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Docket Number:	26-OPT-01
Project Title:	Vaca Dixon Power Center Project
TN #:	268171-1
Document Title:	Appendix U Arges BESS Hazard Mitigation Analysis_VDPC
Description:	The Hazard Mitigation Analysis evaluates fire and safety risks for the Project, detailing compliance with fire codes, results of UL 9540A testing, and mitigation measures such as fire detection, thermal runaway protection, and explosion control to ensure safe operation of the lithium-ion ESS installation. Appendix U.A UL9540 Certificate; Appendix U.B 9540A Test Reports; Appendix U.C SYL User Manual; Appendix U.D Safety Data Sheets; Appendix U.E NFPA 69 Test Report
Filer:	Grace Myers
Organization:	Rincon Consultants, Inc.
Submitter Role:	Applicant Consultant
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Appendix U

Arges BESS Hazard Mitigation Analysis

VACA DIXON POWER CENTER PROJECT

Hazard Mitigation Analysis

COFFMAN PROJECT NO. 251796

IFP SUBMITTAL

December 19, 2025

Prepared for: Arges BESS LLC.

www.coffman.com

HAZARD MITIGATION ANALYSIS

FOR

ARGES BESS

Vacaville, California

Project Number: 251796

Revision	Date	Description
A	11/11/2025	Issued for Review
B	12/19/2025	Issued for Permit

PREPARED BY:

COFFMAN ENGINEERS, INC.

CONTACT:

Patrick Wicker, PE
Engineer, Fire Protection Engineering
619-398-9603

&

Mark Gouveia, PE
Principal, Fire Protection Engineering
406-582-1936

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ABBREVIATIONS

AHJ	Authorities Having Jurisdiction
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 associated with the Vaca Dixion Power Center Project located in Vacaville, California. The site utilizes SYL (model #SU5016U1250KC) enclosures containing Prismatic Lithium Iron Phosphate (LFP) batteries, totaling 100 Megawatts (MW) of battery energy storage. The City of Vacaville Fire Department is the Authority Having Jurisdiction (AHJ) for this BESS facility. 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 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 SYL SU5016U1250KC
Number of ESS Enclosures	100 BOL (128 EOL)
Total Site Footprint	5.75 acres
Capacity	100 MW / 400 MWh

The project will utilize SYL SU5016U1250KC 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 SYL 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.

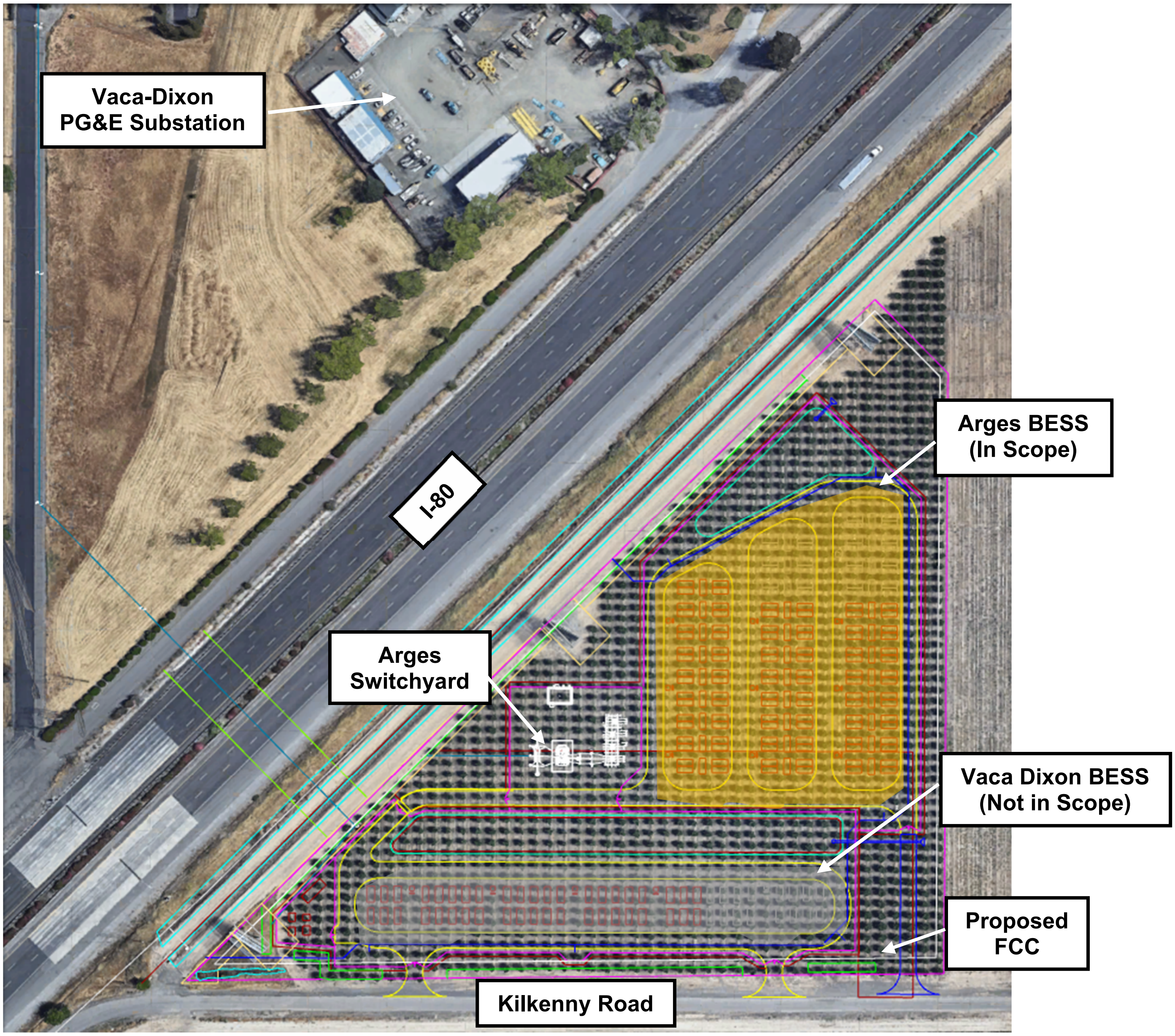


Figure 1.2.1 – Arges BESS Vicinity Map (North ↑)

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.** SYL SU5016U1250KC ESS Enclosure, SGS-CSTC certified to UL 9540. Certificate #: TBD. *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 SYL 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.** 5,016 kWh total per enclosure. Large-scale testing (UL 9540A) has been conducted to justify reduced spacing.
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 Protection by Mechanical Ventilation system has been included. *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 SYL 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. *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 is 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.

1.4 Code Requirements

1.4.1 Applicable Codes and Standards

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

- CFC, California Fire Code, (2025 Edition), as adopted by the City of Vacaville
- NFPA 72, National Fire Alarm and Signaling Code (2025 Edition)
- NFPA 70, National Electrical Code (NEC) (2023 Edition)
- NFPA 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.

1.5 Hazard Mitigation Analysis

1.5.1 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.

1.5.2 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.

1.5.3 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

1.6 System Overview

The SYL 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.

1.6.1 ESS System Description

The SYL 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.

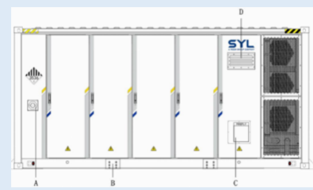
				
Component	**Cell**	**Module**	**Rack/Unit**	**SYL Enclosure**
Manufacturer	Xiamen Hithium Energy Storage Technology Co., Ltd.	SYL	SYL	SYL
Model	LFP71173207/314Ah	SM104KFE5	SR104KFE54	SU5016U1250KC
Nominal Voltage (V)	3.2	332.8	1331.2	n/a
Nominal Capacity (kWh)	n/a	n/a	418	5,015.96
Weight (lbs.)	12.35	1,433	n/a	81,000
Dimensions (in)	6.88 x 8.15 x 2.82	31.10 x 85.35 x 9.57	n/a	19.9 ft x 9.5 ft x 8 ft
Configuration / Chemistry	Prismatic Lithium Iron Phosphate (LiFePO4)	104 Cells (1P104S)	4 Modules (104)4S	416S*12P
Thermal Management	n/a	n/a	Liquid Cooling System	Liquid Cooling System
Listing / Certification	UL 1973	UL 1973	n/a	UL 9540

Table 1.6.1 - SYL Configuration

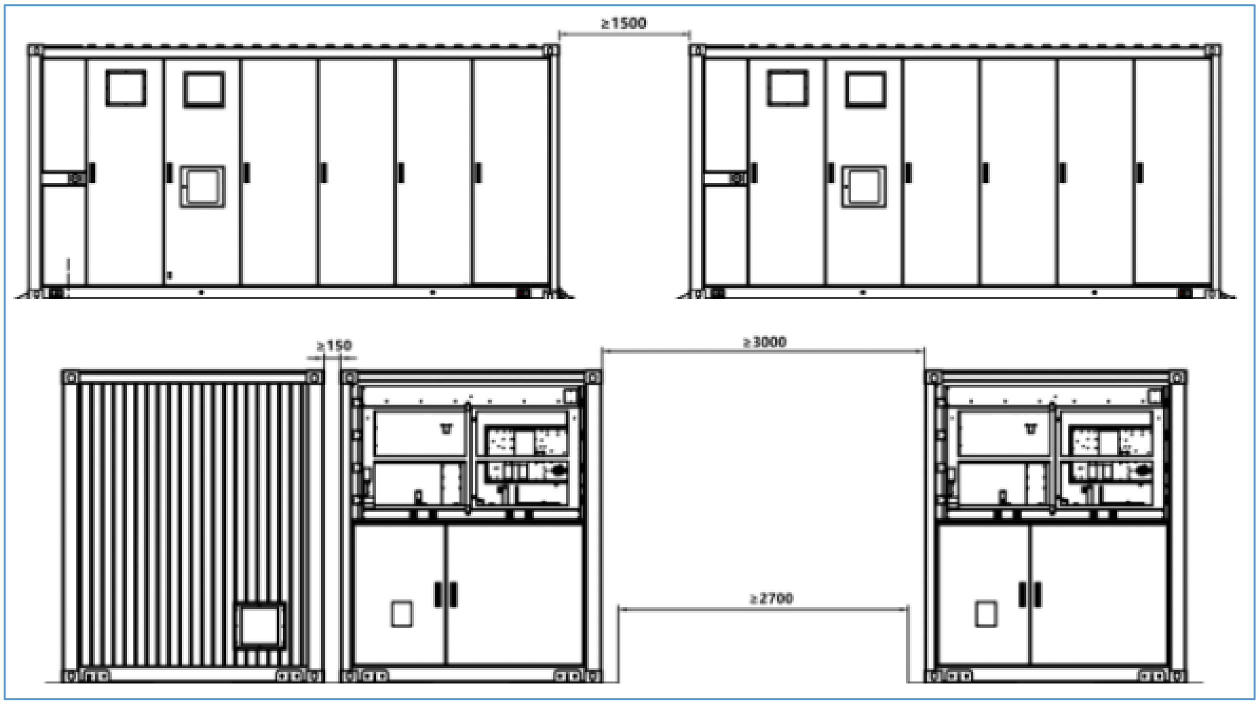


Figure 1.6.1 – ESS Separation Requirements per SYL (Manufacturer)

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 ($LiFePO_4$, LFP) battery cell (Model MB31), certified to UL 1973, was tested according to UL 9540A. Thermal runaway was induced using an external heater. Vent gas was captured in a 100L 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 TUV Rheinland (Shenzhen) Co., Ltd. Dated 8/29/2023, test report no. CH23F118 001. The UL9540A Cell Level Test can be found in Appendix B.

2.1.2 Cell Test Results

The cell's average venting temperature was 203.7 °C (398.66 °F), with an average thermal runaway temperature of 295.7 °C (554.26 °F). Vent gas analysis confirmed flammability when mixed with air. The LFL was 8.1% (vol in air) at 25°C, decreasing to 6.5% 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 TUV Rheinland (Shanghai) Co., Ltd. Dated 6/26/2025, test report no. CN253I80 001. 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 was 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 a SYL 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 6/26/2025, test report no. CN25PS92 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 four cells. Module-to-module propagation of thermal runway was not observed along with no external flaming or sparking and no explosion or flying debris. Gas and smoke venting was observed.

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 (FACP) with two smoke detectors and two heat detectors within the main ESS container, as well as one smoke detector within the enclosure's integration cabinet. A site fire alarm control panel, referred to as a “Fire Command Center” (FCC), located in an approved location monitors all fire alarm signals from each ESS enclosure. ESS Status indicators will be visible at the FCC and the ESS container's associated FACP.

3.1.1 Code Requirements

CFC § 1207.5.4 requires all fire areas containing ESS systems located within buildings or structures to be provided with a smoke detection system in accordance with NFPA 72. The SYL enclosures comply with this requirement.

3.1.2 System Description

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

- Detection: Each SYL 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 (rack) 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: The stand-alone site level fire alarm panels are 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 SYL 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 SYL 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 SYL 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 may either be brought to the site via tankers or accessed from the three on-site fire hydrants located around the perimeter of the Arges BESS facility along the fire department access road. 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 SYL 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 SYL 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 C 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 SYL 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 SYL 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 E 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 SYL 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 E for the full report.
- 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 SYL 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 SYL 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 SYL 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 SYL 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 ventilation system activates 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 SYL 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 SYL ESS battery system or its associated BMS.

4.2.1 Mitigation and System Response

- **BMS Functionality:** The SYL 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 SYL ESS installation.

4.3.1 Mitigation and System Response

- **Normal Operation:** Under normal operating conditions, SYL 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 SYL 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 SYL 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 SYL 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 SYL ESS.

4.6 Failure of the Fire Detection Equipment System

This analysis assesses the impact of a smoke or heat detector failure within a SYL 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 SYL ESS enclosure.

4.7.1 Mitigation and System Response

- **Localized Impact:** An FACP failure primarily affects the SYL 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 SYL 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

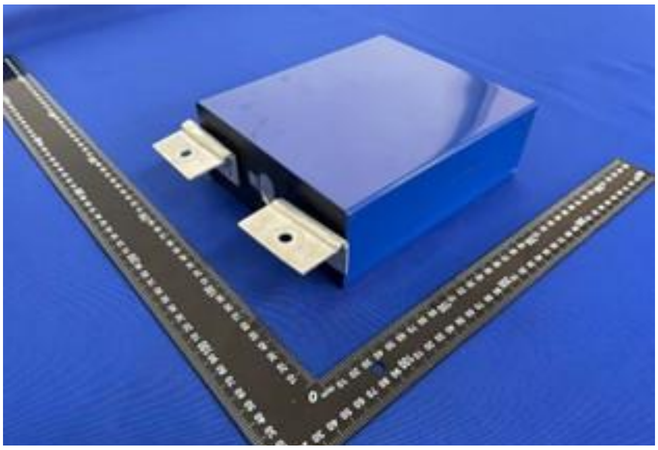
UL 9540 CERTIFICATE

Appendix B

UL 9540A TEST REPORTS

Prüfbericht-Nr.: *Test report no.*:	CN23F118 001	**Auftrags-Nr.:** *Order no.*:	168441619	
Kunden-Referenz-Nr.: *Client reference no.*:	2347845	**Auftragsdatum:** *Order date:*	2023-08-29	
Auftraggeber: *Client*:	Xiamen Hithium Energy Storage Technology Co., Ltd. 201-1, Comprehensive Building 5, No.11, Butang Middle Road, Industrial Base Of Xiamen Torch High Tech Zone (Tongxiang), Xiamen, Fujian, P.R. China			
Prüfgegenstand: *Test item*:	Iron Phosphate-Lithium Cell			
Bezeichnung / Typ-Nr.: *Identification / Type no.*:	LFP71173207/314Ah			
Auftrags-Inhalt: *Order content*:	Test report			
Prüfgrundlage: *Test specification*:	UL 9540A:2019 (Forth Edition)			

Wareneingangsdatum: *Date of sample receipt*:	2023-08-30
Prüfmuster-Nr.: *Test sample no:*	Engineering sample
Prüfzeitraum: *Testing period*:	2023-09-04 - 2023-11-21
Ort der Prüfung: *Place of testing*:	See to clause 1.1 of main report
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shenzhen) Co., Ltd.
Prüfergebnis*: *Test result**:	See main report



erstellt von: *created by:*		**genehmigt von:** *authorized by*:	
Datum: *Date:* 2023-12-06	Jason Zhu	**Ausstellungsdatum:** *Issue date:* 2023-12-06	Xun Yu
Stellung / Position:	Project Engineer	**Stellung** / Position:	Reviewer

Sonstiges /
Other:

This report does not evidence compliance of the provided sample with the relevant standards but only with the referred tests. This test report documents the findings of examination conducted on the delivered product mentioned above only. This report does not entitle the applicant to carry any safety mark on this or similar products. Further for sales or other application purposes of the tested product, any reference to TÜV Rheinland or a test through TÜV Rheinland is only permissible with prior written consent of TÜV Rheinland.

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*

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.*

Introduction

Model fire codes and energy storage system standards require energy storage systems to comply with UL 9540, which in turn requires battery cells and modules to comply with UL 1973. Compliance with these standards reduces the risk of batteries and battery energy storage systems (BESS) creating fire, shock or personal injury hazards. However, they don't evaluate the ability of the BESS installed as intended and with fire suppression mechanisms in place if necessary, from contributing to a fire or explosion in the end use installations.

To address these fire and explosion hazards associated with the installation of a BESS, the fire and other codes require energy storage systems to meet certain location, separation, fire suppression and other criteria. Those codes also provide a means to provide an equivalent level of safety based on large scale fire testing of anticipated BESS installations.

UL 9540A is intended to provide a test method that can be used as a basis for validating the safety of a BESS installation in lieu of meeting the specific criteria provided in those codes. The data generated can be used to determine the fire and explosion protection required for installation of a BESS.

The test method is initiated through the establishment of a thermal runaway condition that leads to combustion within the BESS. The test method outlined in UL 9540A consists of several steps – cell level testing, module level testing, unit level testing and installation level testing. The cell and module level testing steps are information gathering steps to inform the unit and installation level testing.

The following outlines the information that may gathered as part of the testing:

a) Cell level – An individual cell fails in a manner that leads to thermal runaway and fire through a suitable method such as external heating. Data such as off-gassing contents, temperatures at venting and temperatures at thermal runaway are recorded.

b) Module level – One or more cells within a BESS module fail in the manner determined during the cell level testing. Data such as fire propagation in the module, temperatures on the failed cells and surrounding cells, off-gassing contents and heat release data are gathered.

c) Unit level – A complete BESS is installed surrounded by target (e.g. dummy) BESS and walls separated at a distance as intended in its installation. The module level test is repeated on a module located in the BESS in the most unfavorable location. Data such as temperature within the BESS, on surrounding walls and target BESS; incident heat flux on walls and target BESS; observation of fire propagation from BESS to target units and walls as well as observance of explosions or evidence of re-ignition within the BESS; and heat release and off-gassing contents are gathered.

d) Installation level – This test is a repeat of the unit level test with the test conducted within a test room and with the intended fire suppression system installed as well as any overhead cables (that can lead to fire propagation) installed. This test is intended to validate the fire suppression system for the BESS installation. Data such as temperature within the BESS, on surrounding walls and target BESS; incident heat flux on walls and target BESS; fire propagation from the BESS to target units, walls or overhead cables and any observable explosion incidents or re-ignition within the BESS; and off-gassing contents (if needed) and heat release are gathered.

Contents

1 General information

1.1 Test specification

Standard: ANSI/CAN/UL 9540A:2019 (Fourth Edition)

Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

This report presents the result of cell level tests of UL 9540A: 2019.

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

Testing period: 2023-09-04 to 2023-11-17

Refer to Clause 4 for test and measurement instruments.

1.2 General remarks

This report is descriptive and provide the test data only.

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 testing laboratory.

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

1.3 List of attachments

The following attachments resulting from the tests, provided with separate page number, are included in this report.

Appendix A: Cell vent gas lower flammability limit (LFL) test

Appendix B: Cell vent gas burning velocity (S_u) test

Appendix C: Cell vent gas maximum pressure (P_{max}) test

1.4 Revision information

New report, not applicable

1.5 Definitions

CELL – The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, separators, container, and terminals. It is a source of electrical energy by direct conversion of chemical energy.

MODULE – A subassembly that is a component of a BESS that consists of a group of cells or electrochemical capacitors connected together either in a series and/or parallel configuration (sometimes referred to as a block) with or without protective devices and monitoring circuitry.

UNIT – A frame, rack or enclosure that consists of a functional BESS which includes components and subassemblies such a cells, modules, battery management systems, ventilation devices and other ancillary equipment.

BATTERY SYSTEM (BS) – Is a component of a BESS and consists of one or more modules typically in a rack configuration, controls such as the BMS and components that make up the system such as cooling systems, disconnects and protection devices.

BATTERY ENERGY STORAGE SYSTEM (BESS) – Stationary equipment that receives electrical energy and then utilizes batteries to store that energy to supply electrical energy at some future time. The BESS, at a minimum consists of one or more modules, a power conditioning system (PCS), battery management system (BMS) and balance of plant components.

a) INITIATING BATTERY ENERGY STORAGE SYSTEM UNIT (INITIATING BESS) – A BESS unit which has been equipped with resistance heaters in order to create the internal fire condition necessary for the installation level test (Section 9).

b) TARGET BATTERY ENERGY STORAGE SYSTEM UNIT (TARGET BESS) – The enclosure and/or rack hardware that physically supports and/or contains the components that comprise a BESS. The target BESS unit does not contain energy storage components, but serves to enable instrumentation to measure the thermal exposure from the initiating BESS.

Note: Depending upon the configuration and design of the BESS (e.g. the BESS is composed of multiple separate parts within separate enclosures), the unit level test can be done at battery system level. In such case, the BESS is be read as BS throughout this report.

NON-RESIDENTIAL USE – Intended for use in commercial, industrial or utility owned locations.

RESIDENTIAL USE – In accordance with this standard, intended for use in one or two family homes and town homes and individual dwelling units of multi-family dwellings.

THERMAL RUNAWAY- The incident when an electrochemical cell increases its temperature through self-heating in an uncontrollable fashion. The thermal runaway progresses when the cell's generation of heat is at a higher rate than the heat it can dissipate. This may lead to fire, explosion and gas evolution.

STATE OF CHARGE (SOC) – The available capacity in a BESS, pack, module or cell expressed as a percentage of rated capacity.

