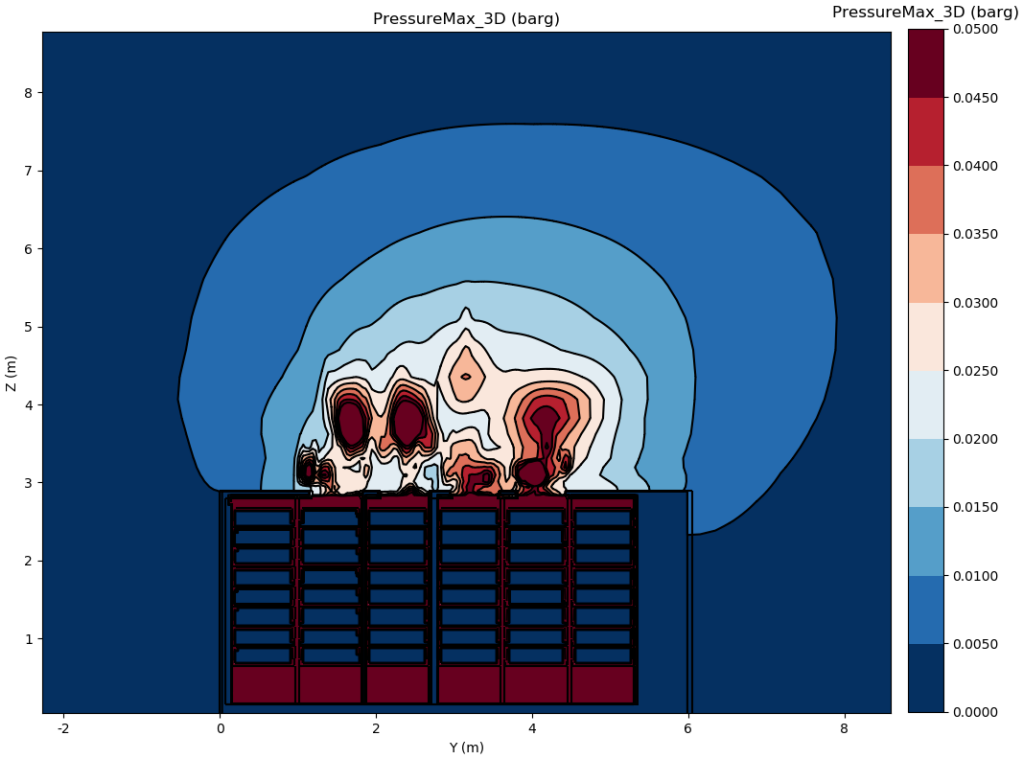


Figure 4-8: Top front center ignition pressure map (outside).

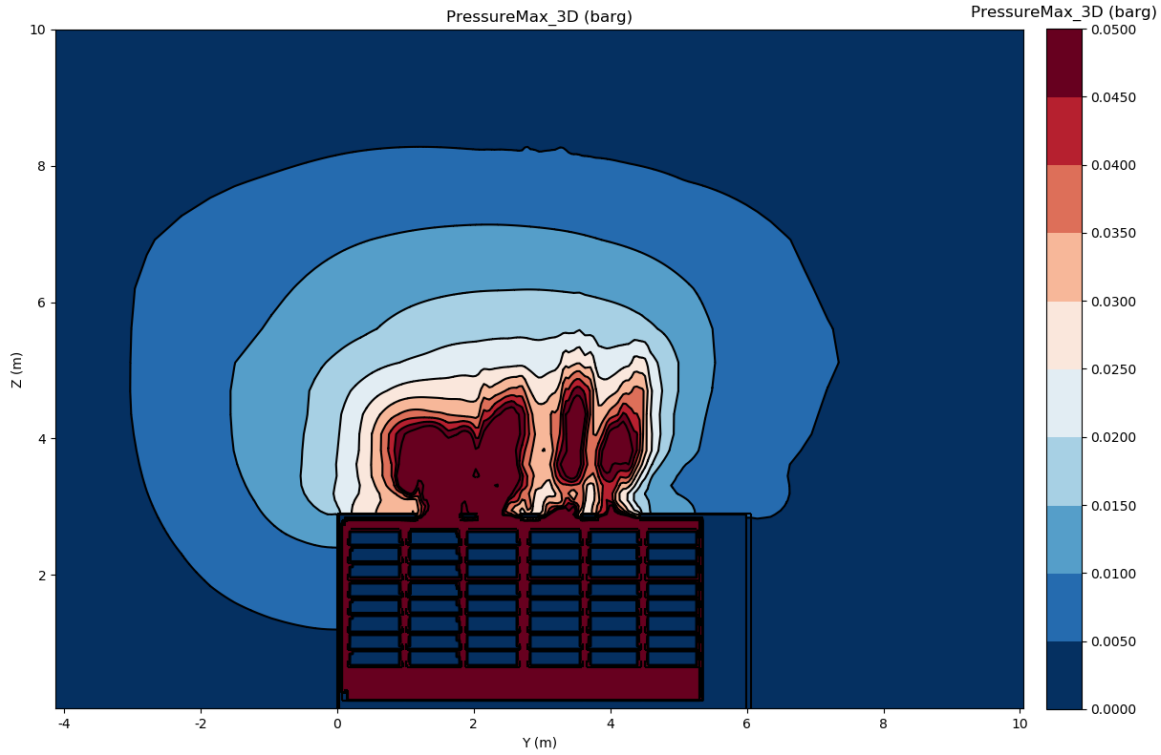


Figure 4-9: Top front corner ignition pressure map (outside).

(3) Temperature map

Figure 4-10 and 4-12 shows the temperature map.