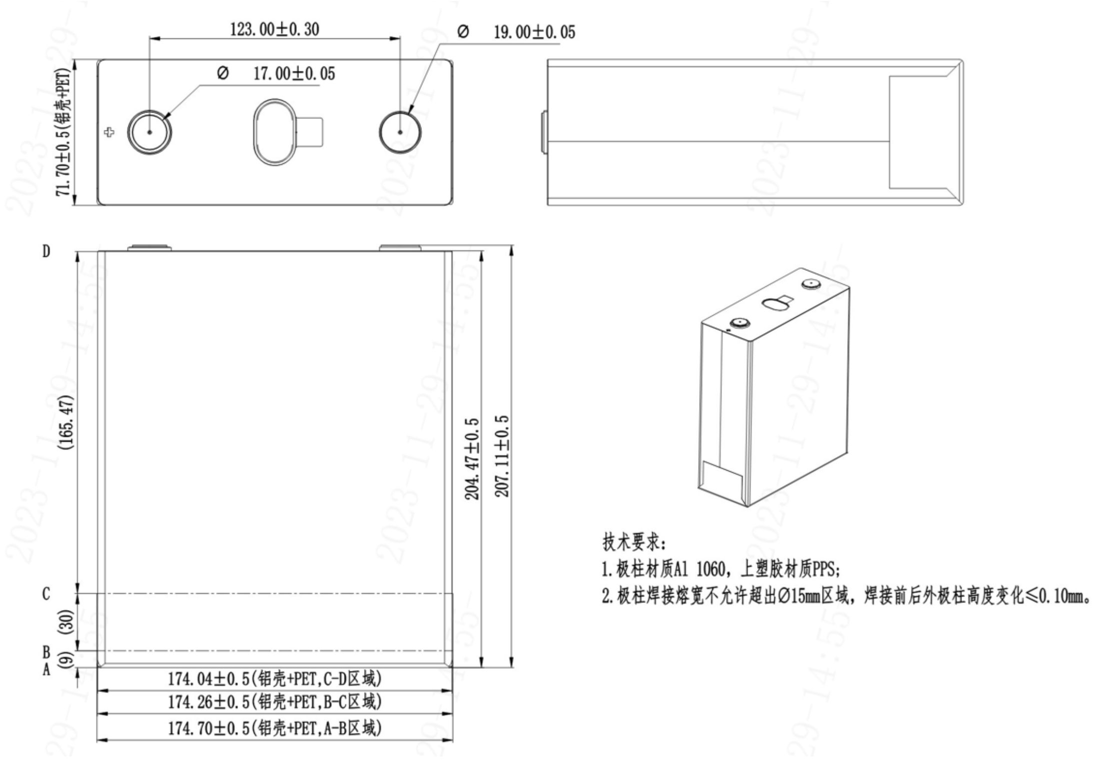
2 General Product Information

2.1 Product information and parameters

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

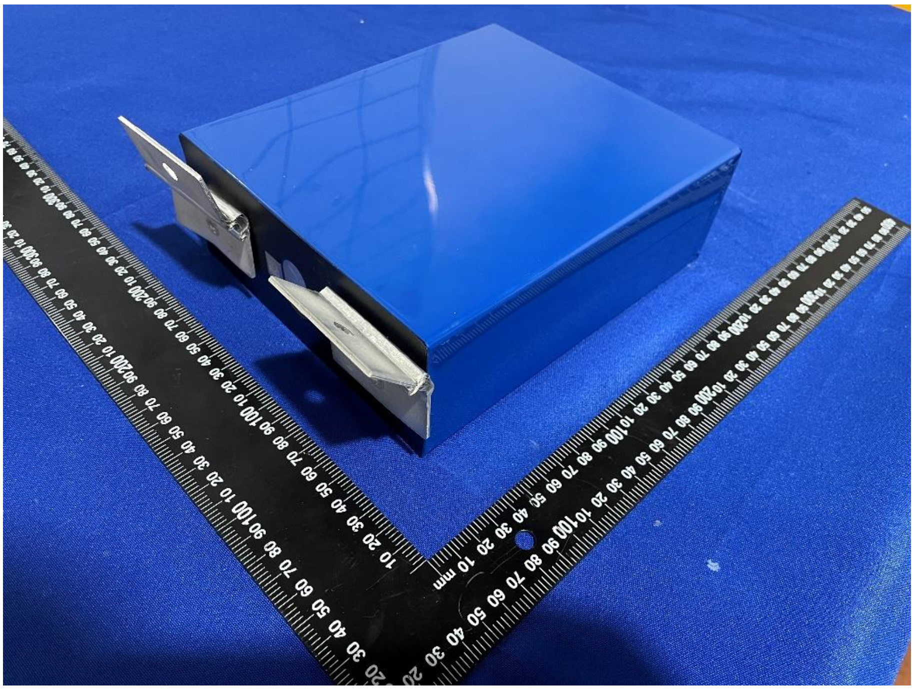
Manufacturer ....:	Xiamen Hithium Energy Storage Technology Co., Ltd. 201-1, Comprehensive Building 5, No.11, Butang Middle Road, Industrial Base Of Xiamen Torch High Tech Zone (Tongxiang), Xiamen, Fujian, P.R. China	
Model number...................................:	LFP71173207/314Ah	
Chemistry ....:	☒ $LiFePO_4$ ☐ NMC ☐ NCA ☐ LTO ☐ Other:	
Physical configuration.......................:	☒ Prismatic ☐ Cylindrical ☐ Pouch	
	Weight(kg):	5.6±0.2
Electrical rating ....:	Rated capacity(Ah):	314 (25°C±2°C)
	Nominal voltage(V):	3.2
Standard charge method ....:	Charge current(A):	157 (25°C±2°C)
	Standard Charge Voltage(V):	3.65
	Cut off current(A):	/
Standard discharge method..............:	Discharge current(A):	157 (25°C±2°C)
	End of discharge voltage(V):	2.5V (T>0°C) 2.0V (T≤0°C)
Maximum continuous charge current :	314A	
Maximum continuous discharge current ....:	314A	
Compliance with UL 1973.................:	☒ Yes, TUV Report No.: CN23RGEH 001 ☐ No	
Note:		

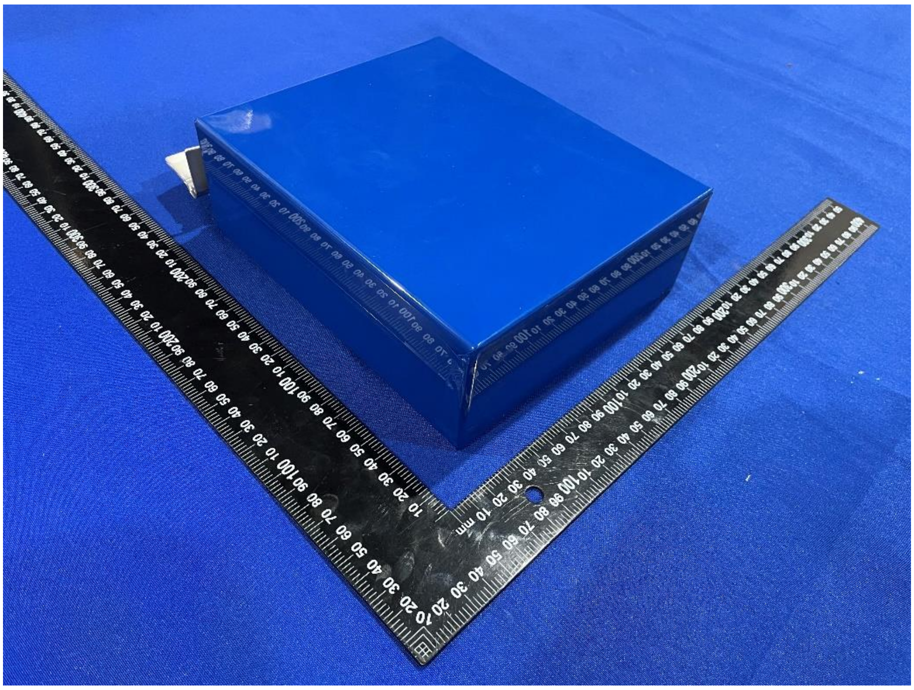
2.2 Diagram with overall dimension

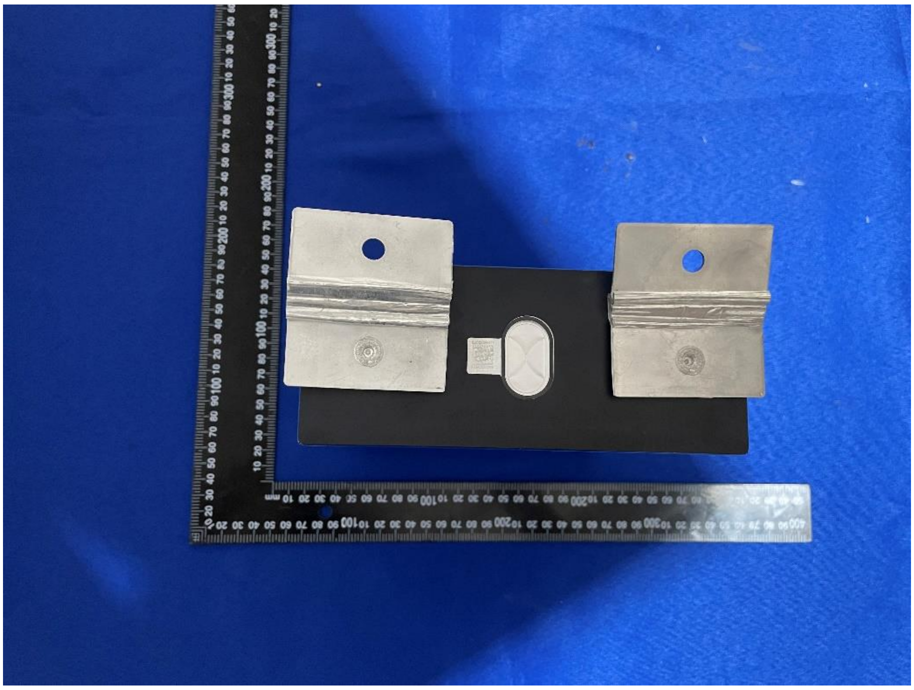


Unit: mm

Photos







3 Cell level test (section 7 of UL 9540A)

3.1 General

This testing is conducted on individual cells and uses various stress conditions such as external heating to force the cells into thermal runaway.

Once the stress mechanism is induced, the test measures the temperature at which the cell vents and then the temperature at which thermal runaway occurs.

The test also measures the volume and pressure of the vent gases that are released from the cells, and the composition of the vent gases.

Cell vent gas with flammable components in its composition should have the following parameters characterized in order to enable deflagration venting design:

a) Measurement of fundamental burning velocity by the vertical tube method described in the Method of Test for Burning Velocity Measurement of Flammable Gases Annex in ISO 817; and

b) Maximum pressure developed in a contained deflagration of an optimum mixture per EN 15967.

Cell level testing performed on the cells used within a BESS module establishes a base line fire test performance that can be evaluated against the fire performance of other battery cells the BESS manufacturer may choose to use within the unit's modules.

If none of the cell samples can be forced into thermal runaway and none of the cell samples vent flammable gases as determined by the ASTM E918 test, during any of the cell level tests, it is not necessary to conduct additional module or unit level testing on BESS that utilize these cells.

3.2 Sample preparation

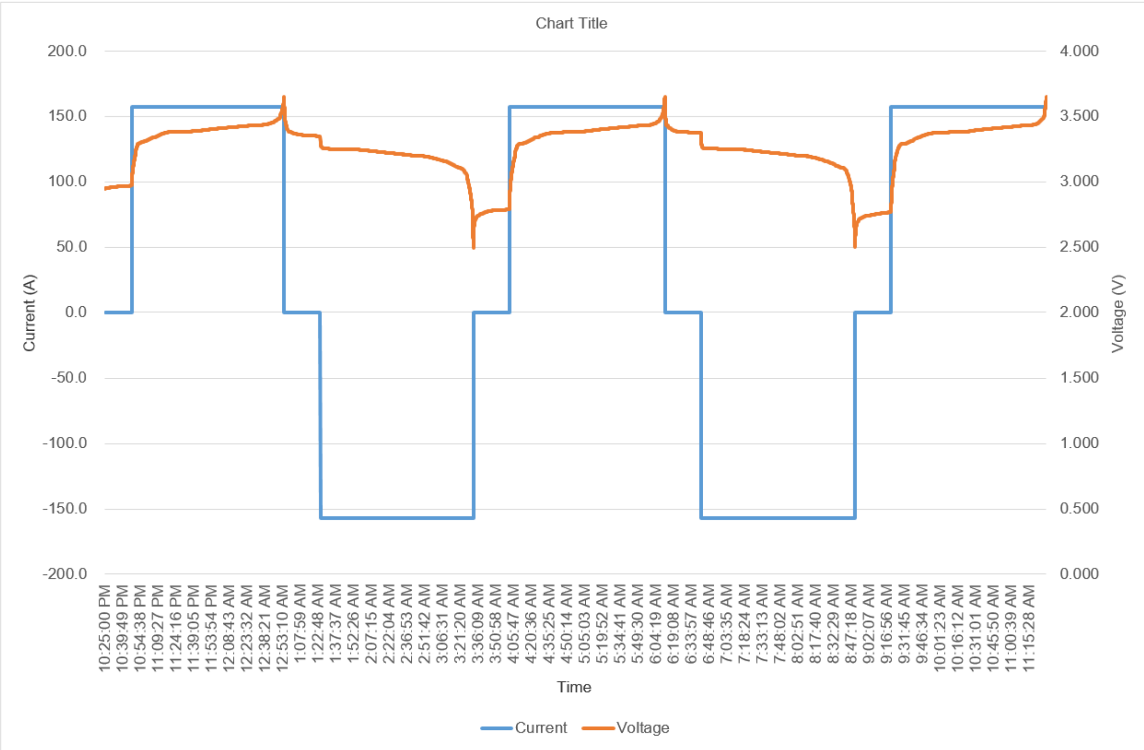
3.2.1 Test method and description

The cells were conditioned, prior to testing, through charge and discharge cycles for 2 cycles using a manufacturer specified methodology (refer to 2.1.1).

During the cycling, ambient condition is maintained within 25°C±2°C and R.H. 50±25 %.

3.2.2 Cell cycling curves

#1



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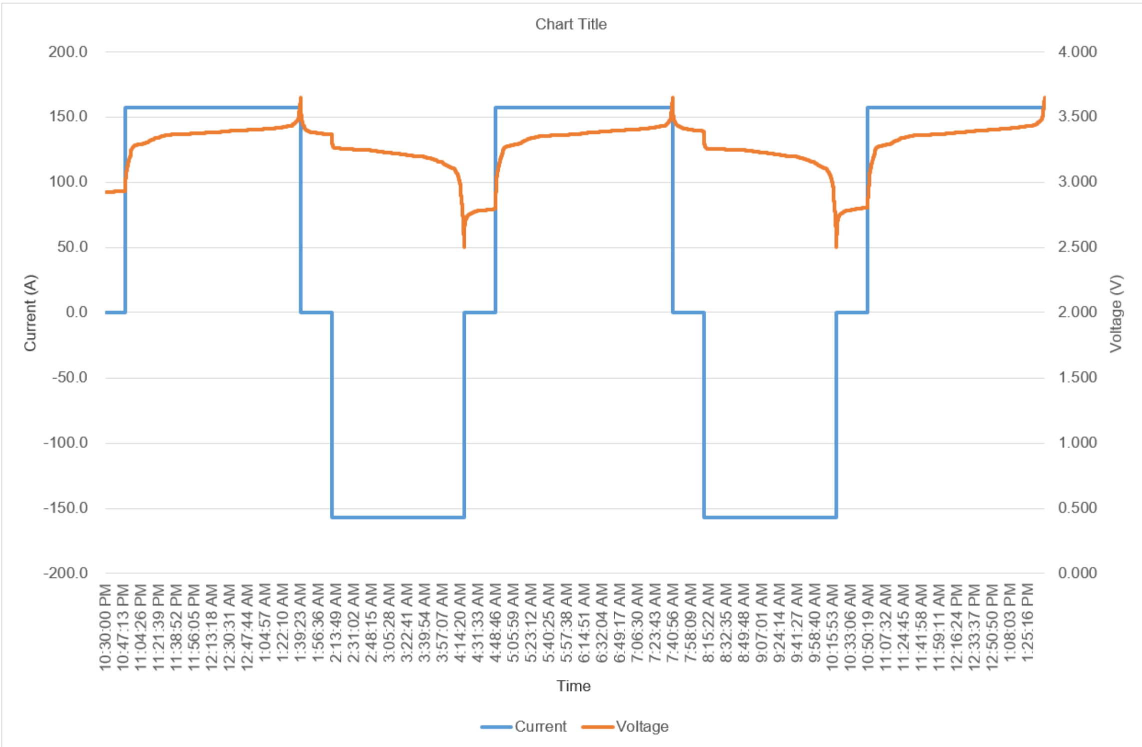


#3

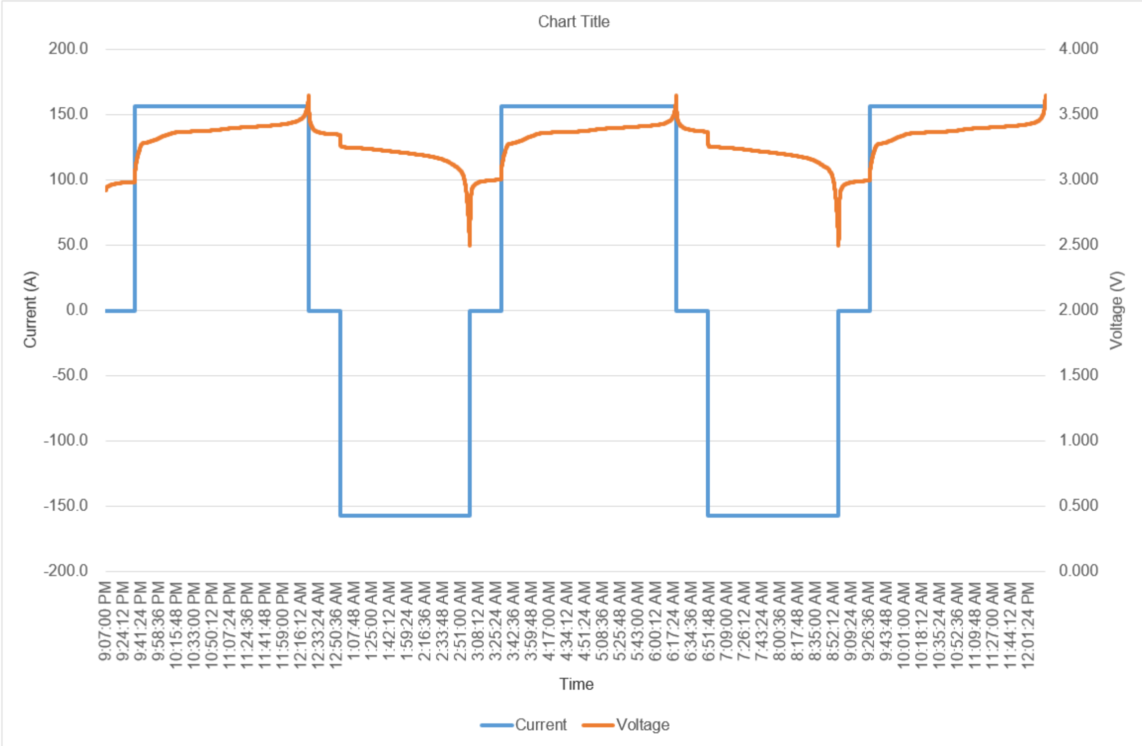


Chart Title
Current (A)
Voltage (V)
Time
Current
Voltage

#4

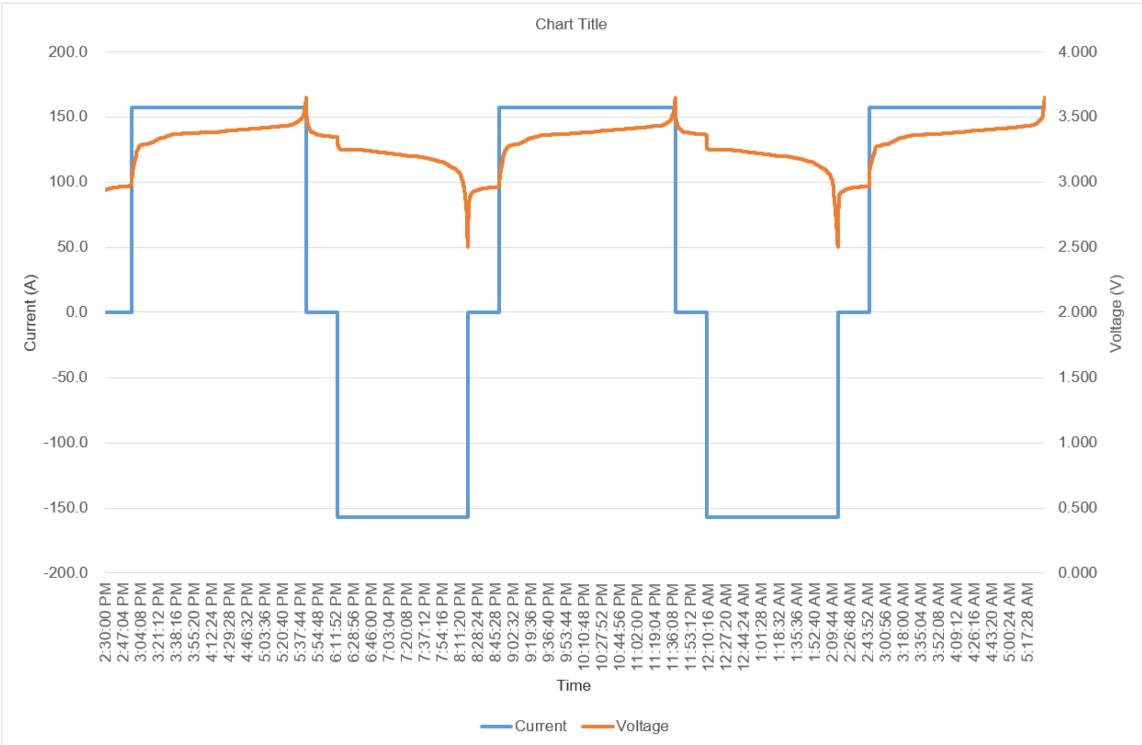


Chart Title
Current (A)
Voltage (V)
Time
Current
Voltage

#5

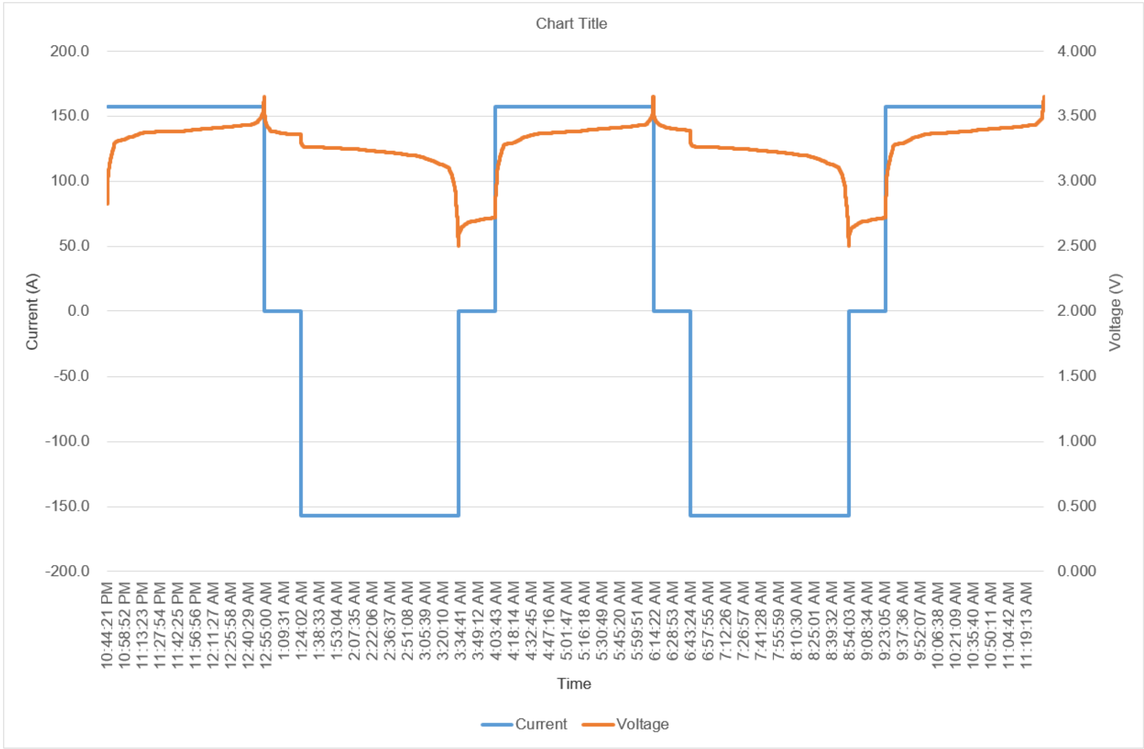


Chart Title
Current (A)
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
Voltage (V)
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
10:44:21 PM
10:58:52 PM
11:13:23 PM
11:27:54 PM
11:42:25 PM
11:56:56 PM
12:11:27 AM
12:25:58 AM
12:40:29 AM
12:55:00 AM
1:09:31 AM
1:24:02 AM
1:38:33 AM
1:53:04 AM
2:07:35 AM
2:22:06 AM
2:36:37 AM
2:51:08 AM
3:05:39 AM
3:20:10 AM
3:34:41 AM
3:49:12 AM
4:03:43 AM
4:18:14 AM
4:32:45 AM
4:47:16 AM
5:01:47 AM
5:16:18 AM
5:30:49 AM
5:45:20 AM
5:59:51 AM
6:14:22 AM
6:28:53 AM
6:43:24 AM
6:57:55 AM
7:12:26 AM
7:26:57 AM
7:41:28 AM
7:55:59 AM
8:10:30 AM
8:25:01 AM
8:39:32 AM
8:54:03 AM
9:08:34 AM
9:23:05 AM
9:37:36 AM
9:52:07 AM
10:06:38 AM
10:21:09 AM
10:35:40 AM
10:50:11 AM
11:04:42 AM
11:19:13 AM
Time
Current
Voltage

3.3 Determination of cell thermal runaway methodology

3.3.1 Test method and description

The cells to be tested were charged to 100% SOC and allowed to stabilize for a minimum of 1 h and a maximum of 8 h before the start of the test.

External film heater rated 220Vac/429W was put below the cell to induce the cell thermal runaway.

The cell sample and heater were clamped by two steel plate together using four bolts during test to simulate the constraint in the BESS module to prevent excessive swelling during the test.

The thermocouple (type K, 24AWG) was located below the heater that used to measure vent and thermal runaway onset temperature.

An AC power supply controller was used to control the voltage supply to the heater and maintain a 4°C/min to 7°C/min heating rate. Once thermal runaway was observed, the heaters were immediately de-energized.

The cell exhibits thermal runaway after establishing the heating rate. 3 additional samples were repeated to demonstrate repeatability.

The vent temperature and thermal runaway onset temperatures were averaged over the tested samples.

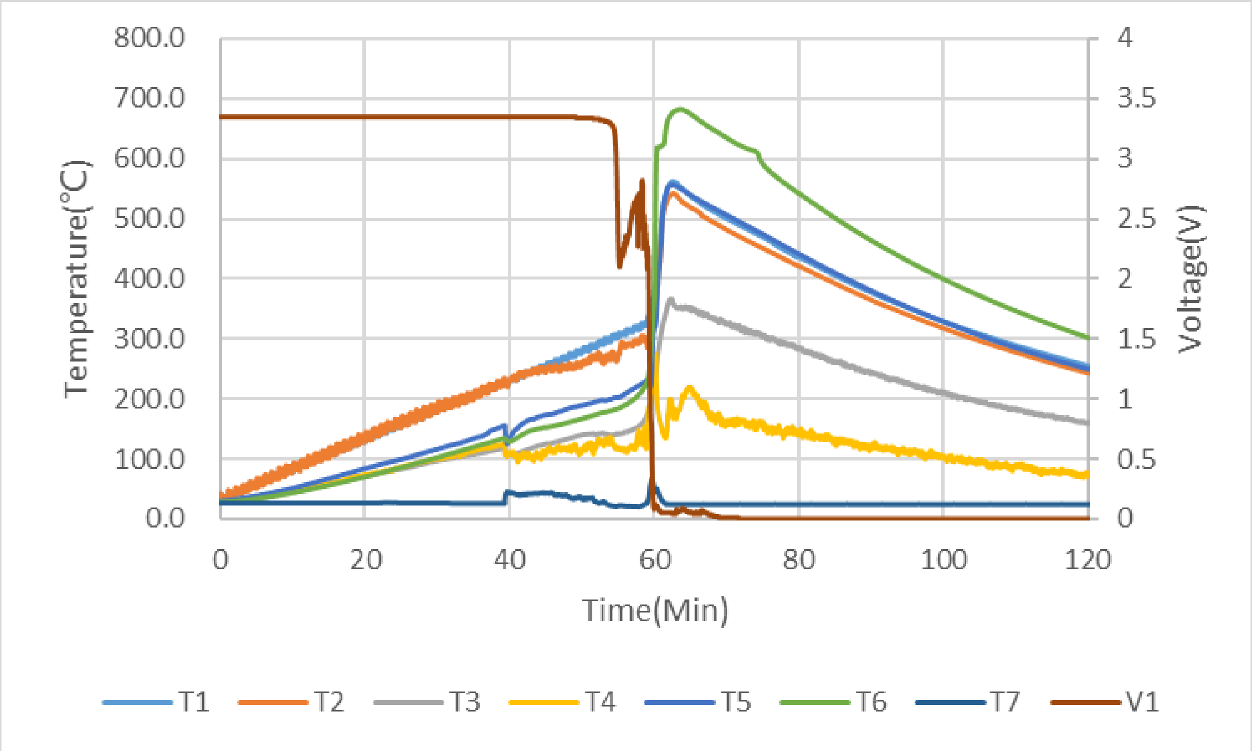
3.3.2 Test result

Ambient conditions at the initiation of the test ....:	26.1°C, 51%R.H.	27.9°C, 51%R.H.	26.1°C, 52%R.H.	27.9°C, 50%R.H.	26.1°C, 51%R.H.
Sample number ....:	#1[1)]	#2	#3	#4	#5
Open circuit voltage before test (V) :	3.35	3.37	3.36	3.35	3.35
Cell vent temperature (°C) ....:	231.4	201.8	200.7	208.5	203.6
Thermal runaway onset temperature (°C) ....:	328.8	306.3	283.5	291.4	301.6
Average cell vent temperature (°C)[2)] ....:	--	203.7			
Average thermal runaway onset temperature (°C) [2)] ....:	--	295.7			

Note:
1) The sample (#1) is for gas vent capture.
2) The temperatures were averaged over the tested samples (#1, #2, #3, #4, #5) excluding the gas vent capture sample (#1).

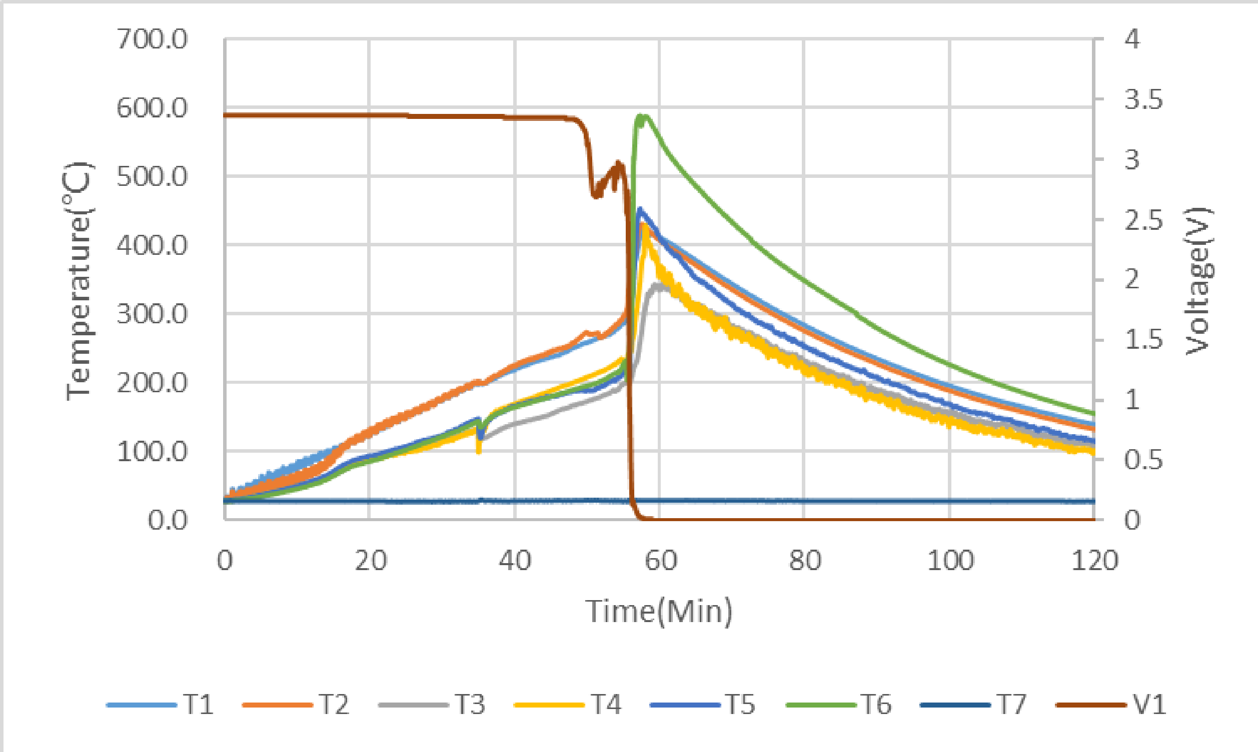
3.3.3 Temperature/voltage vs time curve

#1



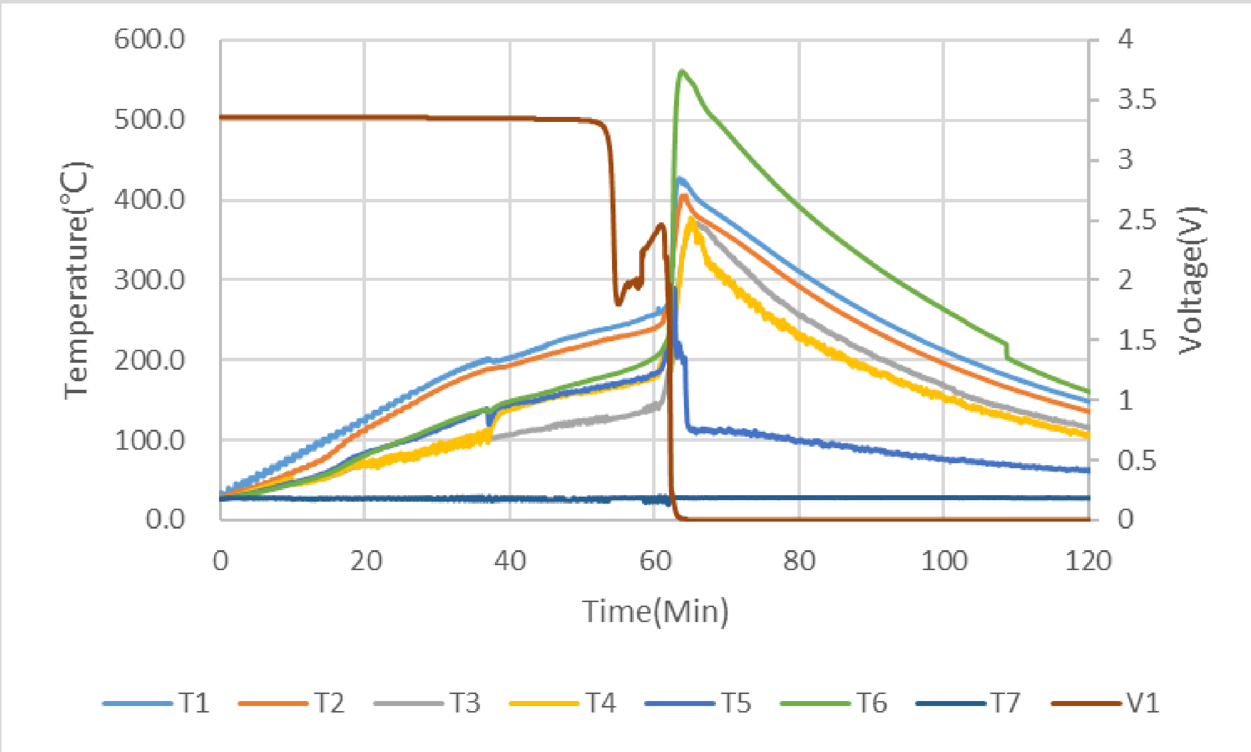
Thermalcouple No.	Location
T1	Cell center below the heater(A side)
T2	Cell center below the heater(B side)
T3	Positive eletrode tap
T4	Near pressure relief valve
T5	Cell narrow side
T6	Cell bottom
T7	Ambient temperature (Inside of pressure vessel)
V1	Cell Voltage

#2



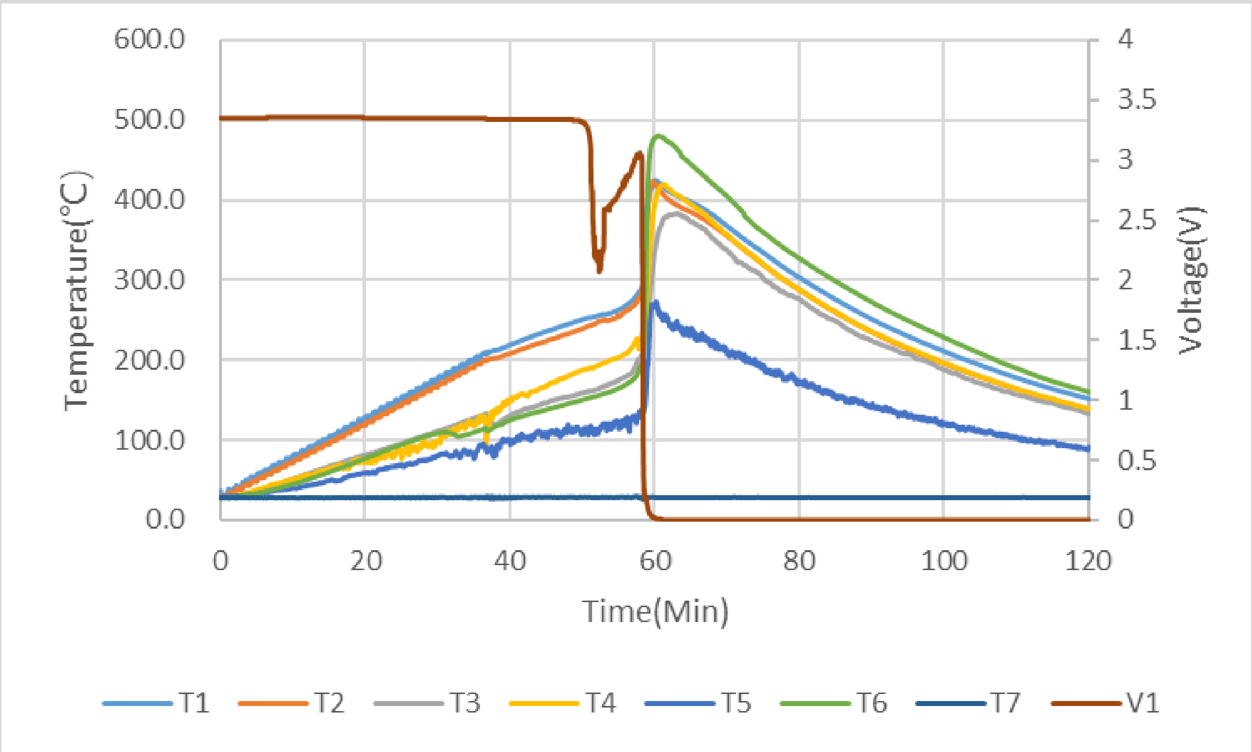
Thermalcouple No.	Location
T1	Cell center below the heater(A side)
T2	Cell center below the heater(B side)
T3	Positive eletrode tap
T4	Near pressure relief valve
T5	Cell narrow side
T6	Cell bottom
T7	Ambient temperature
V1	Cell Voltage

#3



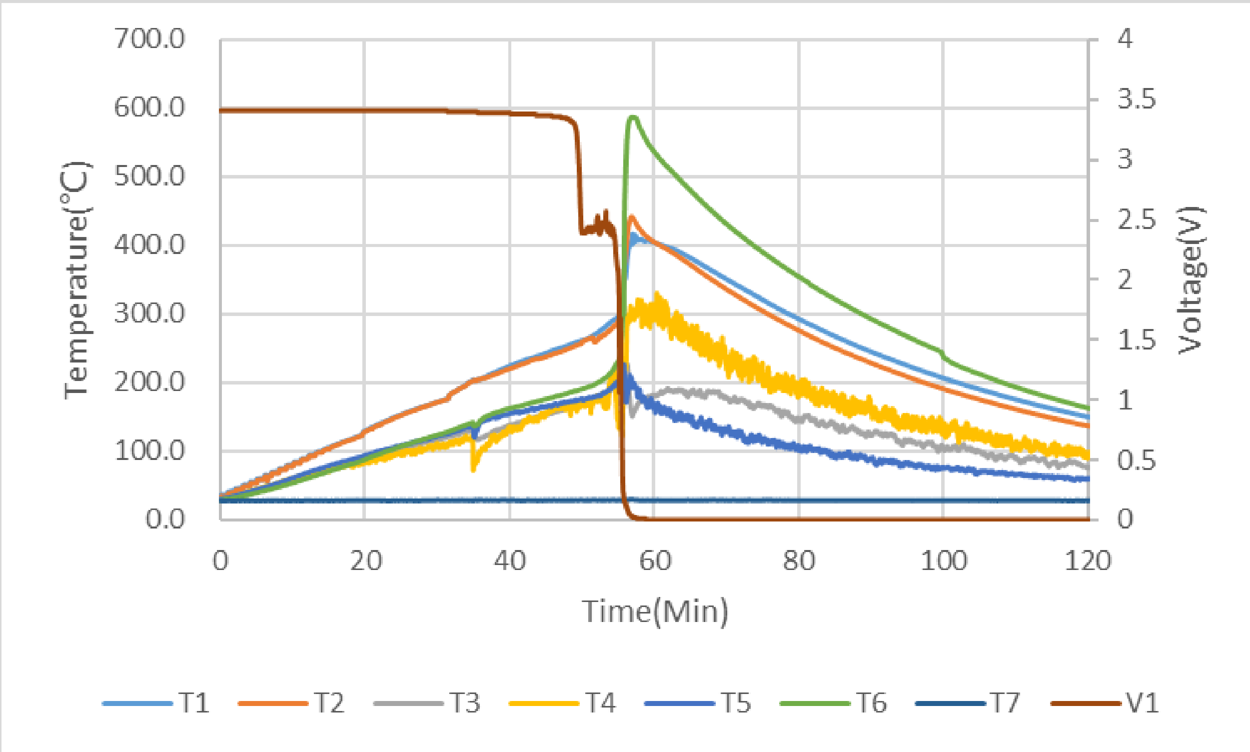
Thermalcouple No.	Location
T1	Cell center below the heater(A side)
T2	Cell center below the heater(B side)
T3	Positive eletrode tap
T4	Near pressure relief valve
T5	Cell narrow side
T6	Cell bottom
T7	Ambient temperature
V1	Cell Voltage

#4



Thermalcouple No.	Location
T1	Cell center below the heater(A side)
T2	Cell center below the heater(B side)
T3	Positive eletrode tap
T4	Near pressure relief valve
T5	Cell narrow side
T6	Cell bottom
T7	Ambient temperature
V1	Cell Voltage

#5



Thermalcouple No.	Location
T1	Cell center below the heater(A side)
T2	Cell center below the heater(B side)
T3	Positive eletrode tap
T4	Near pressure relief valve
T5	Cell narrow side
T6	Cell bottom
T7	Ambient temperature
V1	Cell Voltage

3.4 Cell vent gas generation and capturing

3.4.1 Test method and description

The cells to be tested were charged to 100% SOC and allowed to stabilize for a minimum of 1 h and a maximum of 8 h before the start of the test.

A cell was forced into thermal runaway by the external heating as determined in cell thermal runaway methodology test inside an 280L pressure vessel.

Before testing, the vessel was purged with N_2 to reduce the oxygen content below 1% by volume.

Gas mixtures were collected before and after thermal runaway testing. 0.3L gas collection bag with two valve were used for the gas collection.

Two bags after thermal runaway were used to determine the vent gas composition.

Cell weight was measured before and after test for reference.

Pressure was measured before and after thermal runaway to calculate the total gas produced for reference.

3.4.2 Test result

Ambient conditions .... :	26.1 °C, 51 % R.H
Sample number .... :	#1
Open circuit voltage before test (V) .... :	3.35
Pressure vessel size.......................... :	280L
Initial oxygen content by volume (%) .. :	< 0.1%
Cell weight before test (g).................. :	5626.0
Cell weight after test (g)...................... :	4474.1
Total vent gas produced (L)................	130

3.5 Determination of cell vent gas composition

3.5.1 Test method

Cell vent gas composition was determined using Gas Chromatography (GC) with detection techniques for quantifying component gases.

The gases make up in table 1 is the gas composition after cell thermal runaway.

Table 2 contains normalized volumetric gas compositions by removing the N_2 contributions. This information was used to synthetically replicated gas mixture for further flammability character parameter tests.

3.5.2 Test result

Table 1: Vent gas components

Gas component	Concentration (v, %)
CH_4	1.1092
C_2H_6	0.1655
C_2H_4	0.4196
C_3H_8	0.0545
C_3H_6	0.2250
n-C_4H_{10}	0.0207
n-C_4H_8	0.0666
n-C_5H_{12}	0.0230
iso- C_5H_{12}	0.0339
n-C_5H_{10}	0.0160
CO	4.8960
CO_2	8.1173
H_2	15.0719
N_2	69.7808

Table 2: Vent gas components (normalized)

The gas components N_2 was removed.

Gas component	Concentration (v, %)
CH_4	3.671
C_2H_6	0.548
C_2H_4	1.389
C_3H_8	0.18
C_3H_6	0.745
n-C_4H_{10}	0.068
n-C_4H_8	0.22
n-C_5H_{12}	0.076
iso-C_5H_{12}	0.112
n-C_5H_{10}	0.053
CO	16.202
CO_2	26.861
H_2	49.875

3.6 Flammability character parameters of the cell vent gas

3.6.1 Test method

Upon determination of the cell vent gas composition, the flammability character parameters were determined on sample of the synthetically replicated gas mixture with maximum uncertainty 2%.

Lower flammability limit (LFL) of the cell vent gas was determined in accordance with ASTM E918, testing at both ambient and cell vent temperatures.

The gas burning velocity was determined in accordance with the Method of Test for Burning Velocity Measurement of Flammable Gases Annex in ISO 817.

The maximum explosion pressure P_{lax} was determined on samples of the synthetically replicated gas mixture in accordance with EN 15967.

Below table show the test result only. Detailed test report refer to Appendix A, Appendix B and Appendix C.

References:

ASTM E 918-19 – Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure

ISO 817: 2014/Amd 1: 2017 – Refrigerants- Designation and safety classification

EN 15967: 2011 – Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours

3.6.2 Test result

LFL at 25°C±5°C and 101±5kPa .... :	8.1%	(see Appendix A for details)
LFL at 205°C±5°C and 101±5kPa ...... :	6.5%	(see Appendix A for details)
Burning Velocity S_u(m/s) at room temperature .... :	0.779	(see Appendix B for details)
P_{max} (MPa) at room temperature .... :	0.78	(see Appendix C for details)

3.7 Photos

Sample #1: Gas generation and capturing setup

Sample #1: After thermal runaway test

Sample #2: Thermal runaway test setup

Sample #2: After thermal runaway test

4 List of Test and Measurement Instruments

No.	Equipment	Model	Rating	Last Cal. date
1	Gas Chromatography	8890	--	2023.09.06
2	Hybrid Recorder	TWC-2A	-50~700°C	2023.03.17
3	Data Acquisition	34970A	10mA-1000mA 0.1-300V	2023.07.06
4	Battery Testing System	CT-4004-5V200A-ATL	5V/200A	2023.07.10
5.	Digital multi-meter	15B+	400mVdc~100Vdc	2023.07.10
6.	Electronic Weight	CHS-D	0-10kg	2023.03.17
7.	Gas acquisition system	WRNK-191 HM90-H3-2-BD-801KZ DTM	0-1200°C -0.1~1.5 MPa 0-1000°C	2023.09.07 2023.09.07 2023.09.07
8.	Oxygen analyzer	HG-BX-O2	0-30%	2023.09.07
9.	Gas lower flammability limit test system			
	Temperature measurement	TJ120-CAXL-116U-10-SPW-M	0-300°C	2023.09.07
	Pressure transducer	PTX50G2-TC-A3-CA-H0-PB	-100~150KPa	2023.09.07
10.	Gas explosion test system			
	Temperature measurement	TJ120-CAXL-116U-10-SPW-M	0-300°C	2023.09.07
	Pressure transducer	Kistler 603CAA	0~100MPa	2023.09.07
	Pressure sensor	HM90-H3-2-V2-F1-W2	-0.1~2.0 MPa -0.1~0.15 MPa	2023.09.07
11.	High speed camera	MV-XG1205GC/M-T MV-XG280GC-T	90fps 409fps	--
12.	Combustible gas combustion rate device			
	Temperature measurement	TJ120-CAXL-116U-10-SPW-M	0-300°C	2023.09.07
	straight steel ruler	dawn 1m	1000mm	2023.09.07

Appendix A: Cell vent gas lower flammability limit (LFL) test

Test Method	ASTM E918-19 Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure
Test Item	The lower flammability of gas mixture
Test Apparatus	Test Vessel: 5L closed sphere Ignition system: Fusing Wire
Preparation of Test Mixture	Partial pressure method used inside the vessel; Accuracy: within 0.2% absolute
Symbol and definition	The symbols used in this report are defined as below except otherwise defined: c_s —— Concentration of sample; T_i —— Initial temperature in each trial; p_i —— Initial pressure in each trial; p_{ex} —— Overpressure in each trial; It is considered flame occurred, if pex / pi ≥ 1.07. L_1 —— The minimum sample concentration that gives flame propagation; L_2 —— The maximum sample concentration that does not give flame propagation; LFL —— Lower flammable limit; LFL is expressed as: LFL = (L1+ L2)/2 Concentration defined in this report means volume percentage.
Remark	This report is effective under the specific condition; please seek for the advice of expert for risk assessment in producing, processing, transportation and storage.

LFL test data at room temperature (part)						
Test Condition	Initial Temperature: 25(±5)°C Initial Pressure: 101(±5)kPa					
No.	cs [%]	Ti [°C]	p_i [kPa]	p_{ex} [kPa]	p_{ex} / p_i	Ignition?
1	7.8	22	101.98	108.35	1.062	N
2	8.0	22	101.73	107.67	1.058	N
3	8.0	23	101.88	108.50	1.065	N
4	8.0	23	101.92	108.31	1.063	N
5	8.2	23	102.04	109.65	1.075	Y
6	8.2	23	101.88	109.98	1.080	Y
7	8.2	23	101.54	109.06	1.074	Y
Test result	L1=8.2 %, L2=8.0%, LFL=8.1 % at 25(±5)°C and 101(±5)kPa					

LFL test data at cell vent temperature (part)						
Test Condition	Initial Temperature: 205(±5)°C Initial Pressure: 101(±5)kPa					
No.	cs [%]	Ti [°C]	p_i [kPa]	p_{ex} [kPa]	p_{ex} / p_i	Ignition?
1	6.2	205	101.00	105.12	1.041	N
2	6.4	206	101.46	107.17	1.056	N
3	6.4	207	100.83	107.69	1.068	N
4	6.4	206	101.60	106.46	1.048	N
5	6.6	206	101.21	108.56	1.073	Y
6	6.6	207	101.33	110.73	1.093	Y
7	6.6	203	100.98	109.44	1.084	Y
Test result	L1=6.6%, L2=6.4%, LFL=6.5% at 205(±5)°C and 101(±5)kPa					

Appendix B: Cell vent gas burning velocity (S_u) test

Same synthetically replicated gas mixture as LFL test was used for the test.

Test Method	ISO 817: 2014 / Amd 1: 2017 Refrigerants - Designation and safety classification
Test Item	Burning velocity of flammable gases
Test Apparatus	Test vessel: Glass tube; length 1500 mm; inner diameter 40 mm Ignition system: Electric spark Recorder: High speed camera
Preparation of Test Mixture	Partial pressure method used inside the vessel; Accuracy: within 0.2% absolute
Symbol and definition	The symbols used in this report are defined as below except otherwise defined: c_S —— Concentration of sample; S_S —— Flame propagation speed； a_f —— Cross-sectional area of flame bottom； A_f —— Flame surface area； S_u is calculated as： $S_u = S_S \times \frac{a_f}{A_f}$
Remark	This report is effective under the specific condition; please seek for the advice of expert for risk assessment in producing, processing, transportation and storage.

Burning velocity test data (part)				
Test Condition	Initial temperature: room temperature Initial pressure: atmospheric pressure The oxidant used: synthetic air Smallest flammable substance content increment: 1.0% volume			
No	c_S [%]	S_S [m/s]	a_f/ A_f [m^2]	S_u [m/s]
1	21%	1.032	0.492	0.508
2	22%	1.267	0.510	0.646
3	23%	1.366	0.511	0.698
4	24%	1.426	0.506	0.722
5	25%	1.483	0.509	0.755
6	26%	1.524	0.511	0.779
7	27%	1.467	0.506	0.742
8	28%	1.432	0.504	0.722
9	29%	1.393	0.501	0.698
Test result	Su= 0.779m/s at room temperature and atmosphere pressure.			

Appendix C: Cell vent gas maximum pressure (P_{max}) test

Same synthetically replicated gas mixture as LFL test was used for the test.