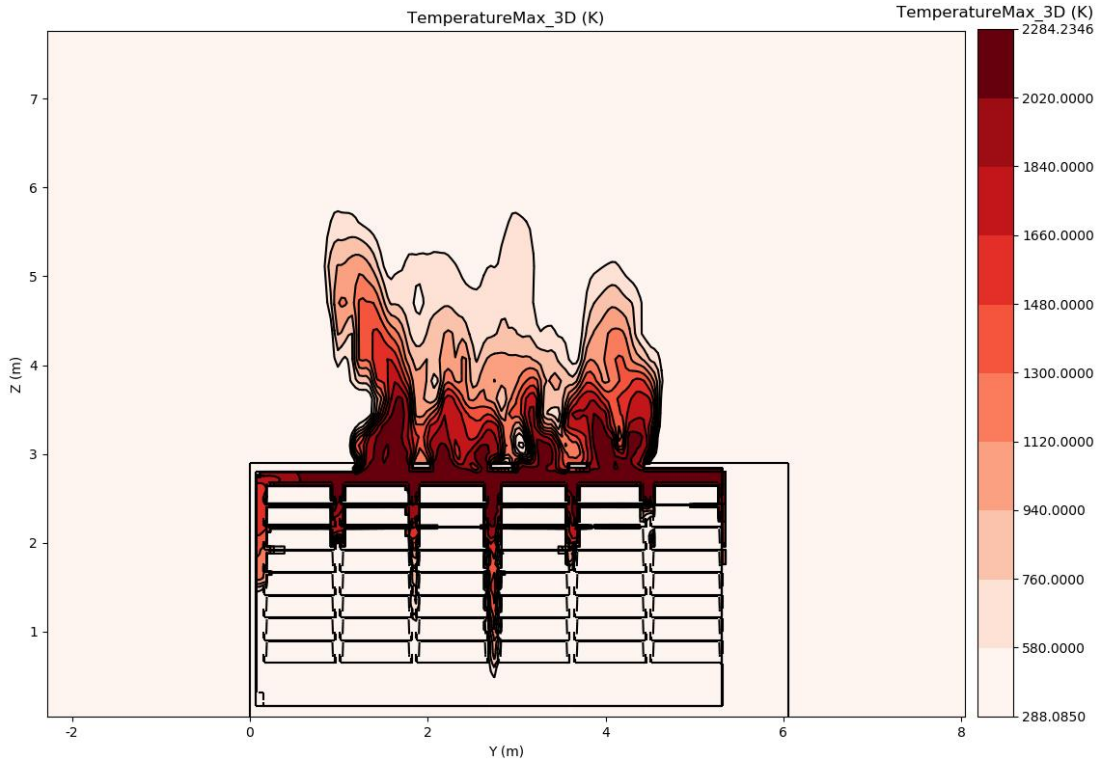


Figure 4-10: Top center ignition temperature map (outside).

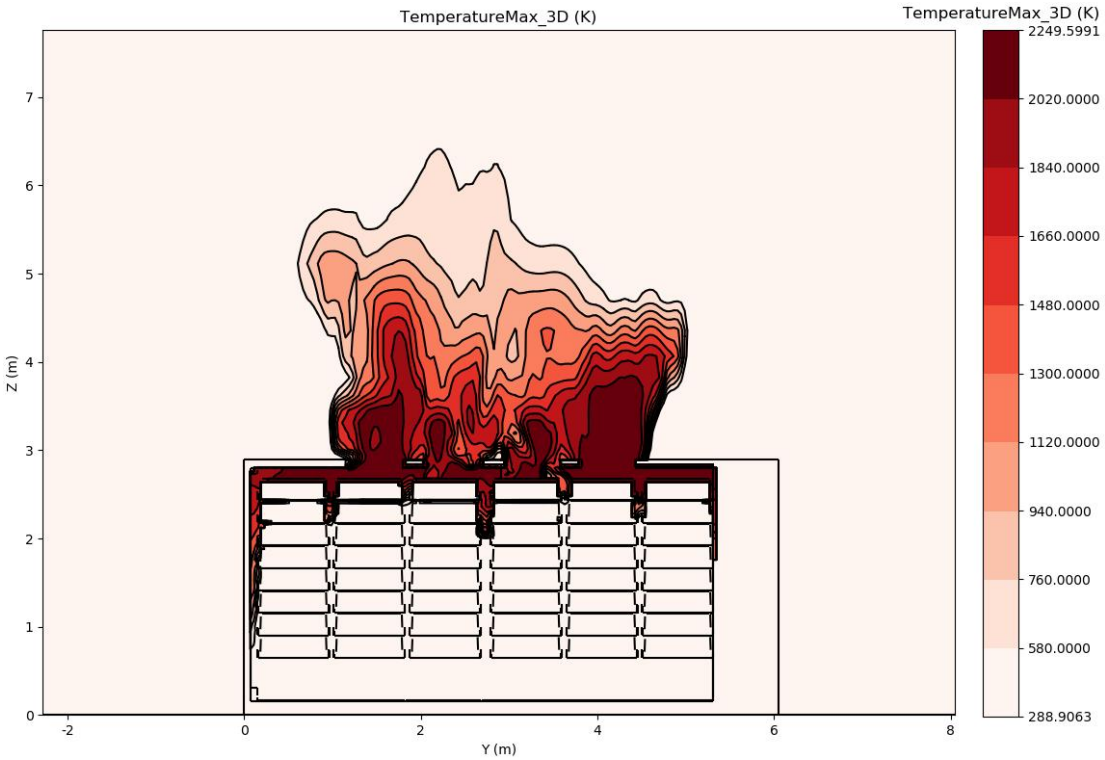


Figure 4-11: Top front center ignition temperature map (outside).