Test Method	EN 15967:2011 Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours
Test Item	Maximum explosion pressure of the gas mixture
Test Apparatus	Test Vessel: 5L closed sphere Ignition system: Fusing Wire
Preparation of Test Mixture	Partial pressure method used inside the vessel; Accuracy: within 0.2% absolute
Symbol and definition	The symbols used in this report are defined as below except otherwise defined: c_s—— Content of flammable substance by volume; p_{exn} —— Explosive overpressure in the n^{th} ignition test at a certain concentration; p_{ex} —— Highest pressure occurring in a closed vessel during the explosion of a specific mixture of flammable substances with air or air and inert gases determined under specified test conditions; P_{Mean}——The average value of the explosion overpressure at a certain concentration; P_{max} —— Maximum explosion pressure; $p_{max}$is expressed as the maximum value of p_{ex}.
Remark	This report is effective under the specific condition; please seek for the advice of expert for risk assessment in producing, processing, transportation and storage.

P_{max} test data (part)						
Test Condition	Initial Temperature: 25(±2)°C Initial Pressure: 101(±5)kPa					
Part of Test Data						
No.	c_s [%]	p_{ex1} [MPa]	p_{ex2} [MPa]	p_{ex3} [MPa]	p_{ex4} [MPa]	p_{ex5} [MPa]
1	19	0.6106	0.6213	0.6119	--	--
2	21	0.6593	0.6599	0.6587	--	--
3	23	0.7070	0.6801	0.6942	--	--
4	25	0.7319	0.7286	0.7308	--	--
5	27	0.7571	0.7565	0.7562	--	--
6	29	0.7550	0.7691	0.7644	--	--
7	29.8	0.7667	0.7693	0.7713	0.7702	0.7688
8	31	0.7796	0.7805	0.7784	0.7815	0.7820
9	31.2	0.7764	0.7782	0.7758	0.7773	0.7672
10	31.4	0.7745	0.7675	0.7583	0.7726	0.7747
11	33	0.7562	0.7517	0.7537	--	--
12	35	0.7350	0.7351	0.7355	--	--

Determination of the explosion pressure			
No.	c_S [%]	P_{Mean} [MPa]	P_{max} [MPa]
1	19	0.6146	0.6213
2	21	0.6593	0.6599
3	23	0.6938	0.7070
4	25	0.7304	0.7319
5	27	0.7566	0.7571
6	29	0.7628	0.7691
7	29.8	0.7693	0.7713
8	31	0.7804	0.7820
9	31.2	0.7750	0.7782
10	31.4	0.7695	0.7747
11	33	0.7539	0.7562
12	35	0.7352	0.7355

Test result	
Content of flammable substance	31 % volume
Smallest flammable substance content increment	0.2% absolute
Maximum explosion pressure (P_{max})	0.78 MPa

End of Test Report

Prüfbericht-Nr.: *Test report no.:*	**CN253I80 001**	**Auftrags-Nr.:** *Order no.:*	326116937
Kunden-Referenz-Nr.: *Client reference no.:*	2084233	**Auftragsdatum:** *Order date:*	2025-06-26

Auftraggeber: *Client:*	**SYL (NINGBO) BATTERY CO., LTD.** No.23 Xingke Zhong Road, Meilin Street, Ninghai, Ningbo City 315609 Zhejiang P.R. China
Prüfgegenstand: *Test item:*	Rechargeable Li-ion Battery Pack
Bezeichnung / Typ-Nr.: *Identification / Type no.:*	SM104KFE5
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:*	2025-07-14
Prüfmuster-Nr.: *Test sample no:*	#2025071401
Prüfzeitraum: *Testing period:*	2025-07-15 ~ 2025-07-22
Ort der Prüfung: *Place of testing:*	See page 5 Testing location
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.
Prüfergebnis*: *Test result*:*	See main report

geprüft von: tested by: Meng Jiang	**genehmigt von:** *authorized by:* Minhao Hu
Datum: *Date:* 2025-08-29 — Meng Jiang	**Ausstellungsdatum:** *Issue date:* 2025-08-29 — Minhao Hu
Stellung / Position: Project Engineer	**Stellung** / Position: Authorizer

Sonstiges:
Other:

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*

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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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. ....:	CN253I80 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...........................:	**SYL (NINGBO) BATTERY CO., LTD.**
Address ....:	No.23 Xingke Zhong Road, Meilin Street, Ninghai, Ningbo City 315609 Zhejiang 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 module 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: Test Setup

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: Module Chemical Heat Release Rate and Smoke Release Rate

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.:	SM104KFE5
Ratings:	332.8 V, 104.5 kWh
Cells in series/parallel:	1P104S
Module dimensions:	2168 mm(L)×790 mm(W)×243 mm(H)
Module weight:	650±10 kg
Module enclosure material:	Plastic cover
Total number of cell(s) went into thermal runaway:	4
Thermal runaway and propagation:	1 initiating cell went into thermal runaway and propagated to 3 adjacent cells
Maximum smoke release rate:	6.1 m^2/s
Total smoke released:	1602.9 m^2
Peak chemical heat release rate:	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 posttest 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 Post-Flaming):

Gas Compound	Gas Type	Pre-Flaming (L)	Post-Flaming (L)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	449.83	No flaming
Carbon Monoxide	Carbon Containing	40.63	No flaming
Carbon Dioxide	Carbon Containing	265.71	No flaming
Hydrogen	Hydrogen	359.81	No flaming
Note: See Attachment F for detailed gas analysis data.			

Result of Testing:

Performance Criteria in accordance with Clause 8.4 and Figure 1.1:

Vent gas is nonflammable as determined by the cell level test;	☐
There is no spread of flame outside of the module; and	☒
The module exterior surface temperature does not exceed the cell venting temperatures as measured adjacent to the initiating cell where the greatest thermal exposure is anticipated.	☒

Necessity of Unit Level Test:

The performance criteria of the module level test as indicated in 8.4 and as shown in Figure 1.1 of UL 9540A 5th 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 5th edition has been met, therefore unit level testing in accordance with UL 9540A need not be conducted.	☐

Tests performed (name of test and test clause):	Testing location:
UL 9540A cl 8. Module Level	HangZhou ZhongChuan Fire Equipment Co., Ltd. No.8, Village 006, Quantou Village, Lankao County, Kaifeng city, Henan Province

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) .... :	SYL (NINGBO) BATTERY CO., LTD. No.8 Sansheng West Road, Meilin Street, Ninghai, Ningbo City 315609 Zhejiang P.R. China
Other: N/A	

UL 9540A Testing Information:

Cell Level Information		
Manufacturer:	Xiamen Hithium Energy Storage Technology Co., Ltd.	
Model number:	LFP71173207/314Ah	
Chemistry:	$LiFePO_4$	
Physical configuration:	Prismatic	
Electrical rating:	Rated capacity:	314 Ah
	Nominal voltage:	3.2 V
UL 9540A cell test report number:	Accepted test report from TÜV Rheinland, Report No.: CN23F118 001	
Average cell surface temperature at gas venting:	203.7°C	
Average cell surface temperature at thermal runaway:	295.7°C	
Gas volume:	130 L	
Lower flammability limit (LFL), % volume in air at the ambient temperature:	8.1%	
Lower flammability limits (LFL), % volume in air at the venting temperature:	6.5%	
Burning velocity (S_u):	0.779 m/s	
Maximum pressure (P_{max}):	0.78 MPa	

Cell Level Gas Composition:

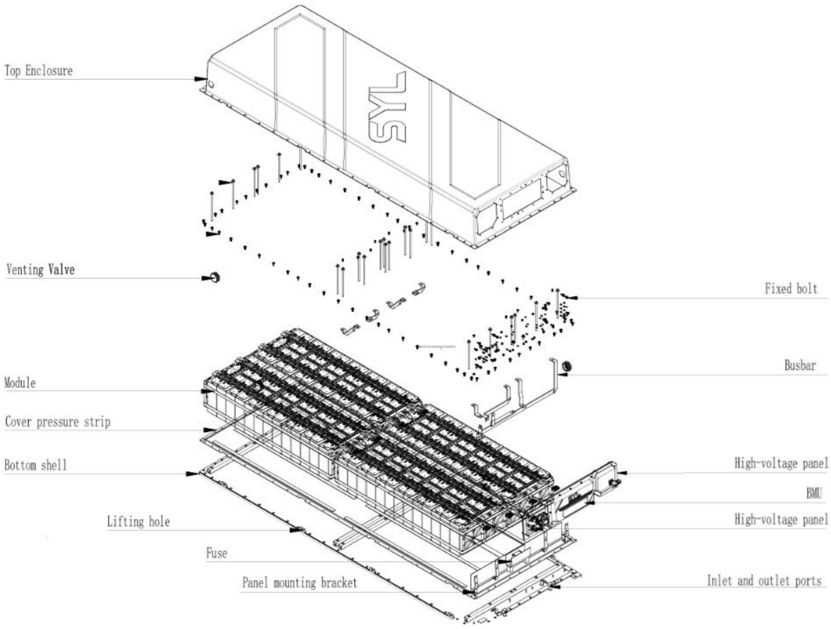
Gas Component		**Concentration % (V/V)**
Methane	CH_4	3.671
Ethylene	C_2H_4	1.389
Ethane	C_2H_6	0.548
Propylene	C_3H_6	0.745
Propane	C_3H_8	0.18
n-Butane	n-C_4H_{10}	0.068
n-Butene	n-C_4H_8	0.22
n-Pentane	n-C_5H_{12}	0.076
iso-Pentane	iso-C_5H_{12}	0.112
n-Pentene	n-C_5H_{10}	0.053

Hydrogen	H_2	49.875
Carbon Monoxide	CO	16.202
Carbon Dioxide	CO_2	26.861
Total	-	100

General Product Information

Photo of module:

Layout of the module contents:



Manufacturer name:		SYL (Ningbo) Battery Co., Ltd.
Model number:		SM104KFE5
Physical configuration:		Plastic cover
		650±10 kg
		Cells in series/parallel: 1P104S
Cooling method:		Liquid cooling
Electrical rating:		Rated capacity: 314 Ah
		Nominal voltage: 332.8 V
Standard charge method:	Standard charge current:	157 A
	Max. charge current:	200 A
	End of charge voltage:	374.4 V
	Temperature range for charging:	0~55 °C
	Recommend charging method:	52 kW CP to max cell voltage reaches 3.6 V
Standard discharge method:	Standard discharge current:	157 A
	Max. discharge current:	200 A
	End of discharge voltage:	260 V
	Temperature range for discharging:	-20~55 °C
	Recommend discharging method	52 kW CP to min cell voltage reaches 2.7 V
Dimension:		2168 mm(L)×790 mm(W)×243 mm(H)
Enclosure material:		PP

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 TÜV Rheinland, Report No.: CN23F118 001	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 TÜV Rheinland, Report No.: CN23RGEH 001 Cert. No.: CU72302476 0001	P
5.1.3	Refer to 7.7.1 for further details to 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 General Product 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.		N/A
5.2.3	Refer to 8.4 for further details to be included in the module level test report.		P
5.3	**Battery energy storage system unit**	Not applicable to module level	N/A
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.		N/A
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
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.		N/A
5.4	**Flow Batteries**	Not applicable to Li-ion cell	N/A

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
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.	See Attachment D	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.		N/A
8	**Module Level**		--
8.1	**Sample**		P
8.1.1	Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a minimum of 2 cycles, using a manufacturer specified methodology to verify that the module is functional. Each cycle shall be defined as a charge to 100% SOC and allowed to rest a maximum of 8 h and then discharged to an end of discharge voltage (EODV) specified by the module manufacturer. During conditioning the ambient temperature and conditions shall be maintained in accordance with 8.2.1.	See Attachment B	P
8.1.2	The module to be tested shall be charged to 100 % SOC or to the manufacturer's specification for a fully charged voltage and allowed to rest for a minimum of 1 hour before the start of the test	The sample stabilized for 2 hours.	P
8.1.3	Prior to initiating the test, the module voltage shall be measured at the module terminals and recorded. If the module is not in a fully charged condition, the module shall be charged again as noted in 8.1.2 and this value shall be recorded.	Module was fully charged prior to initiating the test	P
8.1.4	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.	BMS were not relied upon.	P
8.2	**Test method**		P
8.2.1	Ambient indoor laboratory conditions shall be 25±5°C (77±9°F) and 50±25% RH at the initiation of the test.	See Attachment C	P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
8.2.2	The test shall be conducted under a smoke collection hood that is sized appropriately to collect the gasses generated from the module.		P
8.2.3	The weight of the module shall be recorded before and after testing is completed to determine weight loss.	See Attachment C	P
8.2.4	The number of cells within the module that are forced into thermal runaway can be one or multiple cells. The location of the cell(s) forced into thermal runaway shall be selected to present the greatest thermal exposure to adjacent cells that are not forced into thermal runaway. Factors to be taken into consideration shall include selecting locations within the module where heat transfer is maximized to other cells, cooling by ventilation is restricted or limited, and thermal sensors, detection and suppression discharge points are remote.	One initiating cell was forced into thermal runaway.	P
8.2.5	With reference to 8.2.4, a sufficient number of cells shall be forced into thermal runaway. Cell to cell thermal runaway propagation occurs when at least one additional non-initiating cell goes into thermal runaway during the test. If non-initiating cells only vent during the test, this is not considered a thermal runaway propagation. Temperatures shall be measured on the initiating cells and nearby non-initiating cells.		P
8.2.6	With reference to 8.2.5, temperatures shall be measured on the initiating cells and nearby non-initiating cells to determine thermal runaway propagation. Temperatures shall also be measured on the exterior surface of the module enclosure in the area closest to the initiating cell locations.		P
8.2.7	The methodology used for initiating thermal runaway pursuant to 7.3 shall be used to initiate thermal runaway within the module.	Two external film heaters were used.	P
8.2.8	With reference to 8.2.7, occurrence of thermal runaway shall be verified by sustained temperature above the cell surface temperature at the onset of thermal runaway, as determined in 7.3.1.11.		P
8.2.9	The module shall be placed on top of a non-combustible horizontal surface with the module orientation representative of its intended final installation.		P
8.2.10	The chemical heat release rate of the module in thermal runaway shall be measured with oxygen consumption calorimetry.		P
8.2.11	The chemical heat release rate shall be measured for the duration of the test. See 8.2.12.		P
8.2.12	The chemical heat release rate shall be measured by a measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple.		P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
8.2.13	With reference to 8.2.12, calculate the chemical heat release rate at each of the flows as follows: $HRR_I=[E\times\varphi-(E_{CO}-E)\times\frac{1-\varphi}{2}\times\frac{X_{CO}}{X_{O_2}}]\times\frac{\dot{m}_e}{1+\varphi\times(\alpha-1)}\times\frac{M_{O_2}}{M_a}\times(1-X^O_{H_2O})\times X^O_{O_2}$		P
8.2.14	The hydrocarbon content of the vent gas shall be measured using flame ionization detection. Hydrogen gas shall be measured with an appropriate sensor for the anticipated range of gas as well as for exposure to anticipated contaminants.		P
8.2.15	At the request of the BESS manufacturer, the hydrocarbon components of the vent gas composition 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 m (6.6 feet), or an equivalent gas analyser.		P
8.2.16	The light transmission in the exhaust duct of the heat release rate calorimeter 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. See 8.2.17		P
8.2.17	Smoke release rate shall be calculated as follows: $SRR=2.303(\frac{V}{D})\log_{10}(\frac{I_O}{I})$		P
8.3	**Module test method for high temperature batteries**	Not applicable to Li-ion cell	N/A
8.4	**Module level test report**		P
8.4.1	The report on module level testing shall include the following:		P
	a) Module manufacturer and model number; b) Number of cells in module; c) Module configuration with cells in series and parallel;	See General Product Information	P
	d) Module construction features per 5.2;	See Attachment A	P
	e) Module voltage corresponding to the tested SOC;	See Attachment C	P
	f) Thermal runaway initiation method used including number and locations of cells for initiating thermal runaway;	See Figure 1	P
	g) Heat release rate versus time data;	See Attachment E	P
	h) Flammable gas generation and composition data;	See Attachment F	P
	i) Peak smoke release rate and total smoke release data.	See Attachment E	P
	j) Observation(s) of flying debris or explosive discharge of gases	See Attachment C	P
	k) Observation(s) of sparks, electrical arcs, or other electrical events;	See Attachment C	P
	l) Identification/location of cells(s) that exhibited thermal runaway within the module;	See Figure 1	P

ANSI/CAN/UL 9540A:2025			
Clause	**Requirement - Test**	**Result - Remark**	**Verdict**
	m) Locations and visual estimations of flame extension and duration from the module shall be documented;	See Attachment C	P
	n) Module weight loss based on measurements per 8.2.3; and	See Attachment C	P
	o) Video of the test.	Recorded	P
	p) Cell level test report summary	See page 7	P
8.4.2	Minimum information of items a) through l) were provided in the report for high temperature battery module		N/A
8.5	**Performance at module level testing**		F
8.5.1	Unit level testing in Section 9 is not required if the following performance conditions are met during the module level test:	Unit level testing is required.	F
	a) Vent gas is non-flammable as determined by the cell level test;	Accepted test report from TÜV Rheinland, Report No.: CN23F118 001	F
	b) There is no spread of flame outside of the module; and	No flame was observed	P
	c) The module exterior surface temperature does not exceed the cell venting temperatures as measured adjacent to the initiating cell where the greatest thermal exposure is anticipated.	Max. Temperature during the test: 59.8 °C Criteria Temperature: 203.7 °C	P
8.6	**Performance at high temperature module level testing**		N/A

-- End of Report--

Attachment A: Test Setup

Figure 1. Cell numbering of initiating module

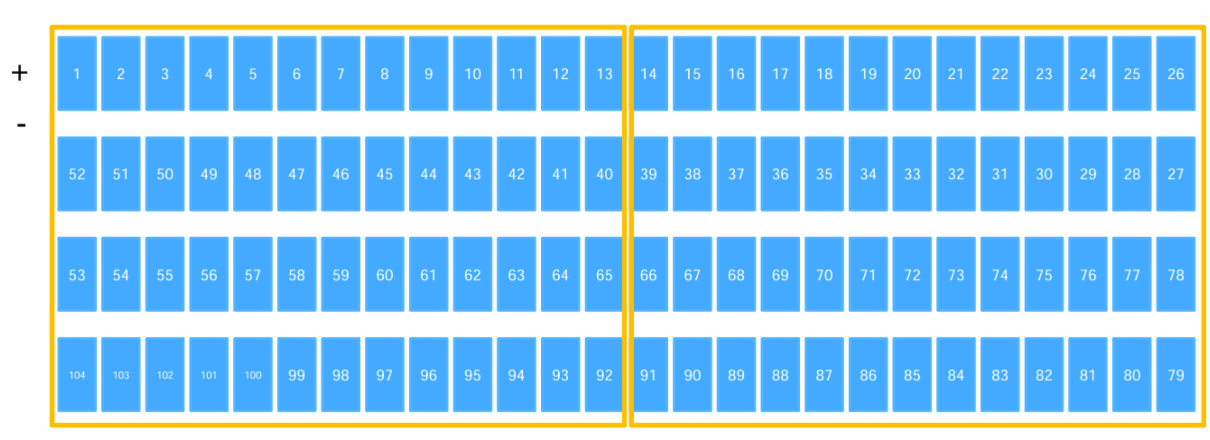


Figure 2.Thermocouple locations of initiating cells

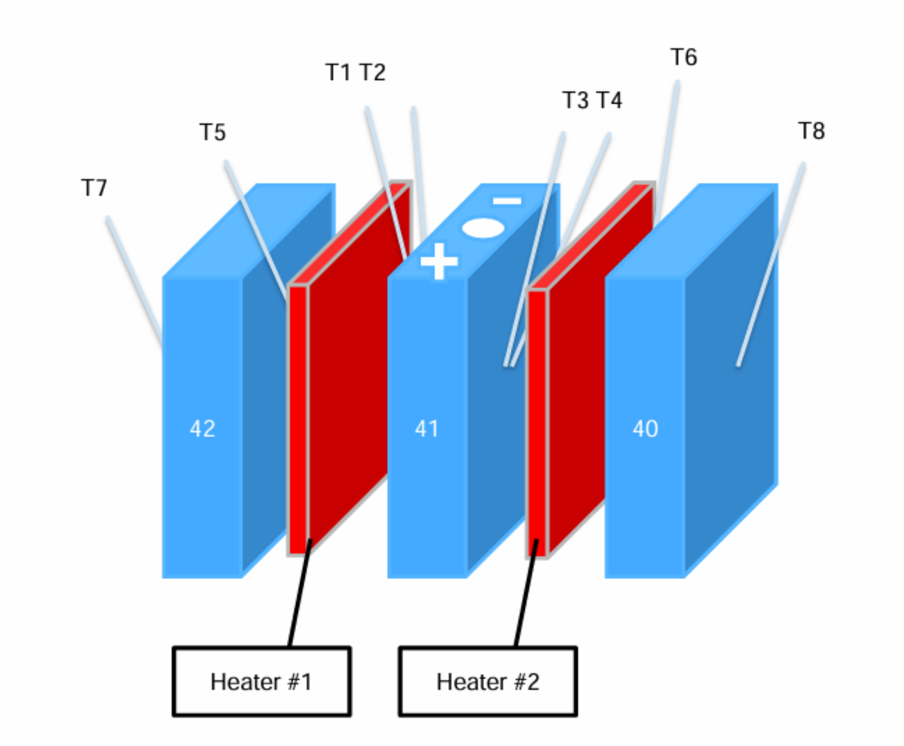


Figure 3. Cell numbering, heater locations and thermocouple locations inside the module

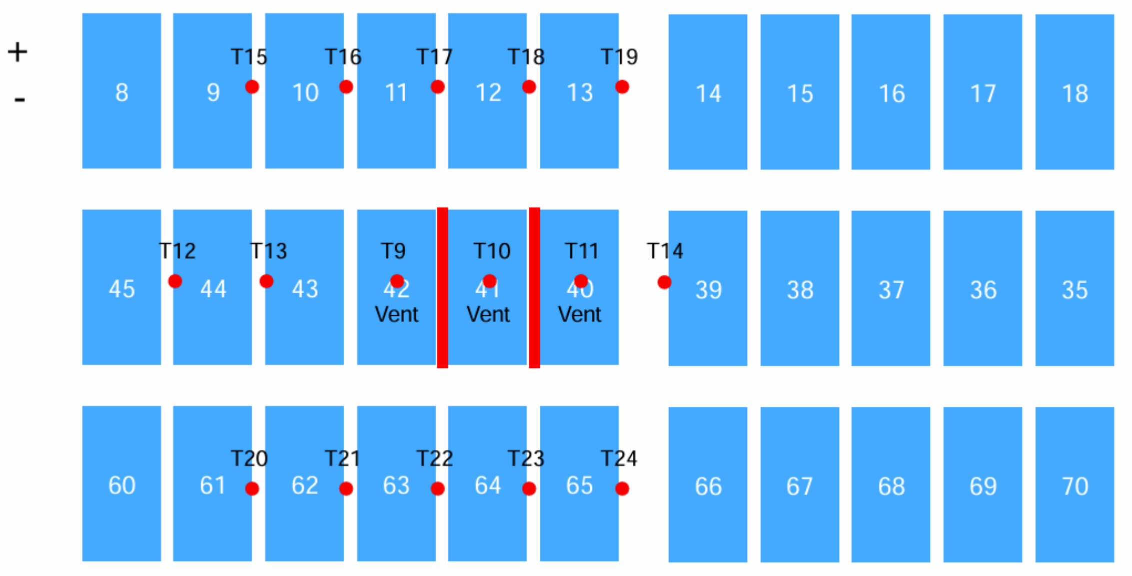
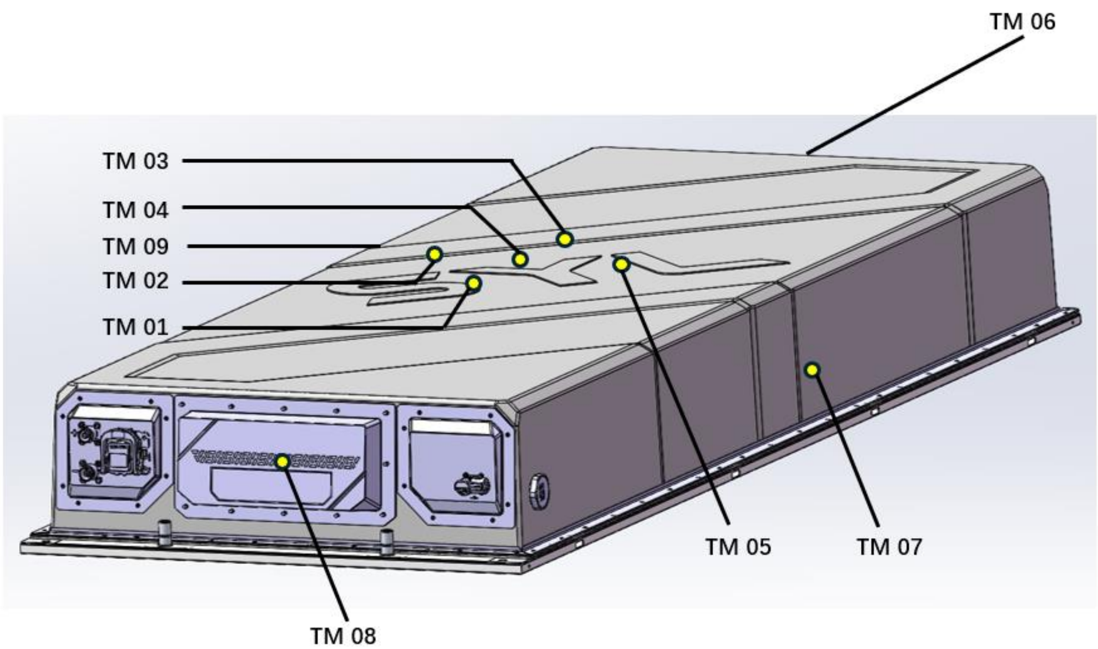


Figure 4. Thermocouple locations outside the module

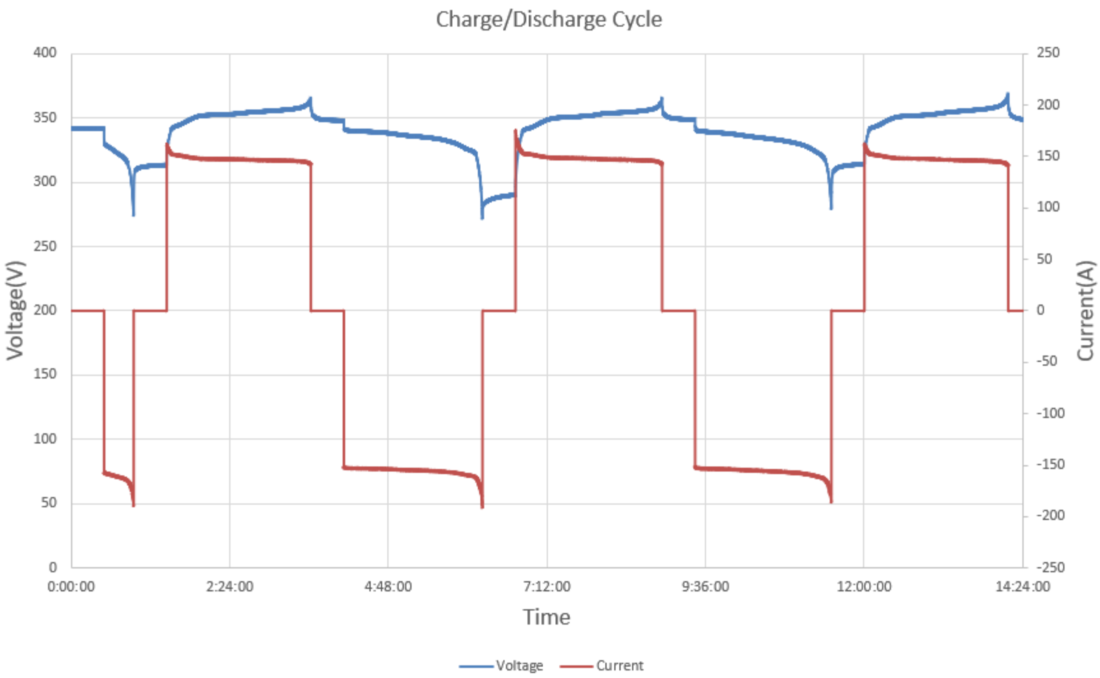


Attachment B: Module Conditioning (Charge/Discharge) Profiles

Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a minimum of 2 cycles, using a manufacturer specified methodology to verify that the module is functional. Each cycle shall be defined as a charge to 100 % SOC and then discharged to an end of discharge voltage (EODV) specified by the module manufacturer.

Ambient indoor laboratory conditions shall be 25 ±5 °C (77 ±9 °F) and 50 ±25 % RH during pre-condition.

Figure 5. Module charge and discharge voltage/current profiles



Attachment C: Observations and Records

Test initiation details	
Ambient conditions at the initiation of the test:	29.6°C, 57.0% R.H.
Sample number:	#2025071401
Open circuit voltage before test:	346.4 V
Weight before test:	643.5 kg (with thermocouples)
Open circuit voltage after test:	332.9 V
Weight after test:	639.0 kg (with thermocouples)
Weight loss:	4.5 kg

Test overview timeline		
Locations (Cell #)	**Event**	**Time**
-	Test start	13:22
#41	Vent	14:03
#41	Thermal runaway	14:11
#40	Vent	14:13
#42	Vent	14:15
#40	Thermal runaway	14:17
#42	Thermal runaway	14:20
#43	Vent	14:24
#43	Thermal runaway	14:28

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 6. Temperature of cell #39~#45

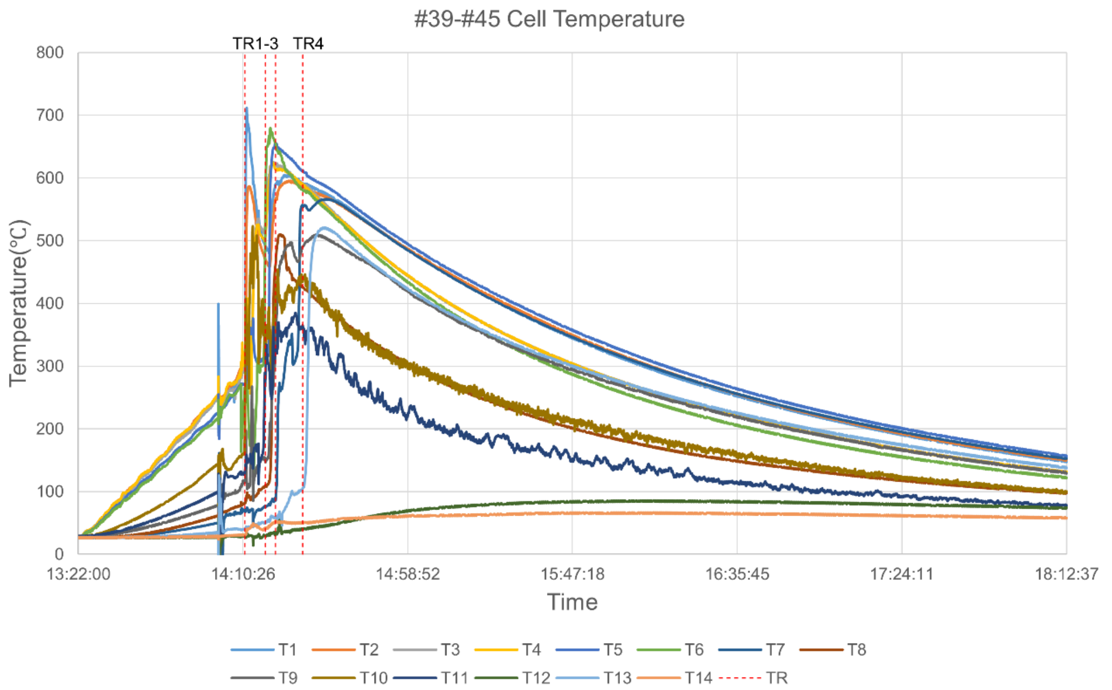
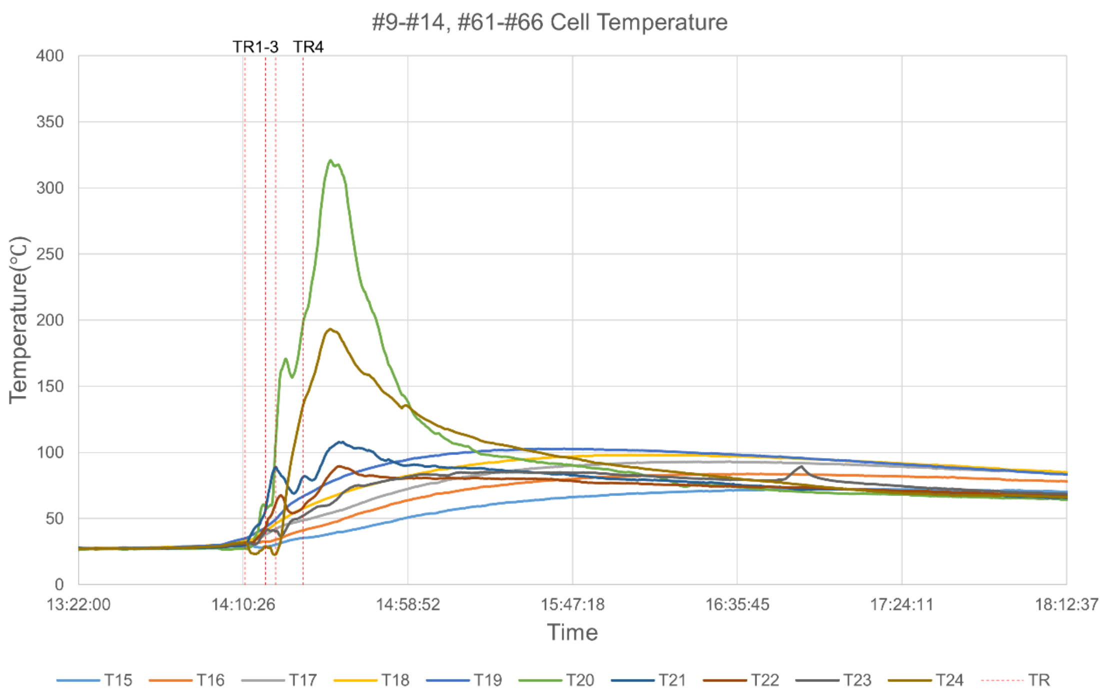


Figure 7. Temperature of cell #9~#14, #61~#66



Maximum Temperature of Module Surface	
UL 9540A Performance Criteria, Cell Surface Temperature at Gas Venting: 203.7°C	
Location	Maximum Temperature (°C)
TM07	59.8

Figure 8. Temperature of module surface

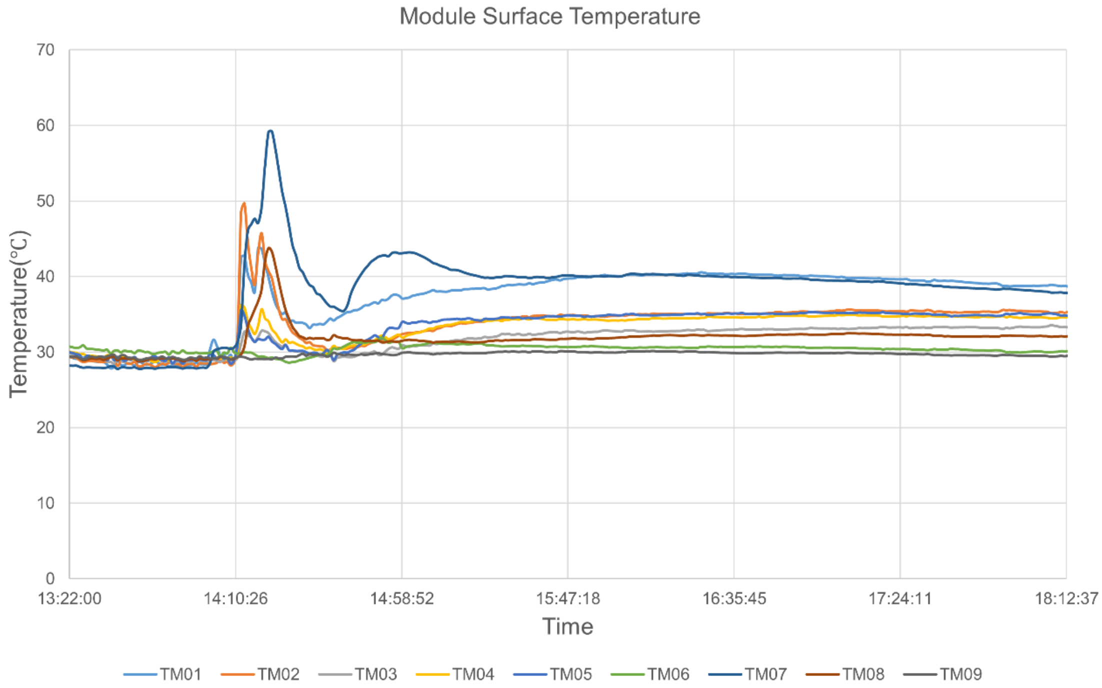
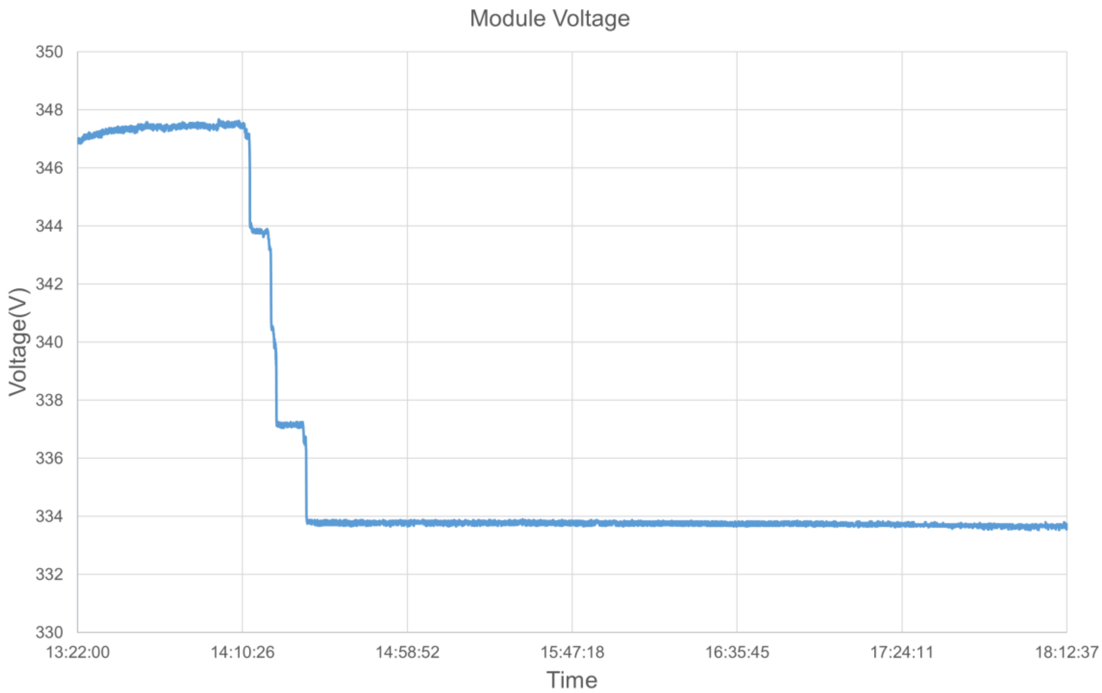


Figure 9. Module voltage



Attachment E: Module Chemical Heat Release Rate and Smoke Release Rate

Smoke and Heat Release Rate		
Smoke Release Rate (SRR)	Maximum SRR(m^2/s)	6.1
	Total Smoke Released(m^2)	1602.9
Heat Release Rate (HRR)	Peak Chemical HRR(kW)	No flaming observed
	Total Heat Release(MJ)	No flaming observed

Figure 10. SRR curve

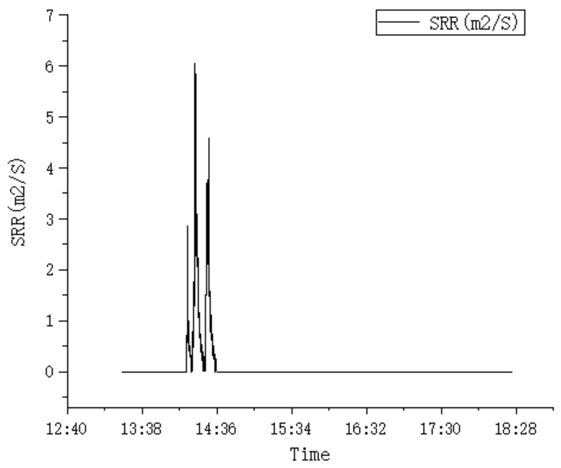
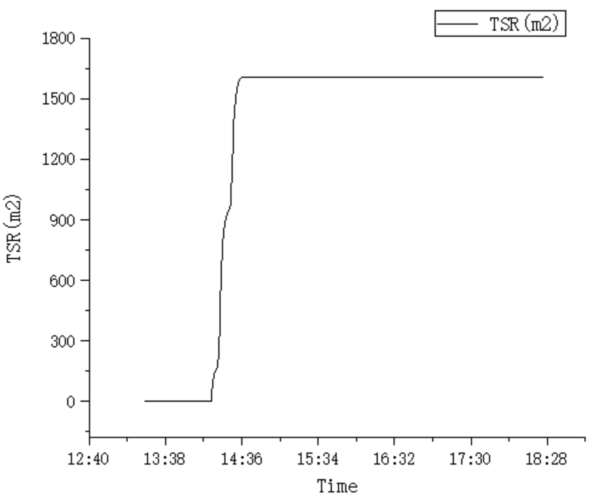


Figure 11. TSR curve



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	449.83	No flaming
Non dispersive infrared analysis	Carbon Monoxide	Carbon Containing	40.63	No flaming
	Carbon Dioxide	Carbon Containing	265.71	No flaming
Solid-state Hydrogen Sensor	Hydrogen	Hydrogen	359.81	No flaming
Note: The collection time is from 13:22 to 18:28				

Measurement Method	**Gas Components**		**Total Volume of Gas (L)**	
			Pre-Flaming	**Post-Flaming**
Fourier-Transform Infrared Spectrometer	Methane	CH_4	47.42	No flaming
	Ethylene	C_2H_4	67.85	No flaming
	Ethane	C_2H_6	11.08	No flaming
	Propylene	C_3H_6	86.08	No flaming
	Propane	C_3H_8	105.44	No flaming

Figure 12. Total hydrocarbons

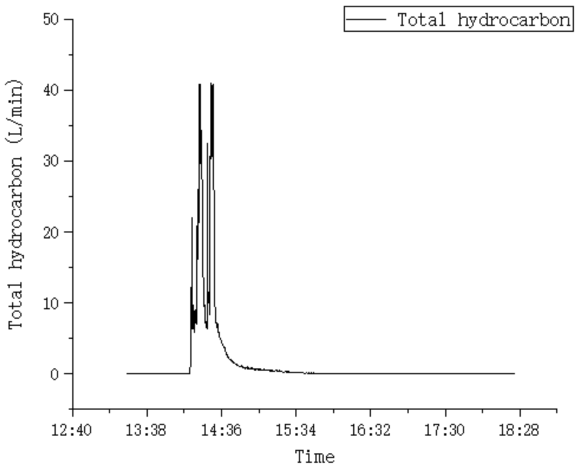


Figure 13. CO, CO_2 concentration

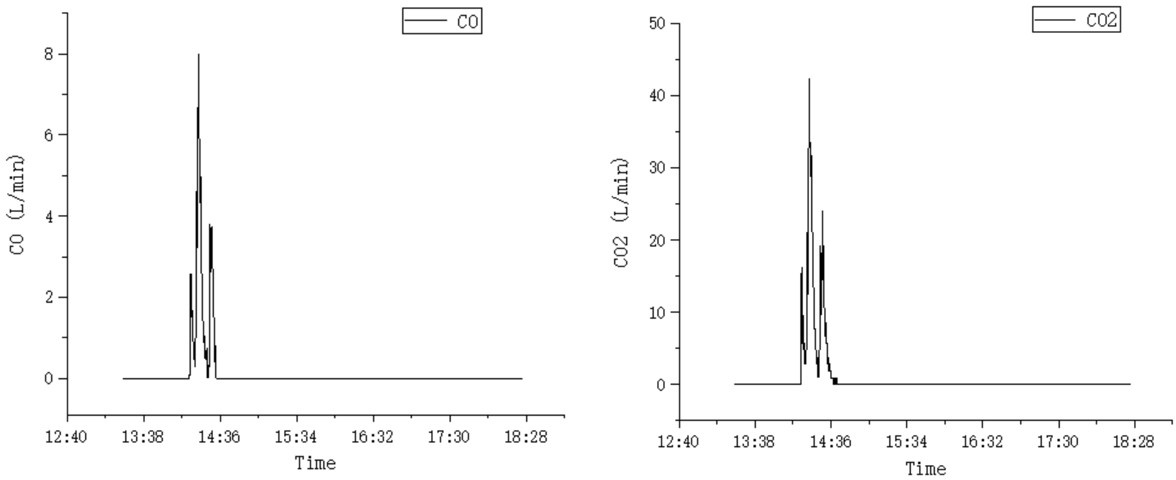


Figure 14. Hydrogen concentration

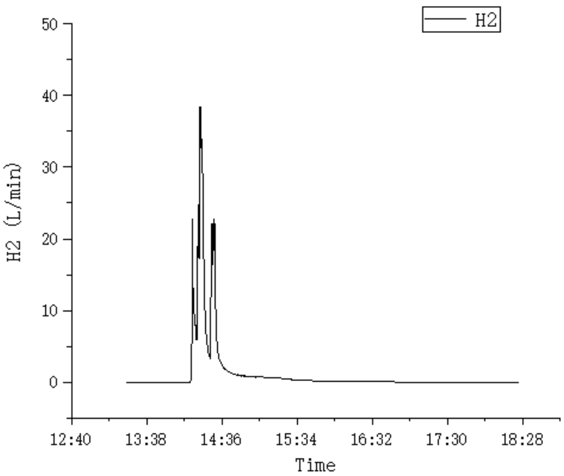
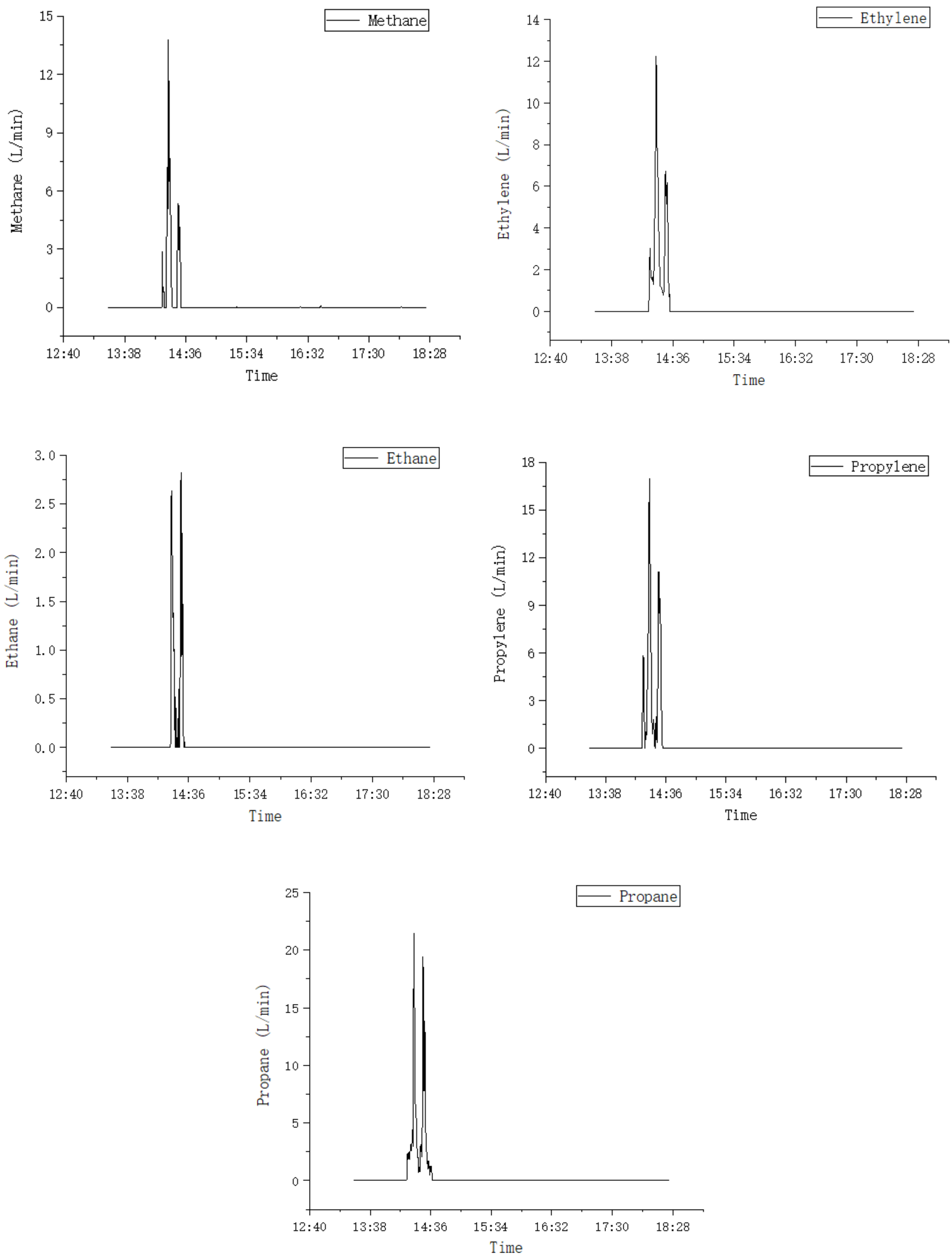