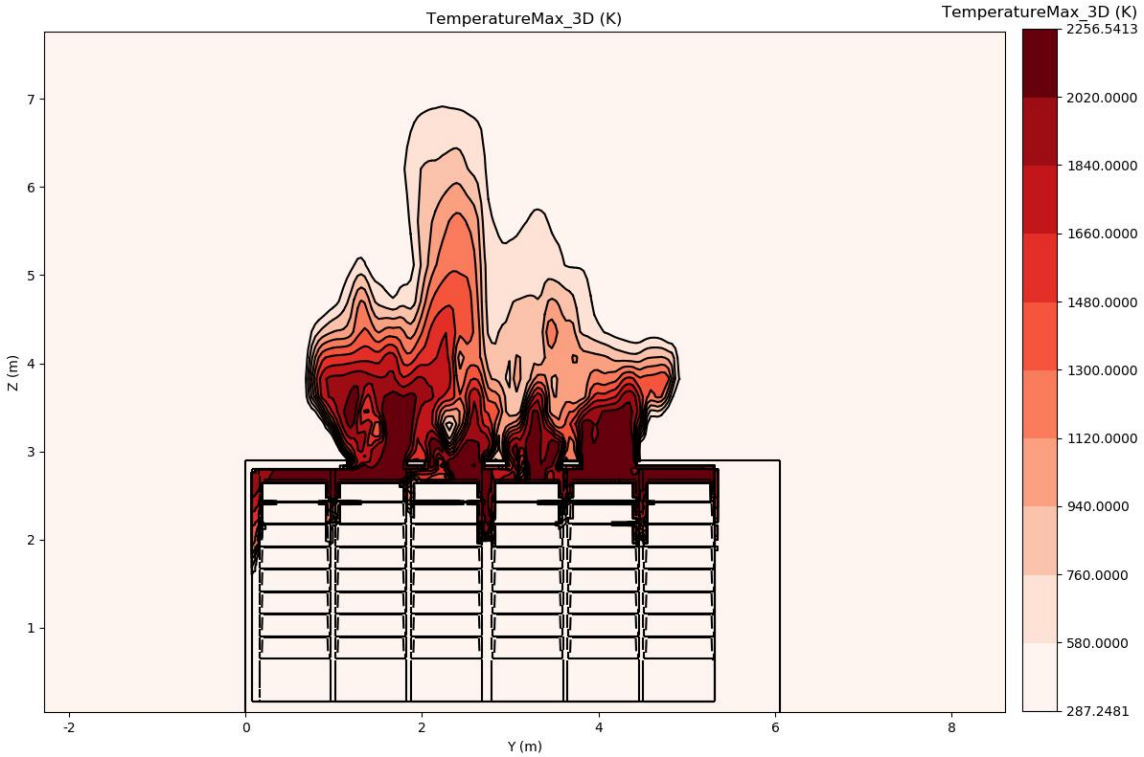


Figure 4-12: Top front corner ignition temperature map (outside).

5. Conclusions

This CFD model has shown that the predicted maximum average pressure on the wall is 0.417 bar-g. The enclosure mechanical analyze report is provided by AESC, and AESC is responsible for the enclosure mechanical strength. The enclosure mechanical analysis report indicates that the enclosure could maintain at least 0.70 bar-g pressure. According to the CFD result, the enclosure could handle the deflagrating pressure and meet the requirement of NFPA 68.

6. References

(1) NFPA68:2023 Standard on Explosion Protection by Deflagration Venting

(2) Cell Level UL9540A Report: UL 4791271040

(3) Module Level UL9540A Report: UL 4791861688

(4) Unit Level UL9540A Report: CN25EW8J 001

(5) Deflagration Simulation of AESC's Energy Storage Container

End of Report

Appendix H

ENCLOSURE LEVEL HMA

AESC

Emergency Response Guide for Lithium Battery Energy Storage

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Please use the latest version of the applicable specifications. Figures of this documentation do not necessarily reflect the exact scope of supply. The actual scope of supply is subject to technical alterations at any time.

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Version History

Version	Date	Designer	Reviewed by	Approved by	Description
1.0	2026.03.04	Allen Su	Ferry Lu Stone Shi	Ferry Lu Stone Shi	Initial Release

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1. Scope of Document

This Emergency Response Guide (ERG) serves as a resource for emergency responders regarding safety around the AESC (HE-L Series products). Customers, site managers and operators should also review this guide to ensure a clear understanding of potential hazards and procedures to be followed in an emergency.

Technical Details contained in this guide are for reference and should not be considered as binding technical description of AESC’ s product. For final details of the product, please refer to the consensus contract that both parties agreed upon.

Project specific Emergency response guide containing contact details will be released prior to project delivery to ensure best suitability for customer preference and regional regulation.

2. Project and Product Information

2.1. Project Information

Table 1. Project Information

Locations	Project Name	Telephone Number
XXX	XXX	XXX

2.2. Safety Data Sheet (SDS) Information

The Safety Data Sheet (SDS) of the Rack system are mainly as follows:

Chemical characterization: Mixtures

Description: Chemical power supply based on nonaqueous electrolyte. Composed by positive electrode, negative electrode, diaphragm, electrolyte and shell.

Table 2. Hazardous ingredients

Main Components				
Common Chemical Name	Chemical Formula	Weight %	CAS No.	EC No.
Lithium Iron Phosphate	LiFePO4	40.5%	15365-14-7	921-062-3
Graphite	C	22%	7782-42-5	231-955-3
Lithium hexafluorophosphate	LiPF6	4%	21324-40-3	244-334-7
Aluminum	Al	14%	7429-90-5	231-072-3
Copper	Cu	8%	7440-50-8	231-159-6
Ethyl methyl carbonate	C4H8O3	10%	623-53-0	208-760-7

Polyethylene	(C2H4)n	1.5%	9002-88-4	618-339-3

2.3. Battery Cells Information

HE-L Series products contain sealed lithium-ion battery cells. Each cell contains a lithium-ion electrode composed of lithium iron phosphate (LFP material) LiFePO4.

2.4. ESS Descriptions

AESC HE-L Product series includes DC system.

The HE-L Product Series code could be interpreted as below:

HE-L/□□□□A

Naming Regulation: 'HE' + '-' + 'Cooling Method' + 'Total DC Capacity ' + 'Serial Number'

Cooling Method: 'L' , Liquid Cooling; 'A' , Air Cooling.

Serial Number: 'A' , 'B' , … Code Used to distinguish different products with same DC Capacity and cooling method.

3. Precautions

3.1. General Precautions



The products described in this document can be hazardous if improperly handled. Consequences of improperly handling include and not limit to property loss, serious injury, and personnel fatalities.

This product contains lithium-ion batteries, which act as an energy source. Do not short circuit, puncture, incinerate, crush, immerse, over discharge, or expose to environment above the product's operating temperature range as described in Elevated Temperature Exposure Hazards. An internal or external short circuit can cause severe overheating and provide a source of ignition which could lead to a fire, including surrounding materials or materials within the cell or battery pack. Under normal conditions of use, integrity of the cells will be maintained, and the internal chemicals will not be exposed. Risk of exposure only occurs in cases of abuse (mechanical, thermal, electrical).

3.2. Electric Shock Hazards

Under normal conditions of use, handling of this product does not pose an electrical hazard as long as the product enclosure remains closed. This product is designed with a variety of safeguards to help ensure that high-voltage batteries remain safe under a variety of expected

abuse conditions. All component cells are sealed within the product as sub-packs within an enclosure and are not accessible from the outside, nor by non-AESC personnel.