Figure 15. Hydrocarbon species



Attachment G: Sample Photos and Test Photos

Figure 16. Sample before test

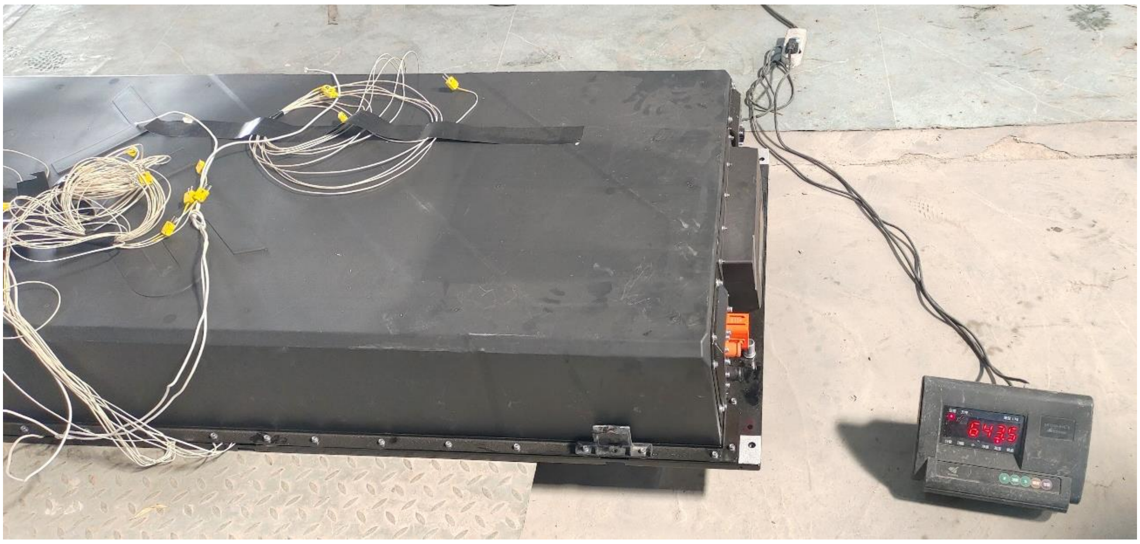
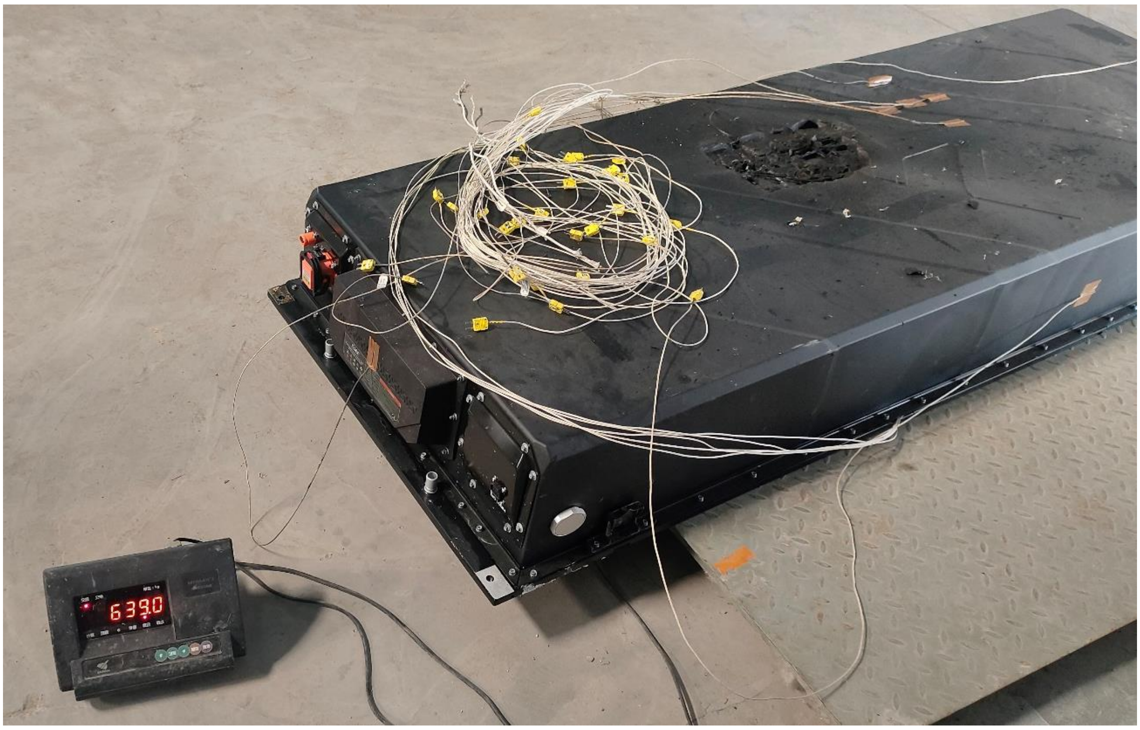
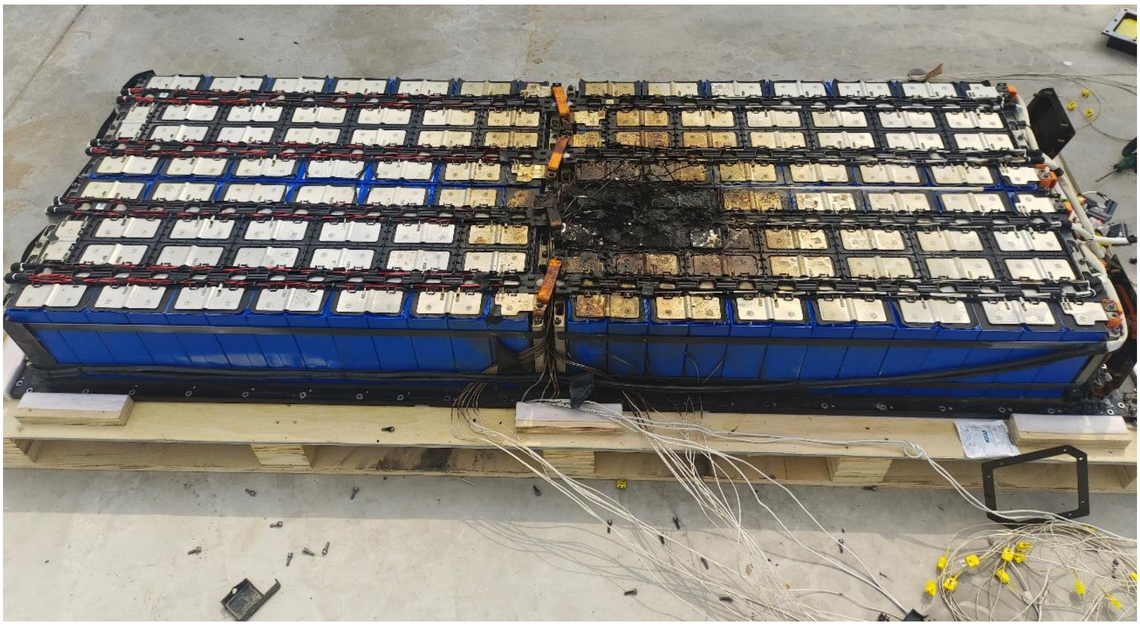


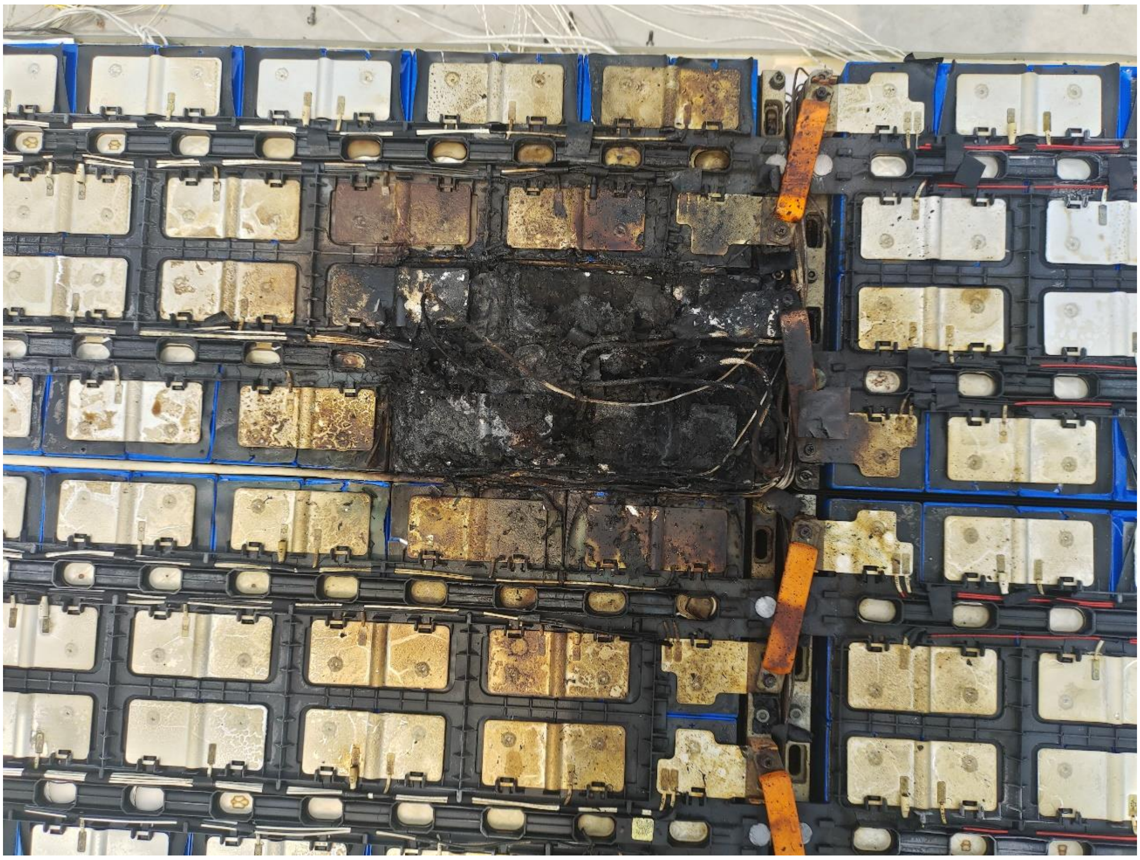
Figure 17. Test setup

Figure 18. Smoke release during test

Figure 19. Sample after test







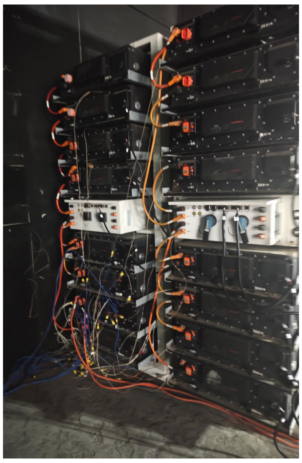
Attachment H: List of Test and Measurement Instruments

No.	Equipment	Model	Rating	Inventory no.	Cal. Expire date
1	Ambient temperature and humidity	SNDWAY SW-572	-30°C ~50°C, 20%RH~100%RH	12005577	2026.2.17
2	Data acquisition equipment	DAQ970A	3-slot cardcage with 6½ digit (22 bit) internal DMM 0.004% basic 1-year dcV accuracy; 0.06% acV accuracy	TY2020000138	2026.2.16
3	Electronic scale	XK3190-A12+E	0-500 kg	65960494169	2026.2.16
4	Paramagnetic oxygen analyser	SERVOMEX4100	O2: paramagnetic sensor, range 0-25%, accuracy 0.02%, response time T90 < 7s	ZY2020000018-1	2026.3.4
5	Velocity probe	2671-25L-D-11-G2-E-N	4-20 mA output, range 0-250pa, accuracy ± 1% F.S	ZY2020000018-2	2026.2.17
6	Photo detector	PDA36A2	Thorlabs optical receiver, wavelength range (350-1000) mm, gain adjustable, voltage output (0-10) V, instability < 0.1%	ZY2020000018-3	2026.2.16
7	Fourier-Transform Infrared Spectrometer	Atmos FIR	Spectral scanning range: 485 - 7500cm-1; Spectral repeatability:< 0.1cm-1	ZY2020000018-5	2026.2.16
8	Non-dispersive infrared carbon dioxide and carbon monoxide sensor	SERVOMEX4100	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	2026.2.16
9	Palladium-nickel thin-film solid state sensor	MODEL 2000	Range: 0-2000ppm, temperature less than 100 ℃, -90~110kPa	ZY2021000210	2026.2.16
10	Flame ionization detector	3010	Accuracy: 2.0%	19937	2026.2.16
11	Heat flux measurement equipment	MW88-JTC08C	0 ~ ± 99999 W/m^2 - 250 ~ 980 °C accuracy 5% response time less than 0.1s	ZY2020000010	2026.2.16
12	Thermopile	RS-WD-HW-1	0-200°C, 4-20 mA, response speed < 0.15 s	28348141942	2026.2.16
13	Data acquisition equipment	TP700	Measuring range -60 °C to 1372 °C Measurement accuracy ± (0.05% rdg.+0.5°C) Display resolution 0.01°C	TY2211000716-2	2026.2.16

14	Data acquisition equipment	TP700	Measuring range-60 °C to 1372 °C Measurement accuracy ±(0.05% rdg.+0.5°C) Display resolution0.01°C	TY2020000217	2026.2.16
15	Multimeter	17b+	AC/DC voltage: 1000V； AC/DC current: 10A； Resistance: 40 ohms Frequency: 100kHz Temperature: 400 degrees Celsius	51631899WS	2026.4.06
16	Low cost metal thermocouple	K-type	(0-1000) °C	/	/
17	Mica heating element	/	Voltage 220V/900W, power cord length of 2 meters, outgoing from the 200 mm side	/	/

Attachment I: Revision Information

New report, no revision information.

Prüfbericht-Nr.: *Test report no.:*	**CN25PS92 001**	**Auftrags-Nr.:** *Order no.:*	326116937	
Kunden-Referenz-Nr.: *Client reference no.:*	2084233	**Auftragsdatum:** *Order date:*	2025-06-26	
Auftraggeber: *Client:*	**SYL (NINGBO) BATTERY CO., LTD.** No.23 Xingke Zhong Road, Meilin Street, Ninghai, Ningbo City 315609 Zhejiang P.R. China			
Prüfgegenstand: *Test item:*	Rechargeable Li-ion Battery System			
Bezeichnung / Typ-Nr.: *Identification / Type no.:*	SR104KFL5n, SR104KFE5n (n=3~4, in step of 1)			
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:*	2025-08-03			
Prüfmuster-Nr.: *Test sample no:*	#2025080301			
Prüfzeitraum: *Testing period:*	2025-08-04 ~ 2025-08-15			
Ort der Prüfung: *Place of testing:*	See page 6 Testing location			
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüfergebnis*: *Test result*:*	See main report			

geprüft von:
tested by: Meng Jiang

Meng Jiang

Datum:
Date: 2025-08-29

Stellung / Position: Project Engineer

genehmigt von:
authorized by: Minhao Hu

Minhao Hu

Ausstellungsdatum:
Issue date: 2025-08-29

Stellung / Position: Authorizer

Sonstiges:
Other:

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*

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 Prüfkonditione n, 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.*
2	Wie vertraglich vereinbart, wurde dieses Dokument nur digital unterzeichnet. Der TÜV Rheinland hat nicht überprüft, welche rechtlichen oder sonstigen diesbezüglichen Anforderungen für dieses Dokument gelten. Diese Überprüfung liegt in der Verantwortung des Benutzers dieses Dokuments. Auf Verlangen des Kunden kann der TÜV Rheinland die Gültigkeit der digitalen Signatur durch ein gesondertes Dokument bestätigen. Diese Anfrage ist an unseren Vertrieb zu richten. Eine Umweltgebühr für einen solchen zusätzlichen Service wird erhoben. Informationen zur Verifizierung der Authentizität unserer Dokumente erhalten Sie auf folgender Webseite: go.tuv.com/digital-signature *As contractually agreed, this document has been signed digitally only. TUV Rheinland has not verified and unable to verify which legal or other pertaining requirements are applicable for this document. Such verification is within the responsibility of the user of this document. Upon request by its client, TUV Rheinland can confirm the validity of the digital signature by a separate document. Such request shall be addressed to our Sales department. An environmental fee for such additional service will be charged. For information on verifying the authenticity of our documents, please visit the following website: go.tuv.com/digital-signature*
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. ....:	CN25PS92 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...........................:	**SYL (NINGBO) BATTERY CO., LTD.**
Address ....:	No.23 Xingke Zhong Road, Meilin Street, Ninghai, Ningbo City 315609 Zhejiang 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:

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: Test Setup

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.:	SR104KFE5n (n=3~4, in step of 1)
Ratings:	1331.2 V, 418 kWh
Cells in series/parallel:	(1P104S)4S
BESS dimensions:	950*2580*2175 mm
BESS weight:	6500 kg
Maximum Target BESS Temperature:	51.2°C
Maximum Wall Surface Temperature:	31.4°C
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:	4
Thermal Runaway and Propagation:	1 initiating cell went into thermal runaway and propagated to 3 adjacent cells
Maximum Smoke Release Rate:	2.14 m^2/s
Total Smoke Released:	759.56 m^2
Peak Chemical Heat Release Rate:	No flaming occurred
Peak Convective Heat Release Rate:	No flaming occurred
Total Heat Release:	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 posttest 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)	☒

Composition & Volume for Each Compound (Pre-Flaming and Post-Faming):

Gas Compound	**Gas Type**	**Pre-Flaming(L)**	**Post-Flaming(L)**
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	306.53	No flaming
Carbon Monoxide	Carbon Containing	26.47	No flaming
Carbon Dioxide	Carbon Containing	217.63	No flaming
Hydrogen	Hydrogen	237.09	No flaming
Note: See Attachment F for detail gas analysis data.			

Result of Testing:

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 occurred, as determined in 7.3.1.10;	☒
Surface temperature measurements on wall surfaces do not exceed 97°C (175°F) of temperature rise above ambient;	☒
Explosion hazards were not observed, including deflagration, detonation or accumulation (to within the flammability limited in an amount that could cause a deflagration) of battery vent gases; and	☒

Necessity for an Installation Level Test:

The performance criteria of the unit level test as indicated in Table 9.1 of UL 9540A 5th 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 5th 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):	**Testing location:**
UL 9540A cl 9. Unit Level	HangZhou ZhongChuan Fire Equipment Co., Ltd. No.8, Village 006, Quantou Village, Lankao County, Kaifeng city, Henan Province

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) .... :	SYL (NINGBO) BATTERY CO., LTD. No.8 Sansheng West Road, Meilin Street, Ninghai, Ningbo City 315609 Zhejiang P.R. China

Other:

N/A

UL 9540A Testing Information:

Cell Level Information		
Manufacturer:	Xiamen Hithium Energy Storage Technology Co., Ltd.	
Model number:	LFP71173207/314Ah	
Chemistry:	$LiFePO_4$	
Physical configuration:	Prismatic	
Electrical rating:	Rated capacity:	314 Ah
	Nominal voltage:	3.2 V
UL 9540A cell test report number:	Accepted test report from TÜV Rheinland, Report No.: CN23F118 001	
Average cell surface temperature at gas venting:	203.7°C	
Average cell surface temperature at thermal runaway:	295.7°C	
Gas volume:	130 L	
Lower flammability limit (LFL), % volume in air at the ambient temperature:	8.1%	
Lower flammability limits (LFL), % volume in air at the venting temperature:	6.5%	
Burning velocity (S_u):	0.779 m/s	
Maximum pressure (P_{max}):	0.78 MPa	

Cell Level Gas Composition:

Gas Component		Concentration % (V/V)
Methane	CH_4	3.671
Ethylene	C_2H_4	1.389
Ethane	C_2H_6	0.548
Propylene	C_3H_6	0.745
Propane	C_3H_8	0.18
n-Butane	n-C_4H_{10}	0.068
n-Butene	n-C_4H_8	0.22
n-Pentane	n-C_5H_{12}	0.076
iso-Pentane	iso-C_5H_{12}	0.112
n-Pentene	n-C_5H_{10}	0.053

Hydrogen	H_2	49.875
Carbon Monoxide	CO	16.202
Carbon Dioxide	CO_2	26.861
Total	-	100

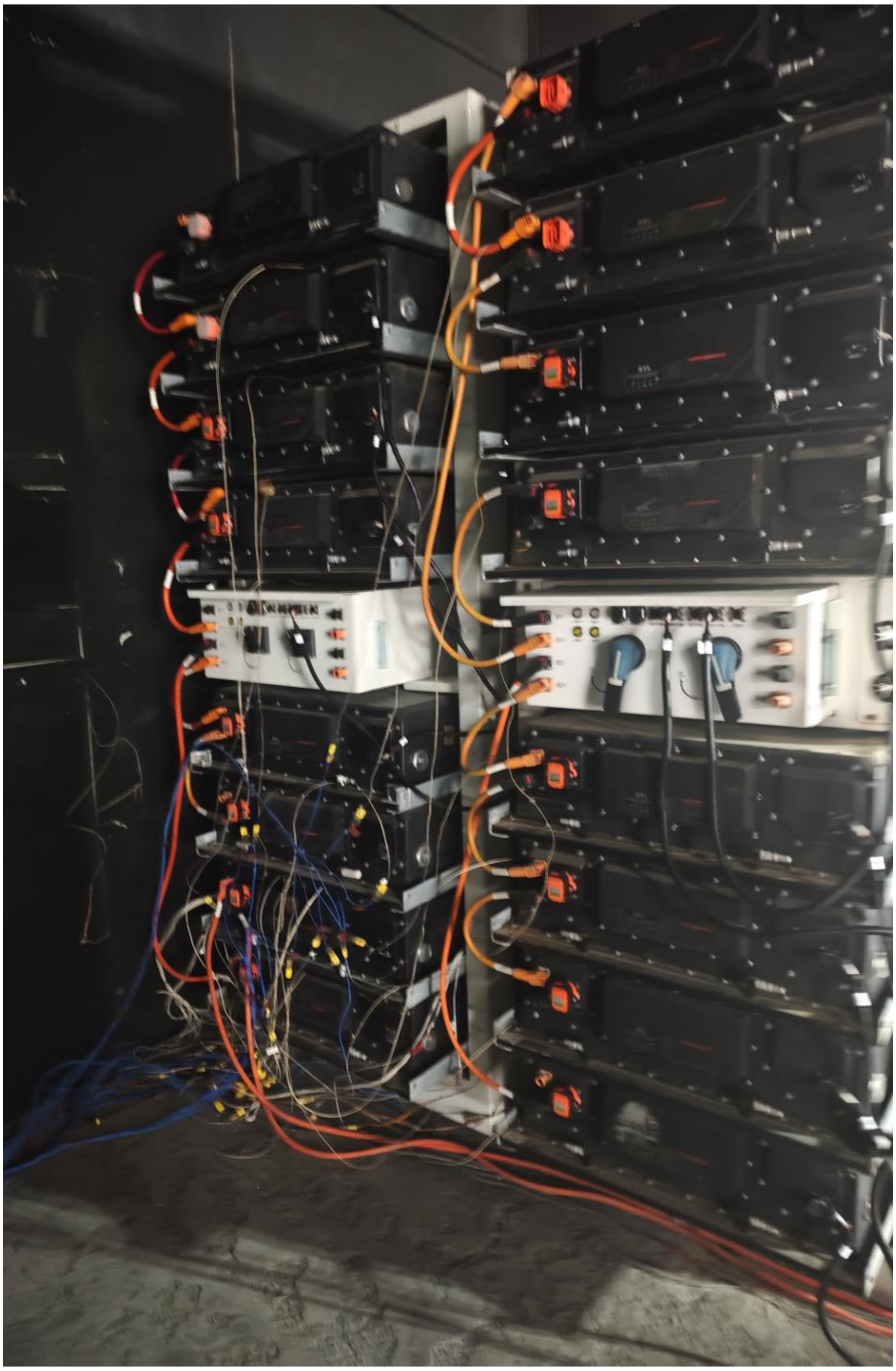
Module Level Information	
Model no.:	SM104KFE5
Ratings:	332.8 V, 104.5 kWh
Cells in series/parallel:	1P104S
Module dimensions:	2168 mm(L)×790 mm(W)×243 mm(H)
Module weight:	650±10 kg
Module enclosure material:	Plastic cover
UL 9540A module test report number:	Accepted test report from TÜV Rheinland, Report No.: CN253I80 001
Total number of cell(s) went into thermal runaway:	4
Thermal runaway propagation:	1 initiating cell went into thermal runaway and propagated to 3 adjacent cells
Maximum smoke release rate:	6.1 m^2/s
Total smoke released:	1602.9 m^2
Peak chemical heat release rate:	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 posttest observation

Gas Composition & Volume for Each Compound (Pre-Flaming and Post-Flaming):

Gas Compound	Gas Type	Pre-Flaming (L)	Post-Flaming (L)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	449.83	No flaming
Carbon Monoxide	Carbon Containing	40.63	No flaming
Carbon Dioxide	Carbon Containing	265.71	No flaming
Hydrogen	Hydrogen	359.81	No flaming

General product information

Photo of battery system



Parameter	Specification	
Product	Rechargeable Li-ion Battery System	Rechargeable Li-ion Battery System
Type/model	SR104KFL53	SR104KFL54

Cell Capacity	314 Ah	314 Ah
Cell Quantity	312	416
Battery structure	(104)3S	(104)4S
Nominal voltage	998.4 V	1331.2 V
Rated capacity	313.5 kWh	418 kWh
Upper limit charging voltage	1123.3 V	1497.6 V
Discharge cut-off voltage	842.4 V	1123.2 V
Maximum charging current	100 A	100 A
Maximum discharging current	100 A	100 A
Temperature range for charging	0~55°C (Environment)	0~55°C (Environment)
Temperature range for discharging	-20~ 55°C (Environment)	-20~ 55°C (Environment)
Recommend charging method by manufacturer	78 kW CP to max cell voltage reaches 3.6 V	104 kW CP to max cell voltage reaches 3.6 V
Recommend discharging method by manufacturer	78 kW CP to min cell voltage reaches 2.7 V	104 kW CP to min cell voltage reaches 2.7 V
Dimension	950*2580*2175 mm	950*2580*2175 mm
Weight	6500 kg	6500 kg
Cooling type	Liquid cooling	Liquid cooling

Parameter	**Specification**	
Product	Rechargeable Li-ion Battery System	Rechargeable Li-ion Battery System
Type/model	SR104KFE53	SR104KFE54
Cell Capacity	314 Ah	314 Ah
Cell Quantity	312	416
Battery structure	(104)3S	(104)4S

Nominal voltage	998.4 V	1331.2 V
Rated capacity	313.5 kWh	418 kWh
Upper limit charging voltage	1123.2 V	1497.6 V
Discharge cut-off voltage	842.4 V	1123.2 V
Maximum charging current	200 A	200 A
Maximum discharging current	200 A	200 A
Temperature range for charging	0~55°C (Environment)	0~55°C (Environment)
Temperature range for discharging	-20~ 55°C (Environment)	-20~ 55°C (Environment)
Recommend charging method by manufacturer	156 kW CP to max cell voltage reaches 3.6 V	208 kW CP to max cell voltage reaches 3.6 V
Recommend discharging method by manufacturer	156 kW CP to min cell voltage reaches 2.7 V	208 kW CP to min cell voltage reaches 2.7 V
Dimension	950*2580*2175 mm	950*2580*2175 mm
Weight	6500 kg	6500 kg
Cooling type	Liquid cooling	Liquid cooling

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 TÜV Rheinland, Report No.: CN23F118 001	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 TÜV Rheinland, Report No.: CN23RGEH 001 Cert. No.: CU72302476 0001	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.		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**		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.		N/A
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
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

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
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
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 4-11 for test installations	P

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
	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
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

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
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 4	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
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

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
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 4	P
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

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
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
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

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
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
	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

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
	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
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 5	P
	c) The construction of the initiating BESS unit per 5.3;	See figure 5	P

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
	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 5	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 4	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 4	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 4	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
	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

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Clause	**Requirement – Test**	**Result - Remark**	**Verdict**
	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: 51.2°C Criteria Temperature: 203.7°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: 31.4°C Criteria Temperature: 126.5°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: Test Setup

Figure 1. Cell numbering of initiating module

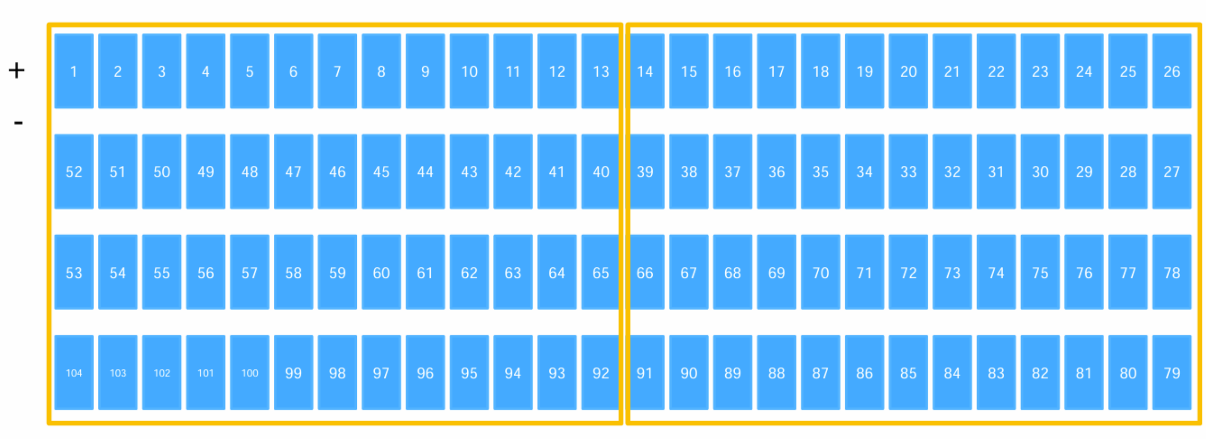


Figure 2. Thermocouple locations of initiating cell

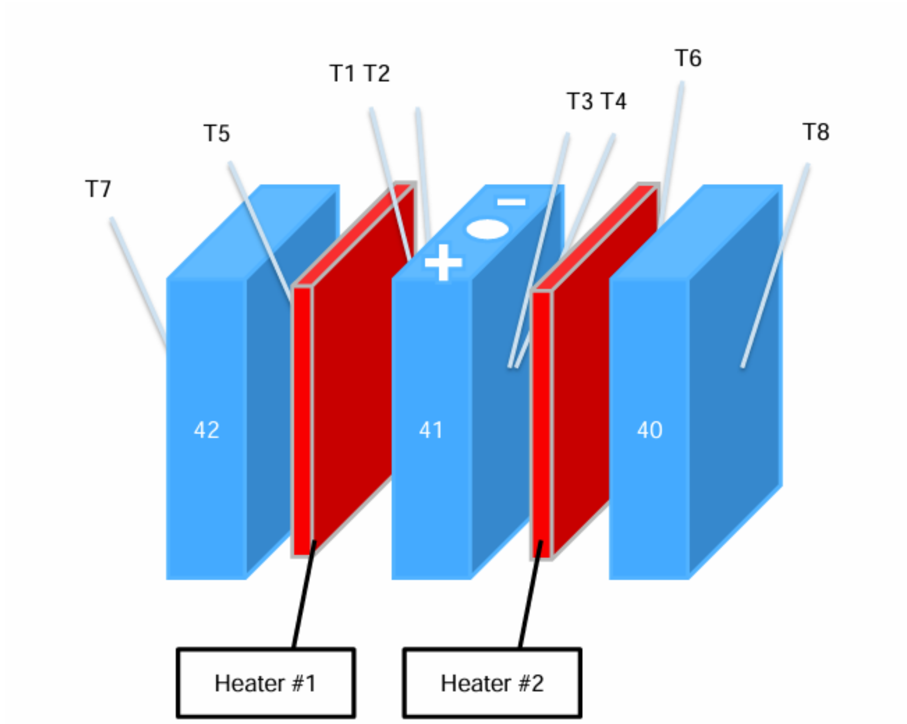


Figure 3. Cell numbering, heater locations and thermocouple locations inside the module

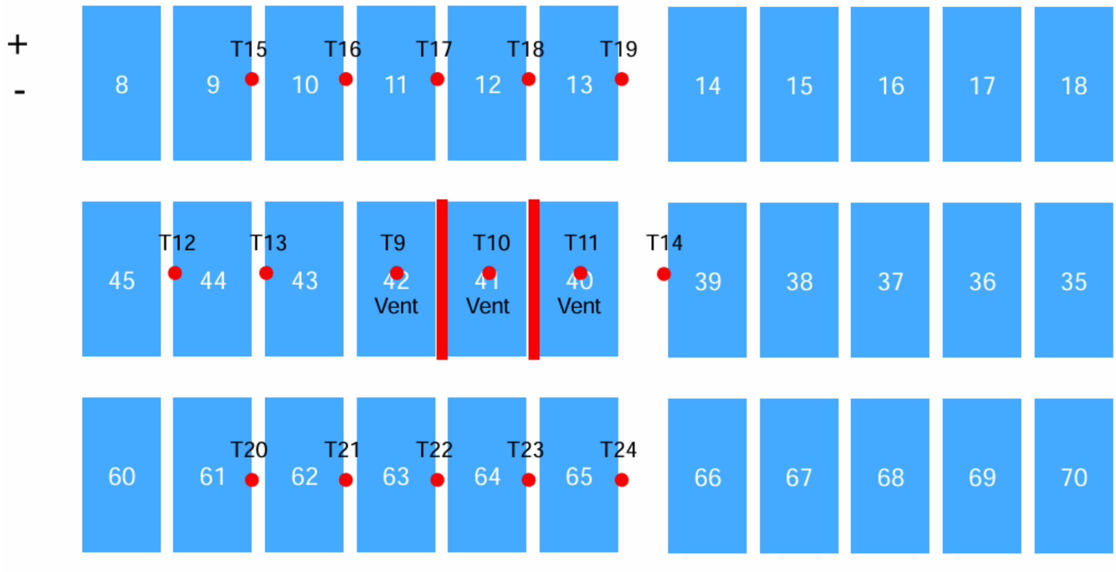


Figure 4. Thermocouple locations outside the module

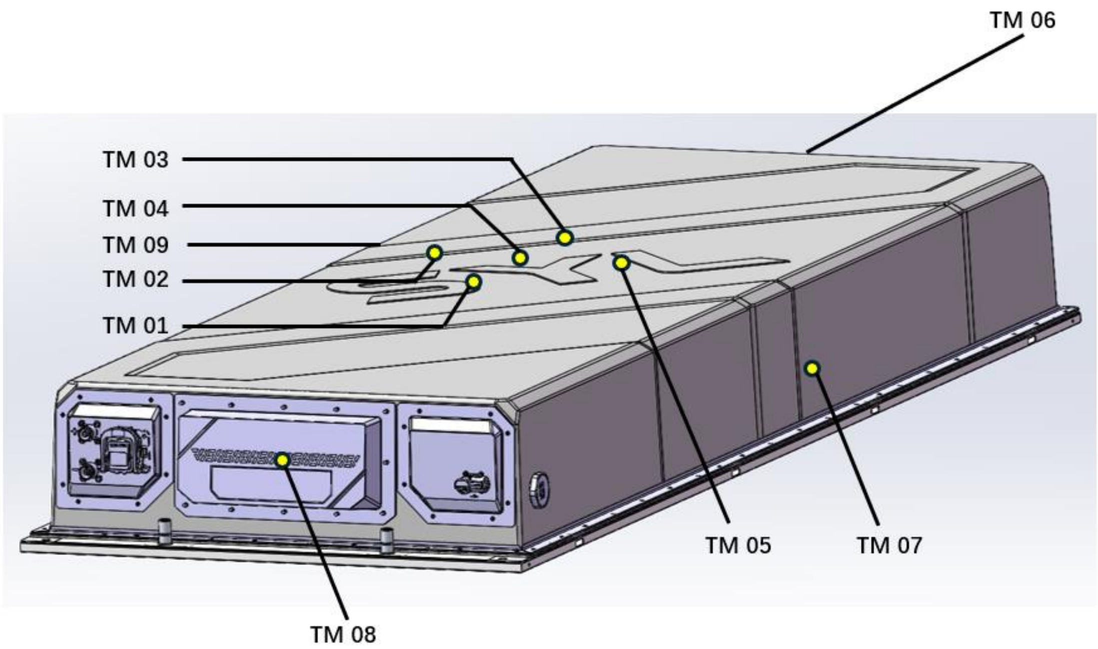


Figure 5. Test site setup diagram with separation distance (Top view)

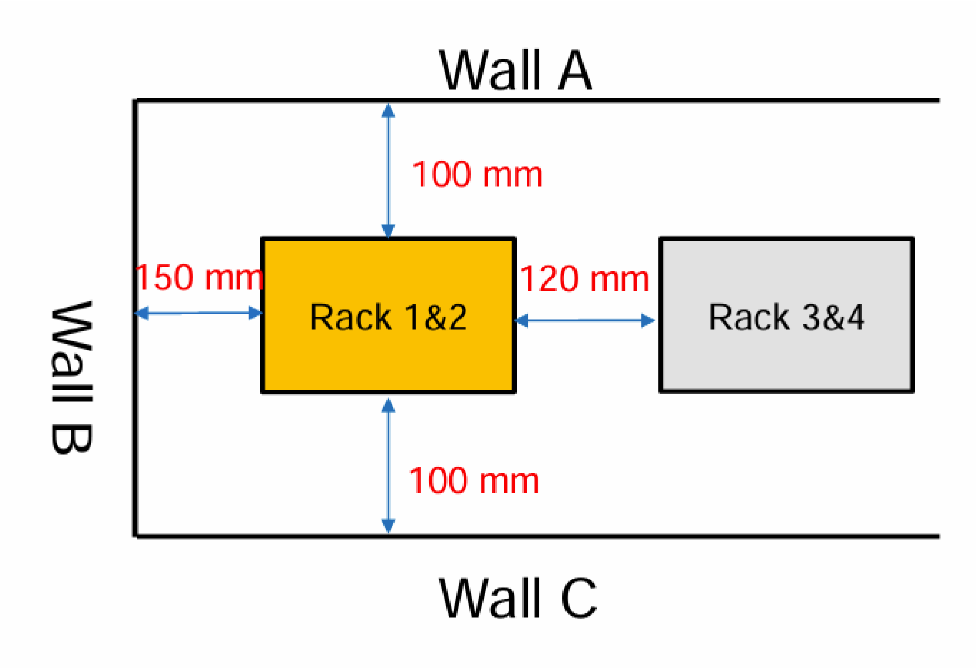


Figure 6. Module numbering in units

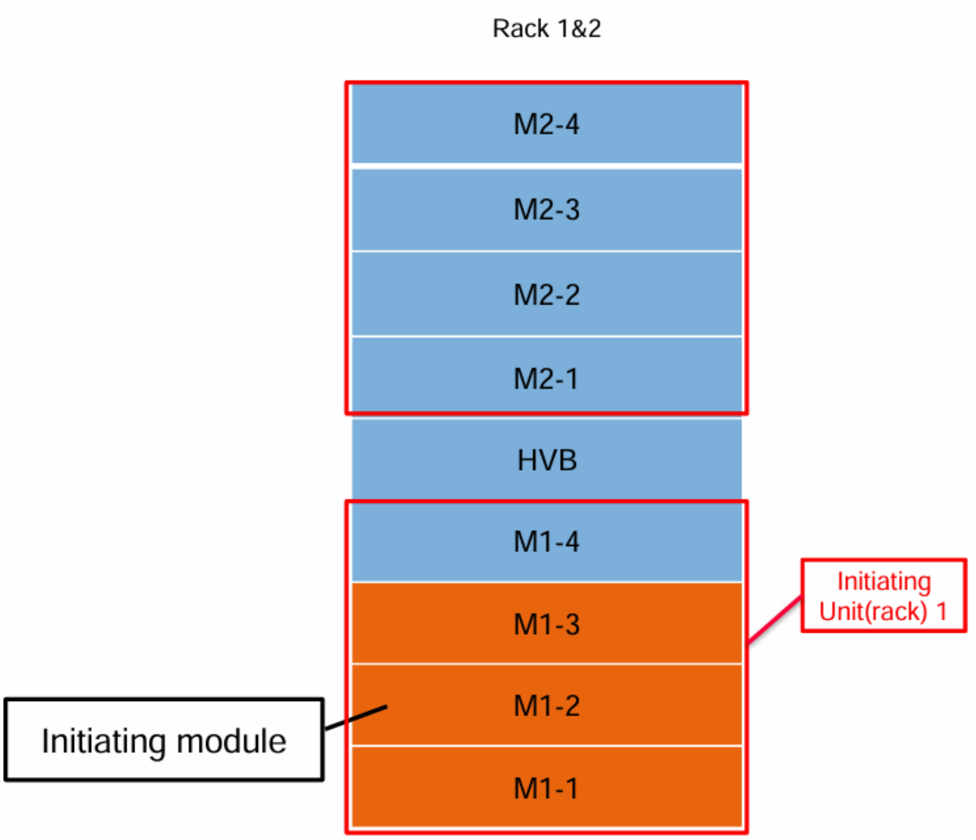
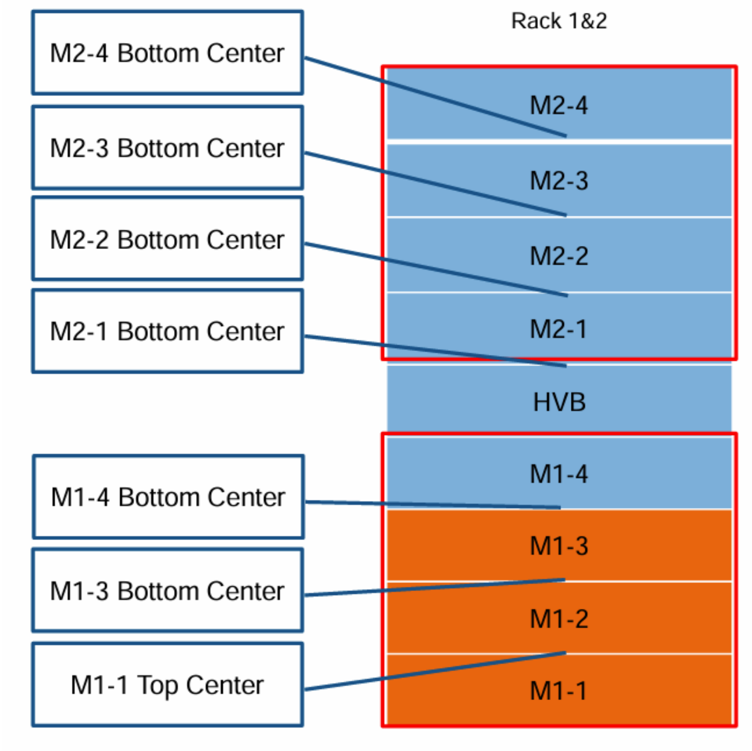
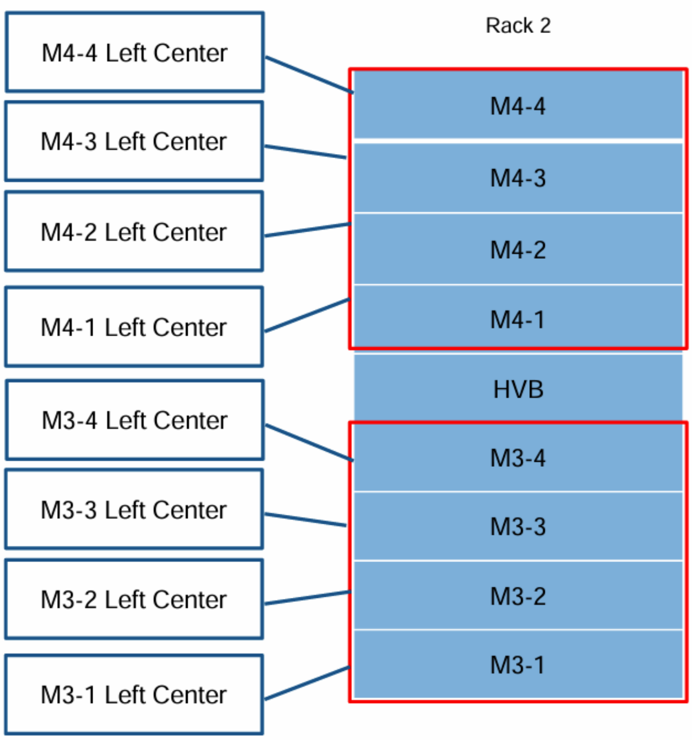


Figure 7. Thermocouple locations on modules in initiating rack 1&2



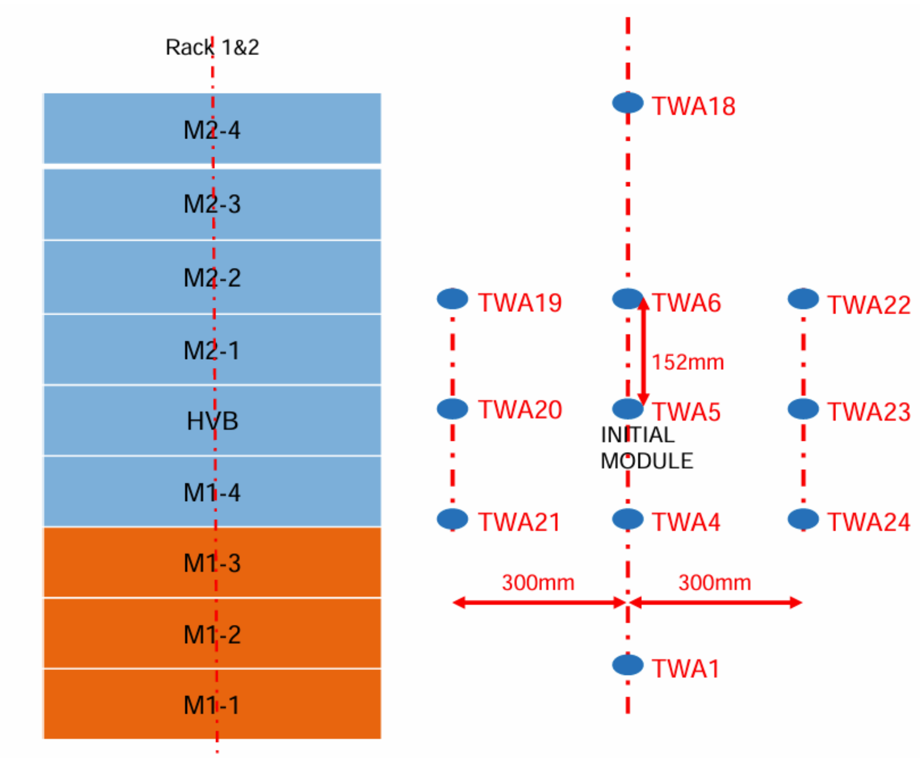
View direction: towards instrument wall A with reference to Figure 4

Figure 8. Thermocouple locations on modules in target rack 3&4



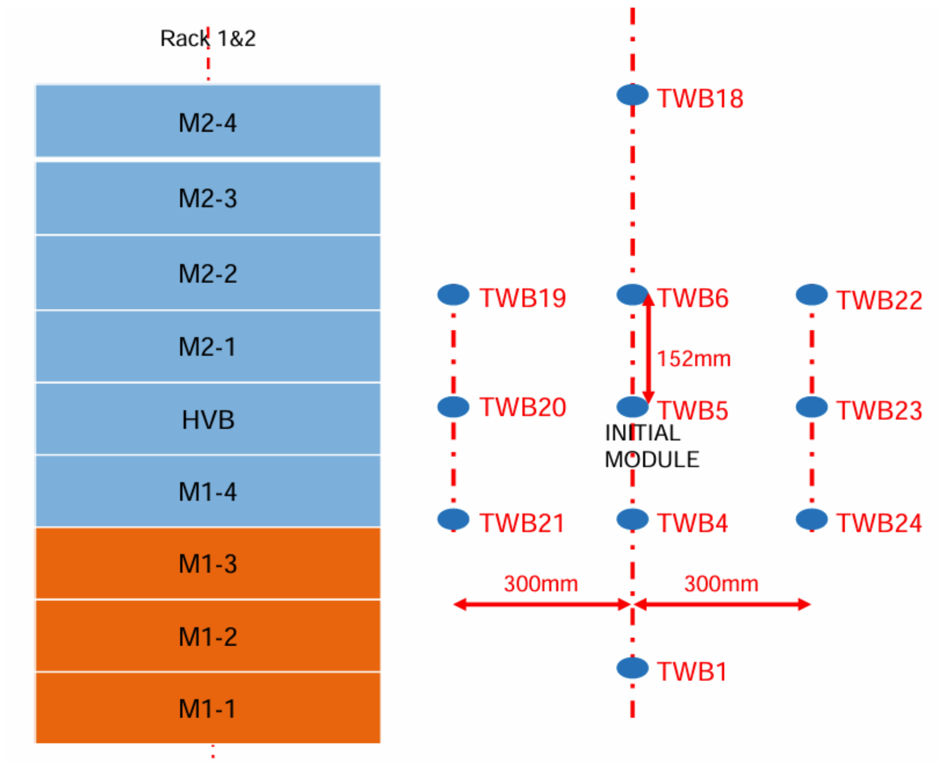
View direction: backward instrument wall A with reference to Figure 4

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



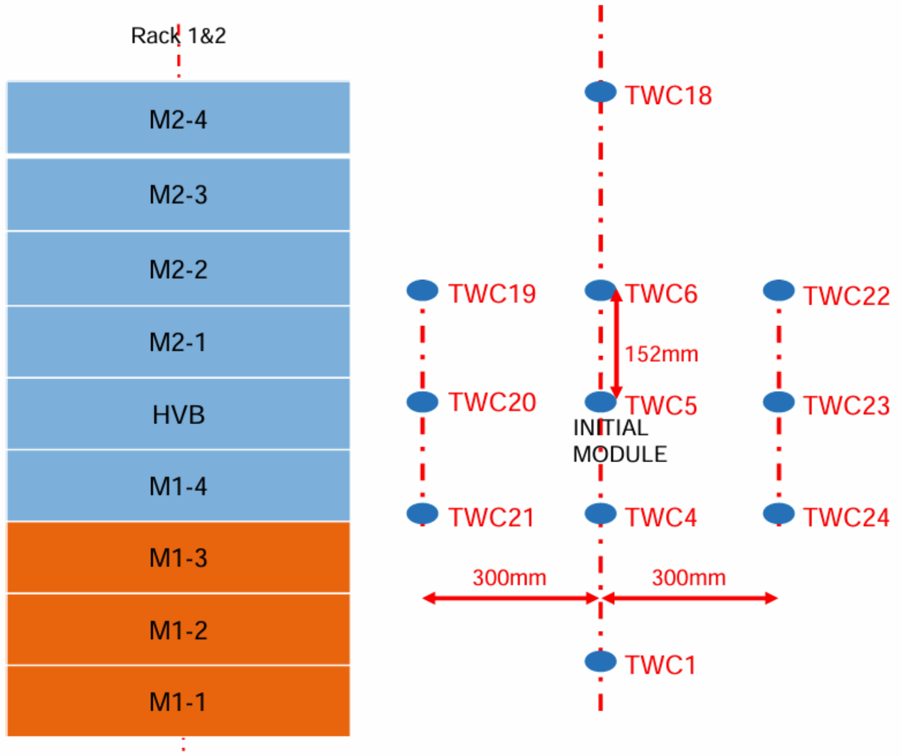
View direction: towards instrument wall A with reference to Figure 4