If the product's enclosure and/or safety circuitry are compromised or severely damaged, there may be a risk of high voltage and electric shock. Battery packs may contain large amounts of energy even when discharged normally, which may result in injury or death if not handled properly. If the product is visibly damaged or its enclosure is damaged, take appropriate high voltage precautions until the hazard has been assessed (and, if necessary, eliminated). Danger has been assessed (and dissipated if necessary).

3.3. Elevated Temperature Exposure Hazards

This product is designed to withstand operating ambient temperatures up to 50°C (122°F) or up to 100% operating humidity (condensation) as indicated in the product specifications.

This product is designed to withstand storage temperatures up to 60°C (140°F) or as shown in the product specifications, and <95% relative humidity (non-condensing) for up to 24 hours without affecting the health of the equipment.

Prolonged exposure of the product to such conditions exceeding design limits may increase the potential for thermal runaway and product failure. Exposing the battery pack to local heat sources such as flames may cause a thermal runaway reaction in the battery and should be always avoided.

3.4. Mechanical Damage Hazards

Mechanical damage to the product can result in a number of hazardous situations (described below), including:

(1) Battery pack coolant leakage
(2) Refrigerant leakage
(3) Battery electrolyte leakage
(4) Rapid heating of individual cells due to exothermic reactions of materials (cell thermal runaway), cell outgassing, and propagation of self-heating and thermal runaway reactions to adjacent cells.
(5) Fire outbreak

(6) Product failure

To prevent mechanical damage, Products should be stored properly when not in use or prior to installation.

3.5. Coolant leakage Hazards

Thermal management of the product is achieved through liquid cooling using a 50/50 mixture of ethylene glycol and water.

Mechanical damage to the installed product may cause coolant leakage. The coolant liquid will have color and does not have a strong odor.

For information on the toxicological hazards associated with ethylene glycol as well as ecological effects and disposal considerations, please refer to the MSDS for the battery coolant.

Prolonged exposure of the product to leaking coolants may cause additional damage to the product, such as corrosion and damage to protective electronics.

3.6. Refrigerant Leakage Hazards

The product's thermal management system includes R-513a and R32 refrigerant in a sealed system. Mechanical damage to the product may result in the release of refrigerant. This release looks similar to the emission of smoke.

For information on the toxicological hazards and ecological effects and disposal considerations associated with R-513a and R32, please refer to the MSDS for R-513a and R32.

3.7. Electrolyte Leakage Hazards

The possibility of electrolyte spillage from product batteries is very low due to the following reasons:

(1) During the manufacturing process, the liquid electrolyte is largely absorbed into the battery material. During normal operation of the battery, electrolyte is also consumed.
(2) Batteries are sealed. Even if a single cell is damaged in a way that could cause a leak, its leakage volume would be negligible.
(3) Batteries are assembled into closed module compartments that are inaccessible to personnel. The product architecture prevents any direct contact with the battery cells.

Therefore, reporting the volume of electrolyte within the product is impractical as free liquid electrolyte is not present, and the battery and product design prevent the possibility of leakage throughout the project life.

3.8. Vented Electrolyte Hazards

Lithium-ion batteries are sealed cells, so electrolyte leakage should not occur under normal conditions of use. If subjected to abnormal heating or other abusive conditions, the electrolyte and electrolyte decomposition products may evaporate and be expelled from the battery. Outgassing is a common early indicator of a thermal runaway reaction, an unusual and dangerous condition.

Regulatory testing shows that combustion products from lithium-ion batteries can include flammable and non-flammable gases. Based on this testing, the flammable gas was found to be below its lower flammability limit (LFL) and did not pose a deflagration or explosion risk to first responders or the public. The study found that these nonflammable gases are comparable to smoke encountered in Class A structure fires and do not produce any unique or atypical gases beyond those found in modern combustion of combustible materials.

If the distance is very close, the exhaust gas may irritate the eyes, skin, and throat. Battery exhaust gases are often hot; exhaust gas temperatures may exceed 600°C (1,110°F) when exiting the battery. Exhaust electrolytes are flammable and may ignite upon contact with an active ignition source such as an open flame, spark, or sufficiently heated surface. Expelled electrolytes may also ignite on contact with a battery undergoing a thermal runaway reaction.

4. Emergency Response Requirement

DANGER!

Response should only be performed by trained professionals.

In case of any emergency , the general requirements for emergency response are as follows:

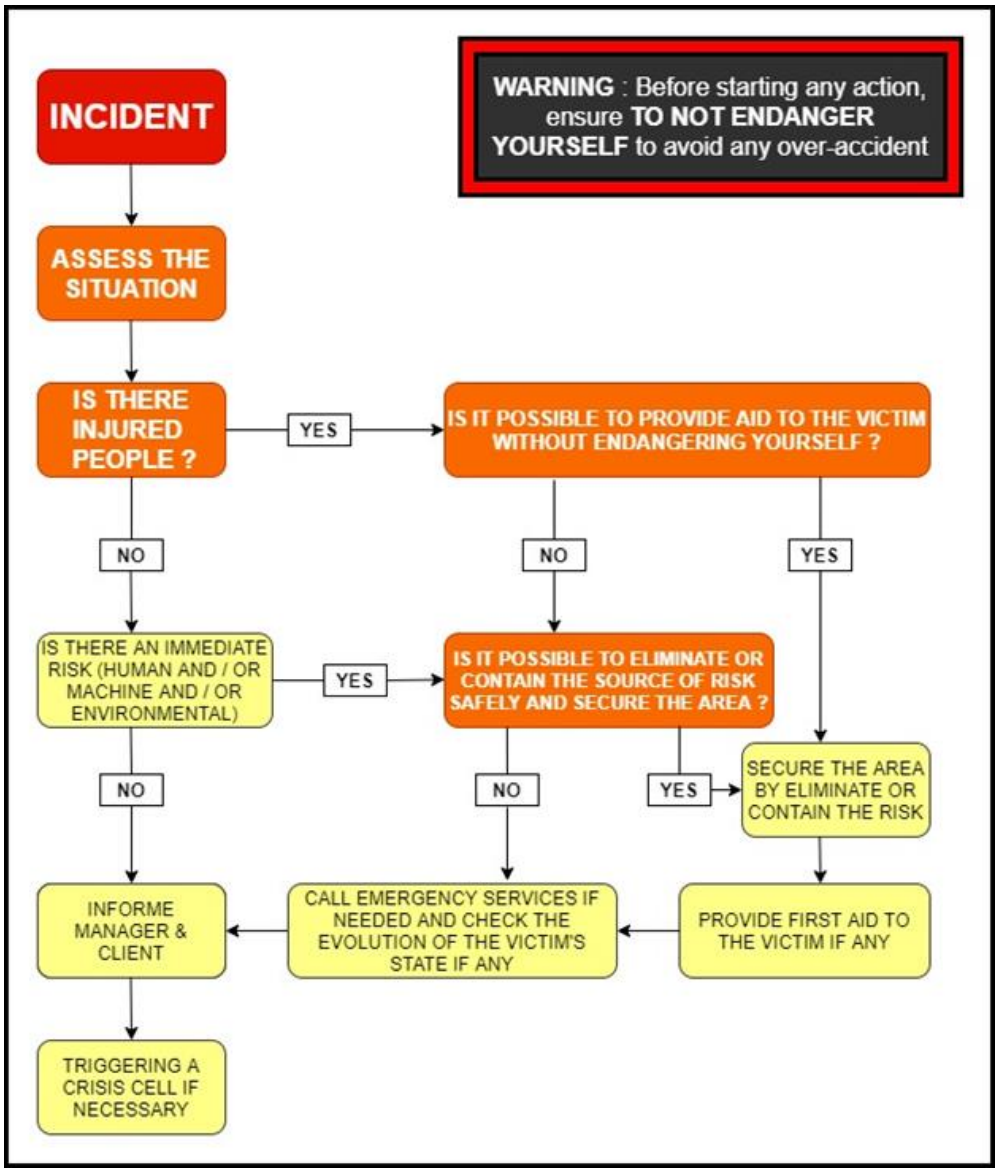

Figure 1. Emergency Response Flowchart

4.1. Storage or Operation Emergency Response

During storage or operation, emergencies may occur including: Smoke or fire, Suspicious odor, physical damage to the product.

In case of any emergency above happened, isolation of the energy source and denying entry should be the first priority and follow the responding process as below:

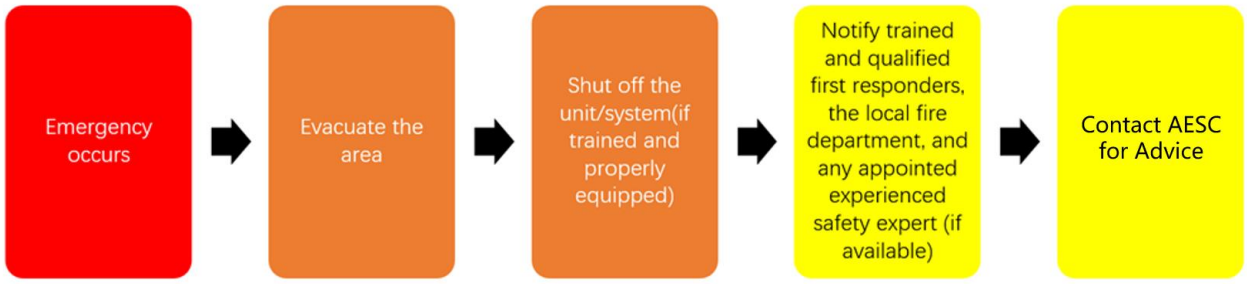

Figure 2. Responding Process of Storage or Operation Emergency

4.2. Transportation- Emergency Response

Here are some common emergencies may occur during transportation:

(1) Vehicle getting fire for some uncertain reasons, such as engine or tires overheat, short circuit of electrical line;

(2) Driver or other third party people getting injured during a road accident;

(3) Suspicious odor observed near the product;

(4) Smoke or fire emanating from the product;

(5) a severe physical impact on the product during a road accident;

(6) tipping over of the product caused by a road accident;

In case of above emergencies, follow the responding process as below:

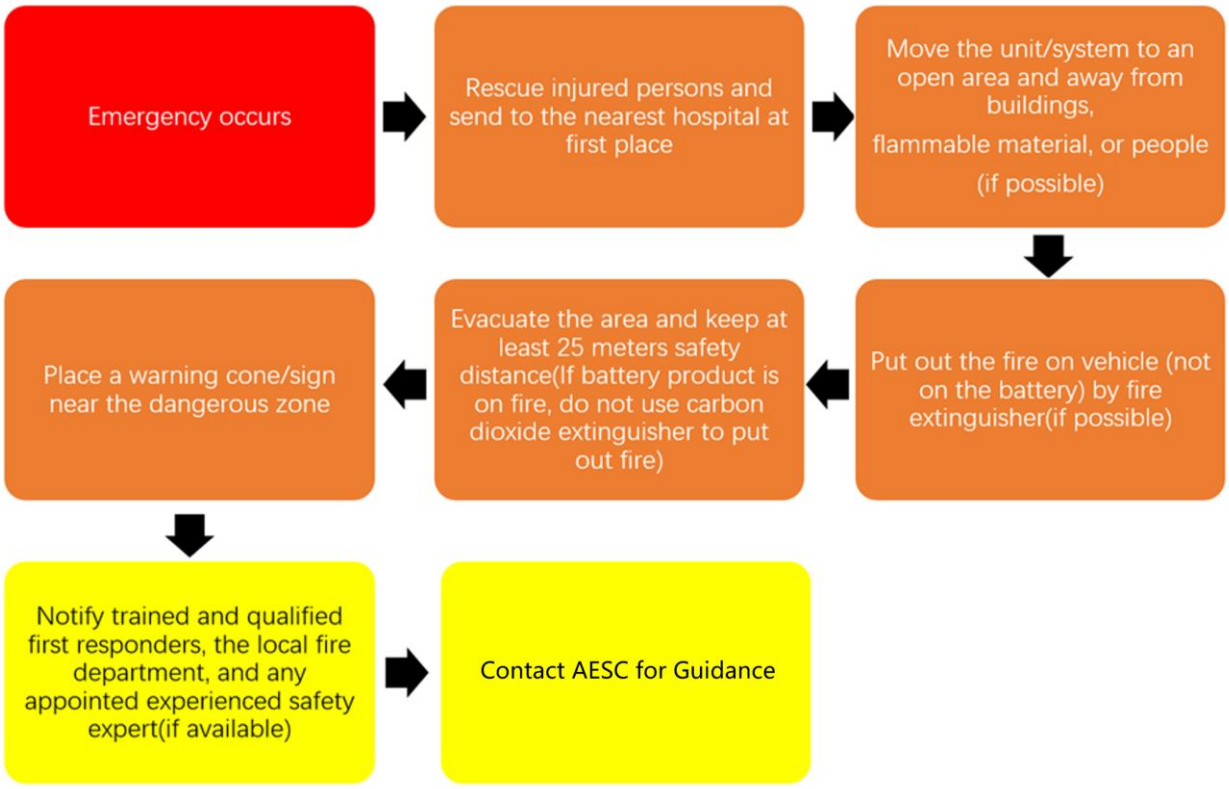

Figure 3. Responding Process of Transportation- Emergency

5. Response for Fire/Explosion

DANGER!

Only trained professionals should respond to the emergencies.

DANGER!

When responding to a fire event, wear self-contained breathing apparatus (SCBA) and structural firefighting gear while .

DANGER!

When responding to a fire event, do not approach the unit and attempt to open any doors.

If fire, smoke, or suspicious odor is observed emanating from the product, follow the responding process as below:

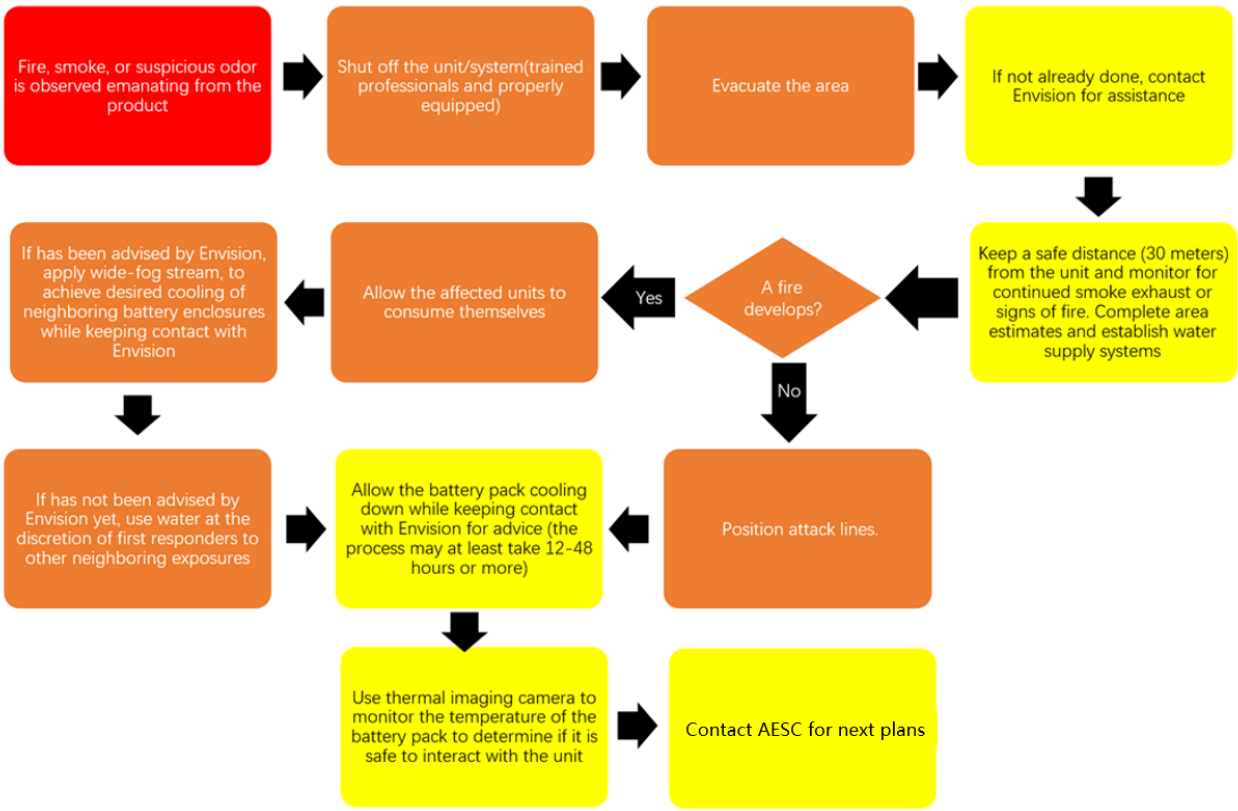

Figure 4. Emergency Response for Fire/Explosion

6. Emergency Shut-down

DANGER!

Shutting power off the product will not de-energize the battery may still present a risk of electric shock.

If smoke or fire is observed emanating from the battery, do not approach the unit and attempt to open any doors. Immediately cut off the main power supply of the product under the premise of ensuring the safety of the personnel (engage the emergency stop button, and at the same time, notify the owner to open AC breaker or disconnect, or to disconnect the power supply of the field station by the owner if the personnel cannot be approached due to the uncontrolled fire).

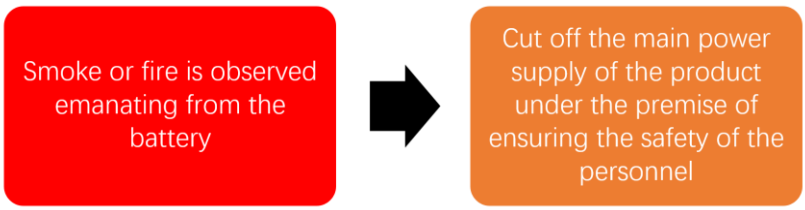

Figure 5. Shutting Down in an Emergency

7. First Aid

7.1. First Aid for Electric Shock / Electrocution

The first step in first aid for electric shock/ electrocution is to quickly remove the electric shock victim from the power source, and the second step is on-site rescue and then seek immediate medical assistance.

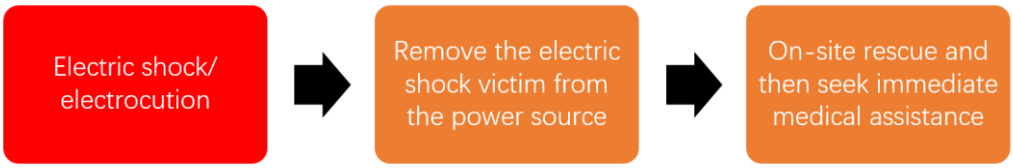

Figure 6. First Aid for Electric Shock / Electrocution

7.2. First Aid for Contact with Leaked Electrolyte

If leaked electrolyte contact skin, follow the responding process as below:

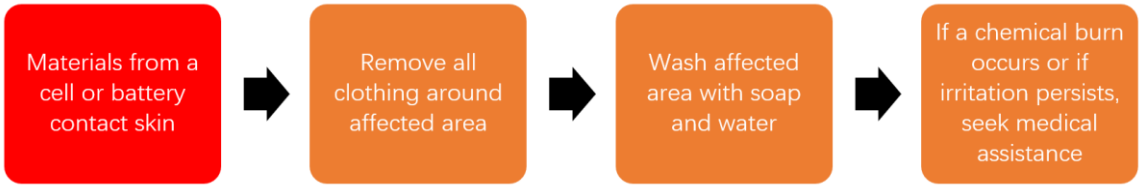

Figure 7. First Aid for Contact with Leaked Electrolyte

For eye contact, follow the responding process as below:

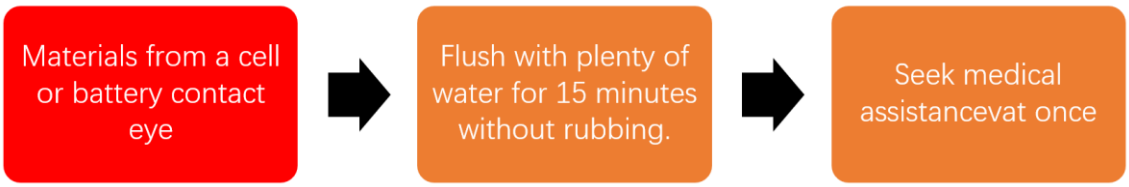

Figure 8. First Aid for Contact with Leaked Electrolyte

7.3. First Aid for Inhalation of Electrolyte Vapors

If inhalation of electrolyte vapors occurs, follow the responding process as below:



Figure 9. First Aid for Inhalation of Electrolyte Vapors

7.4. First Aid for Vent Gas Inhalation

If inhalation of vent gases occurs, follow the responding process as below:

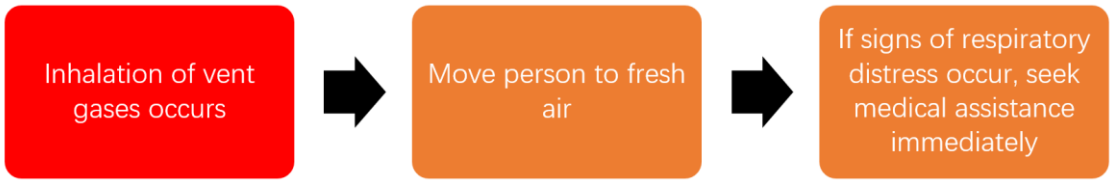

Figure 10. First Aid for Vent Gas Inhalation

8. Product Storage Precautions

Ideally, the product should be stored at a charging state (SOC) of 40% or lower. The product should not be stored for a long time in a fully charged or fully discharged state, as both situations can have adverse effects on battery life.

If the system level storage time is long, it is necessary to measure and archive the voltage of the batteries in the battery system on a monthly basis. If the voltage of the battery cells inside the battery pack is measured to be less than 3V. AESC recommends activating the batteries according to the rated charging and discharging conditions of the product, and adjusting the SOC to around 30% or 40% after charging and discharging. For final storage guidance and requirements, please refer to the consensus contract for the project.

The storage area should be protected from flooding.

Please avoid storage areas near high temperatures or heating equipment.

Long term storage areas should comply with local fire regulations.

9. Damaged Product Handling Precautions

If the product is damaged, contact AESC immediately.

If a product has been damaged, heating may occur, and may ultimately resulting in a fire. Damaged or opened batteries/cells can cause rapid heating, release of flammable vapors, and propagation of self-heating and thermal runaway reactions to neighboring cells/batteries.

Wait at least 24 hours before handling or transporting the damaged product. If no smoke, flames, signs of coolant leaks, or signs of heating are observed within 24 hours, the product can be disconnected and moved to a safe location. Contact AESC for specific instructions on evaluating, disconnecting, and preparing damaged product for transportation.

Damaged products should be monitored for signs of smoke, flame, coolant leakage or heat during storage. If full monitoring of the product is not possible (e.g. during extended storage), the product should be stored in a safe location to ensure subsequential reaction will not occur.

A secure storage location for damaged batteries should be free of flammable materials, accessible only to trained professionals, and located 15 m downwind of occupied buildings. For example, a fenced-in open yard may be a suitable safe location. Do not store damaged cells/batteries next to undamaged products. Damaged products may be further damaged during transportation and may cause a fire. To further reduce this risk, do handle damaged products with extreme caution.

10. Disposal Procedures Precautions

For disposal after a fire or thermal event, or after reaching their lifespan, AESC can be one of the priority suppliers to contact and handle.

If the product is directly processed locally, please communicate with the relevant local authorities on the plan for handling and recycling lithium-ion batteries.

Please note that these products do not contain heavy metals such as lead, cadmium, or mercury.

11. Maintenance or Repair Precautions

AESC requires all maintenance, services, and repairs to be carried out on the product by AESC approved service personnel or AESC authorized repair agencies.

Improper service or repair by personnel without AESC' s approval or authorization may invalidate the limited warranty of the product, leading to product failure and even safety accidents.

12. Transportation Precautions

According to the international dangerous goods regulations, the Lithium-ion batteries are regulated as Class 9 Miscellaneous dangerous goods, UN number:3480. So the packing, labeling, marking and documentation must strictly pursuant to the related regulations, such as the International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA)---by air; the International Maritime Dangerous Goods (IMDG) Code---by marine; European Agreements concerning the International Carriage of Dangerous Goods by Road (ADR); the USA' s hazardous materials regulations (see 49 CFR 173.185).

Since the international transportation regulations may be modified periodically and vary by region, to ensure compliant transportation, all the individuals involved in the preparation of dangerous goods must be well trained and have good knowledge about the updated regulations.

UN Number	3480
Proper Shipping Name	Lithium-Ion Batteries
Hazard Classification	Class 9 Miscellaneous
Packing Group	N/A

End of this document

Appendix I

SHORT CIRCUIT STUDY



Test of Short Circut on Rack Level

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VERSION HISTORY

Version	Date	Designer	Reviewed by	Approved by	Description
1.0.0	2025.05.16	Yongqiang.W	Lvbin.W	Phil.H	Released

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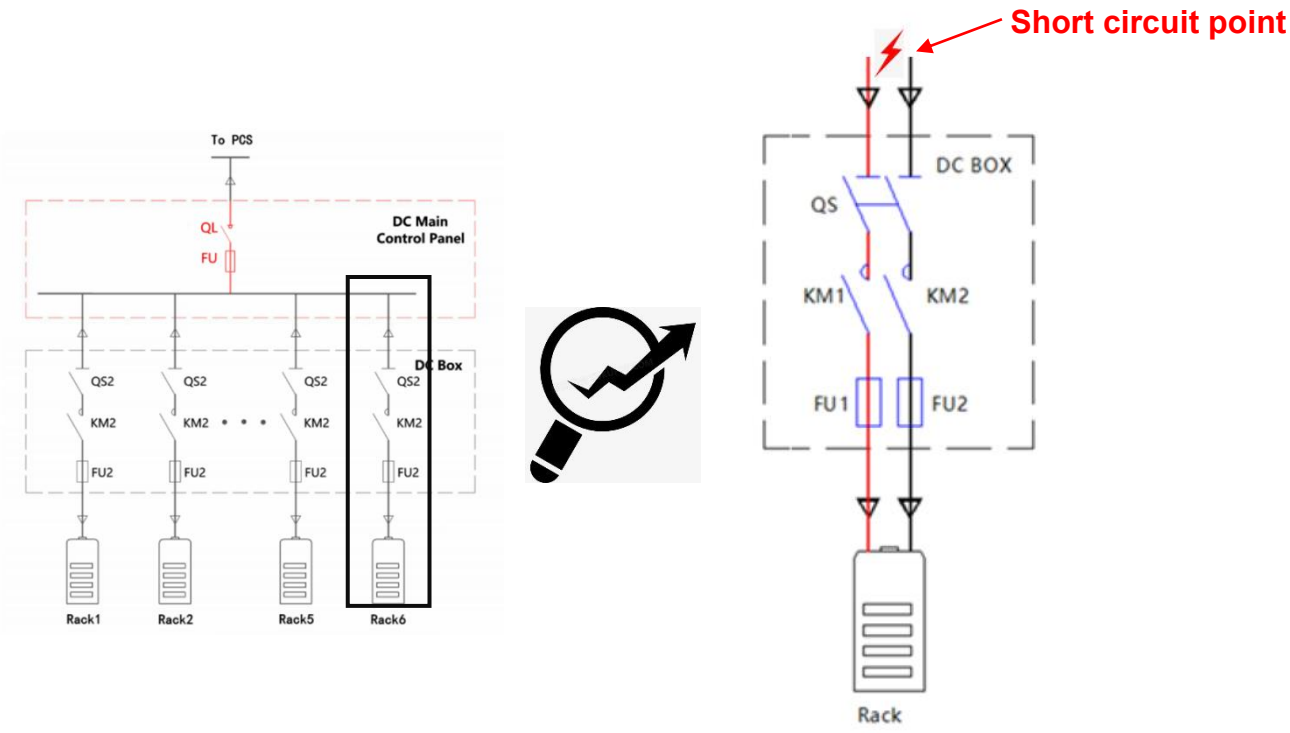
1. TEST SAMPLE CONFIGURATION

Short circuit test is carried out at the rack level, including 8 battery packs and a Junction Box. The configuration information is as follows:

No.	Item	Configuration	Remark
1	Cell type	LFP	
2	Cell Capacity (Ah)	315	
3	Cell Energy (Wh)	1008	
4	Rack Config	2P52S	
5	Pack Voltage Range (V)	130~189.8V	
6	Rack Config	2P416S	
7	Rack Rated voltage	1331.2	
8	Rack Voltage Range (V)	1164.8~1497.6	
9	Junction Box	1500V	Including fuses, DC contactors, etc.

2. SHORT CIRCUIT POINT LOCATION

Short circuit point is between the positive and negative electrodes of the Junction box output battery:



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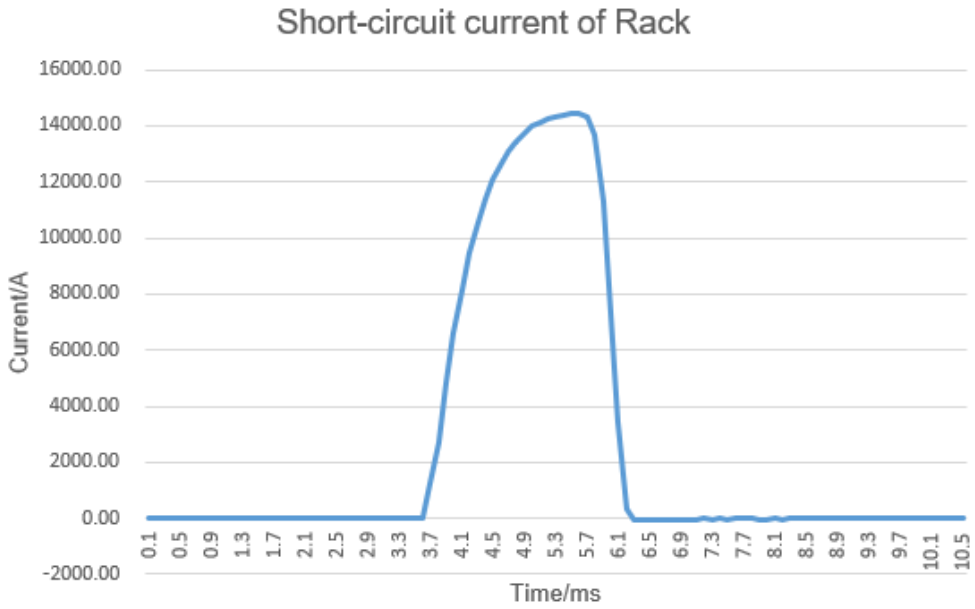
Single Rack only

3. TEST RESULTS

Short-circuit test standard is based on UL1973;
Short-circuit test the external connection resistance is 19.629mΩ (standard value ≤20mΩ);
Short-circuit current curve is as follows:



- Peak Short-circuit current:**14450A**
- Short-circuit duration: **2.6ms**

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