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



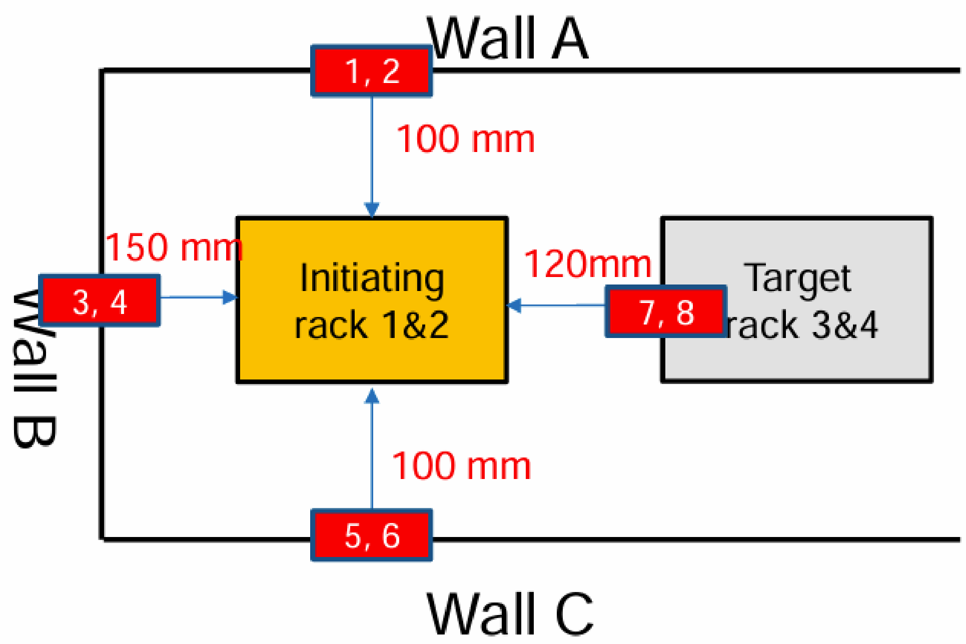
View direction: towards instrument wall B with reference to Figure 4

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



View direction: towards instrument wall C with reference to Figure 4

Figure 12. Heat flux sensor locations on instrument walls

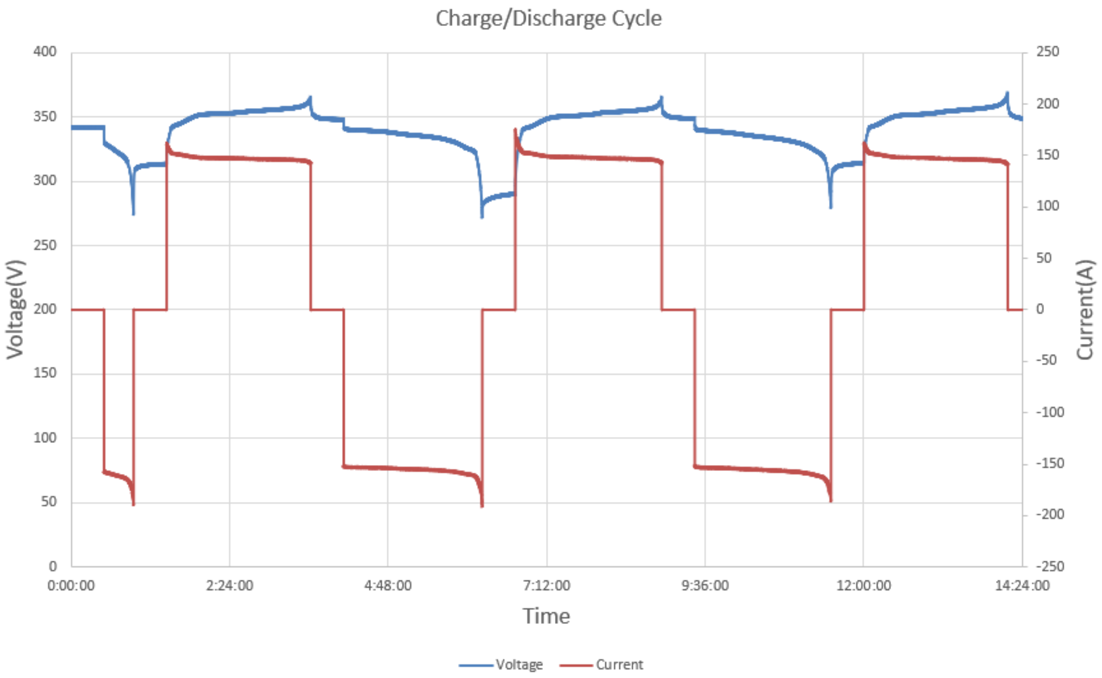


Attachment B: Module Conditioning (Charge/Discharge) Profiles

Module samples shall be conditioned, prior to testing, through charge and discharge cycles for a minimum of 2 cycles, using a manufacturer specified methodology to verify that the module is functional. Each cycle shall be defined as a charge to 100 % SOC and then discharged to an end of discharge voltage (EODV) specified by the module manufacturer.

Ambient indoor laboratory conditions shall be 25 ±5 °C (77 ±9 °F) and 50 ±25 % RH during pre-condition.

Figure 13. Module charge and discharge voltage/current profiles



Attachment C: Observations and Records

Test initiation details	
Ambient conditions at the initiation of the test:	29.5°C, 45.0% R.H.
Sample number:	#2025080301
Open circuit voltage before test:	346.4 V
Weight before test:	645.0 kg (with thermocouples)
Open circuit voltage after test:	332.9 V
Weight after test:	642.5 kg (with thermocouples)
Weight loss:	2.5 kg

Test overview timeline

Locations (Cell #)	Event	Time
-	Test start	15:34
#41	Vent	16:16
#40	Vent	16:26
#42	Vent	16:28
#41	Thermal runaway	16:28
#40	Thermal runaway	16:39
#42	Thermal runaway	16:43
#43	Vent	16:48
#43	Thermal runaway	16:50

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. Temperature of cell #39~#45

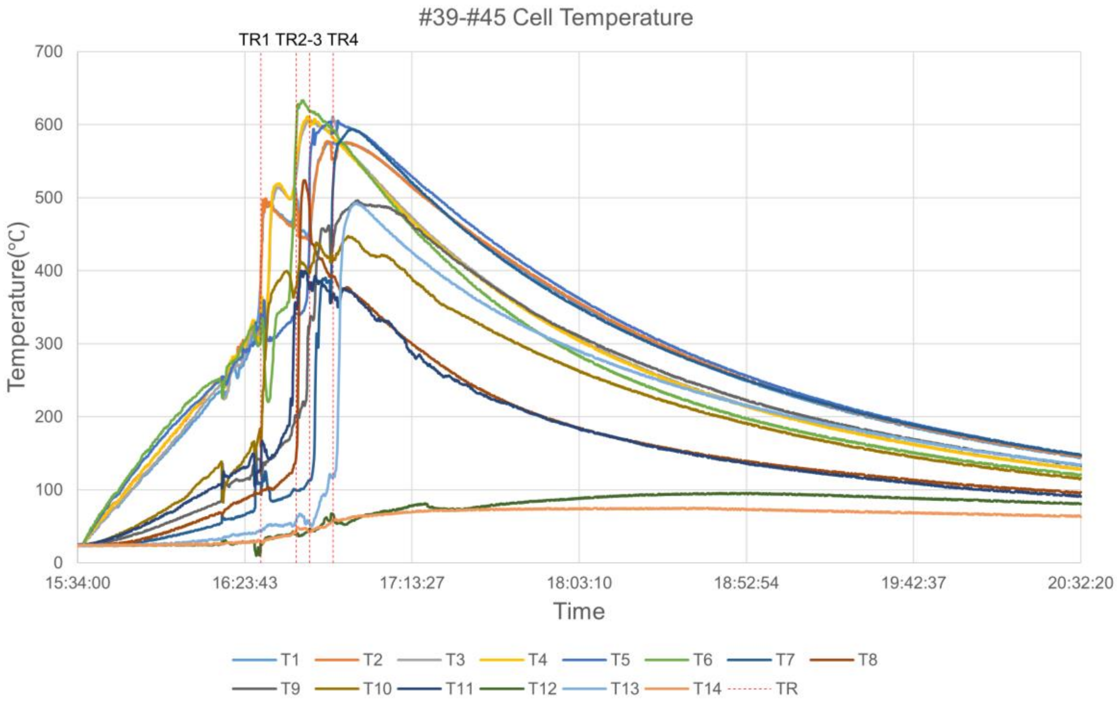
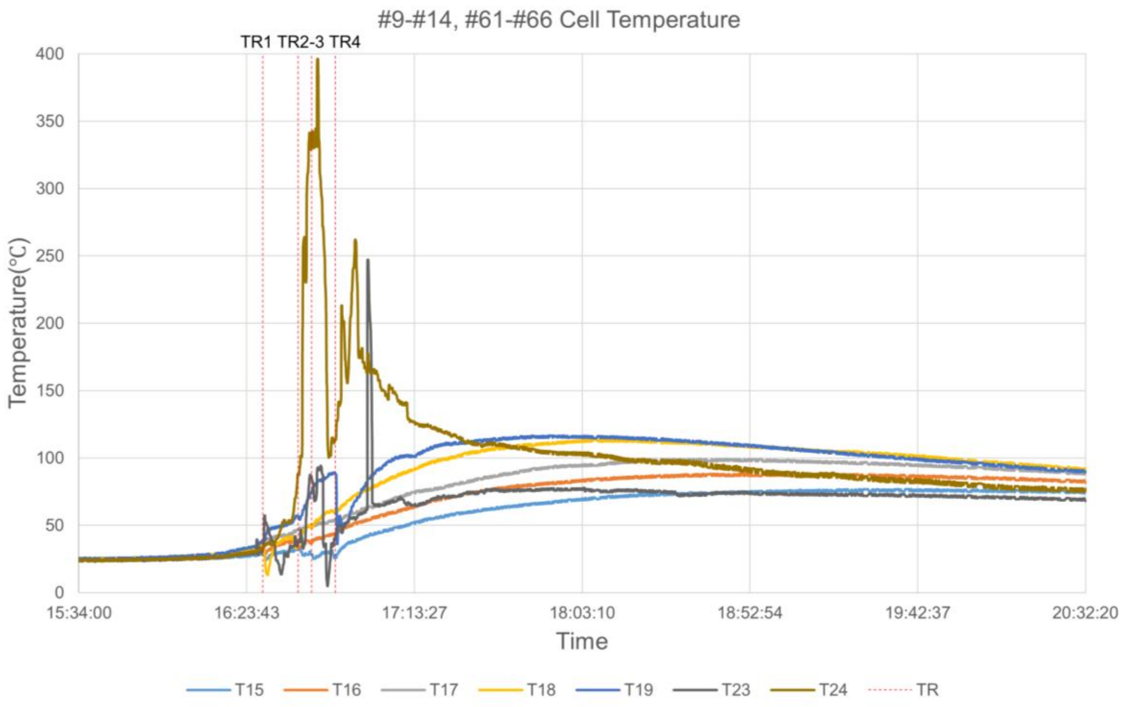


Figure 15. Temperature of cell #9~#14, #61~#66



Note: Thermocouples T20-T22 were damaged during the test.

Figure 16. Temperature of module surface

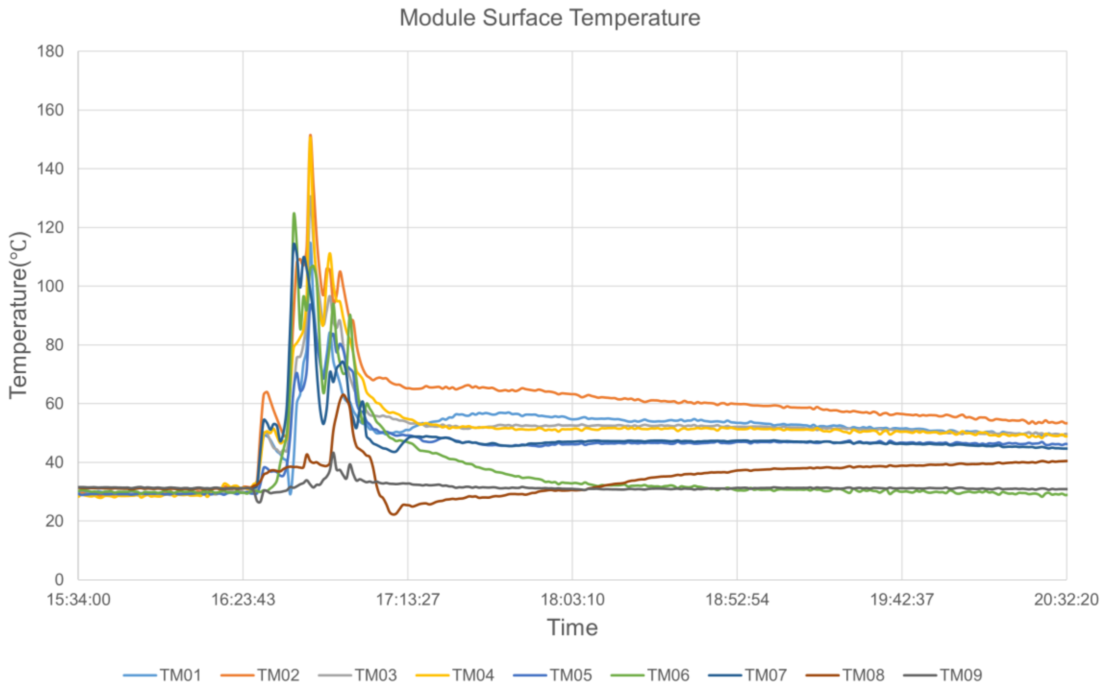


Figure 17. Module voltage

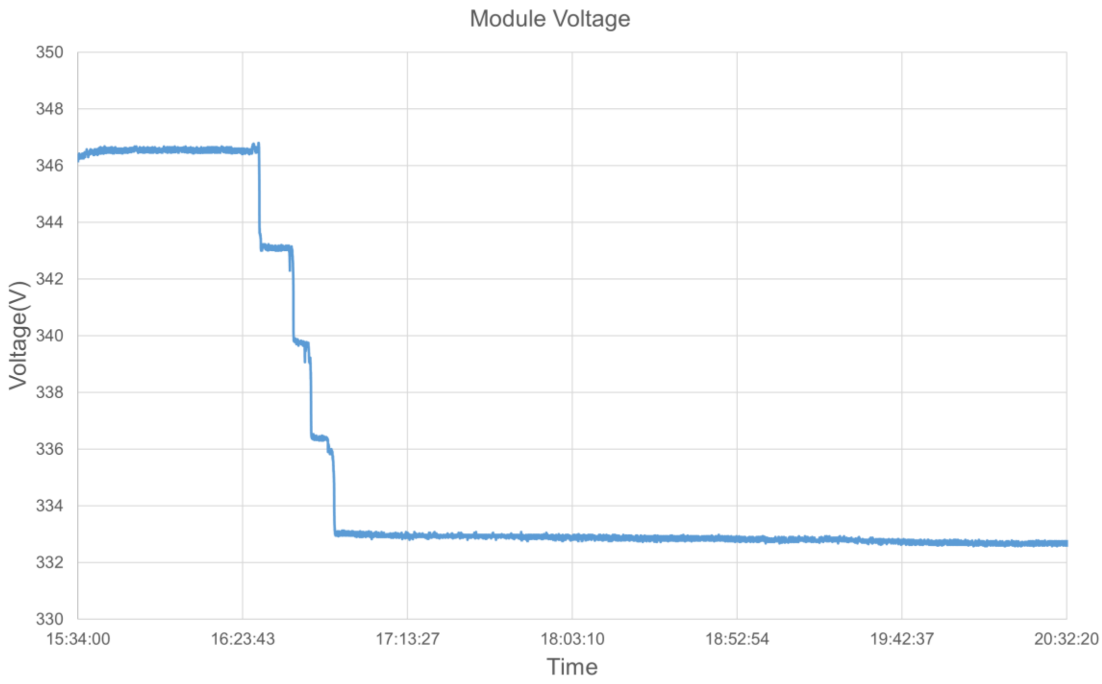
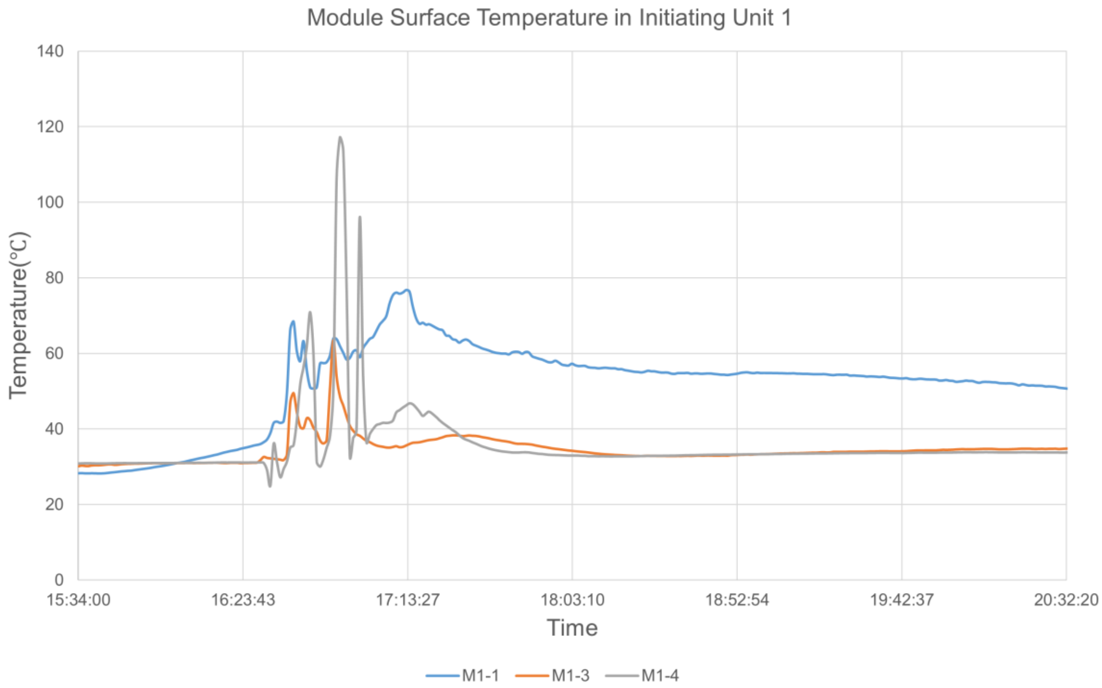


Figure 18. Surface temperature of modules in initiating unit 1



Maximum Temperature in Target Units		
UL 9540A Performance Criteria, Cell Surface Temperature at Gas Venting: 203.7 °C		
Location		Maximum Module Temperature (°C)
Surface temperature of modules in target unit 2	M2-1	51.2
Surface temperature of modules in target unit 3	M3-3	34.6
Surface temperature of modules in target unit 4	M4-2	31.6

Figure 19. Surface temperature of modules in target unit 2

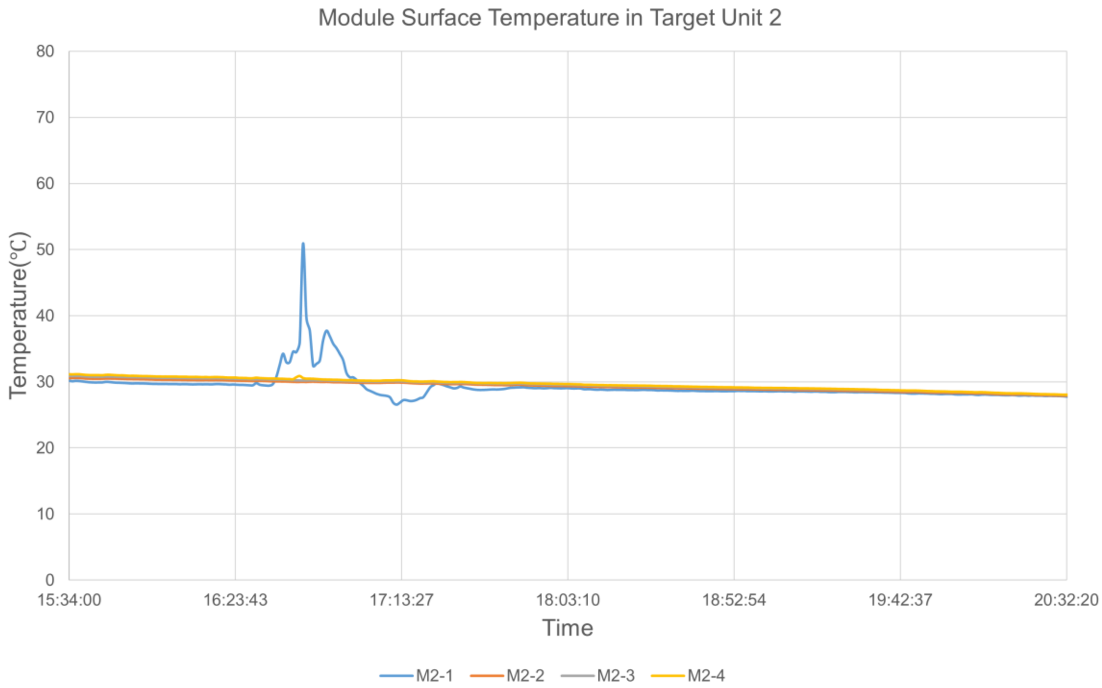


Figure 20. Surface temperature of modules in target unit 3

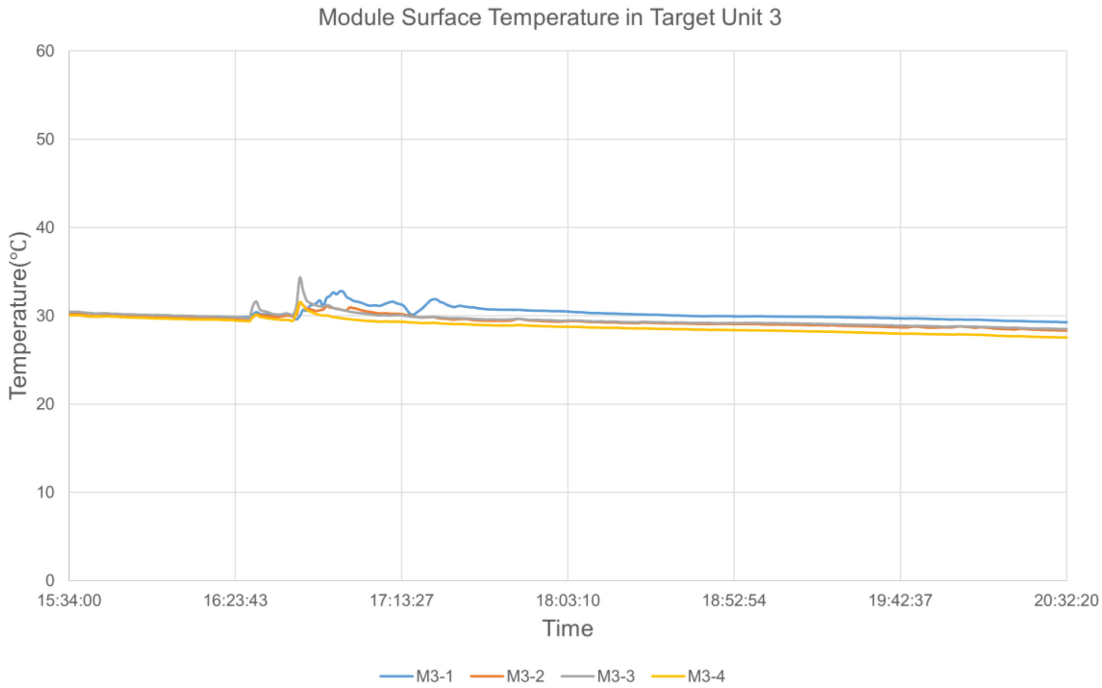
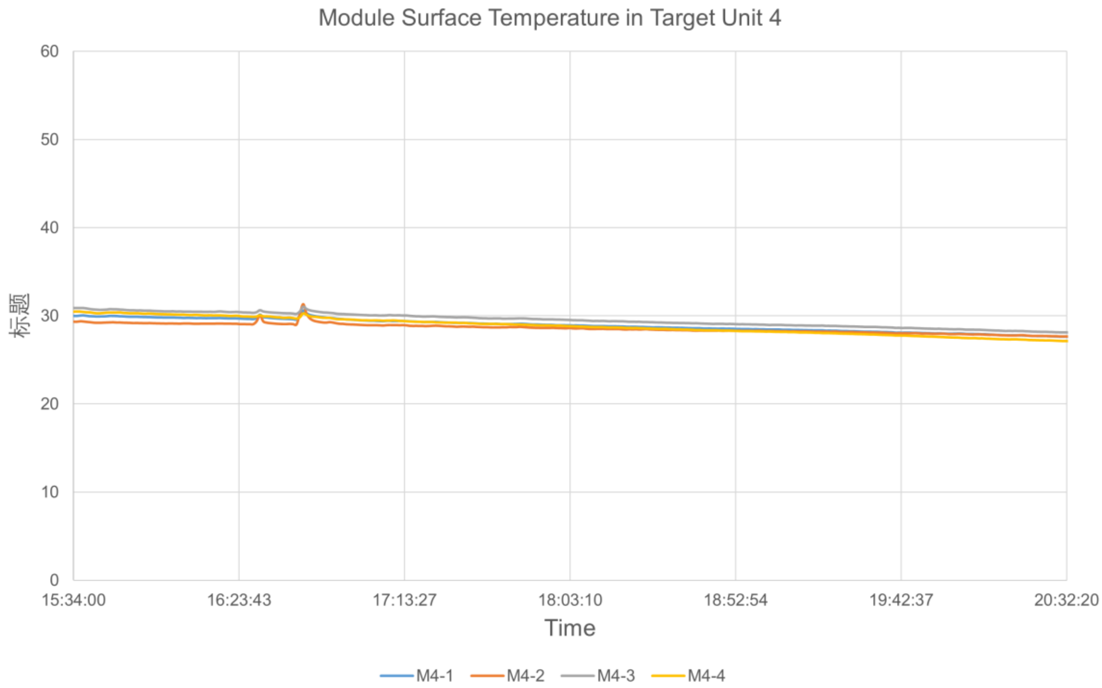


Figure 21. Surface temperature of modules in target unit 4



Maximum Temperature on Instrument Wall		
Ambient Temperature: 29.5 °C		
UL 9540A Performance Criteria, Ambient + 97°C: 126.5 °C		
Location		Maximum Wall Temperature (°C)
Wall A	TWA5	31.2
Wall B	TWB24	31.3
Wall C	TWC24	31.4

Figure 22. Temperature on instrument wall A

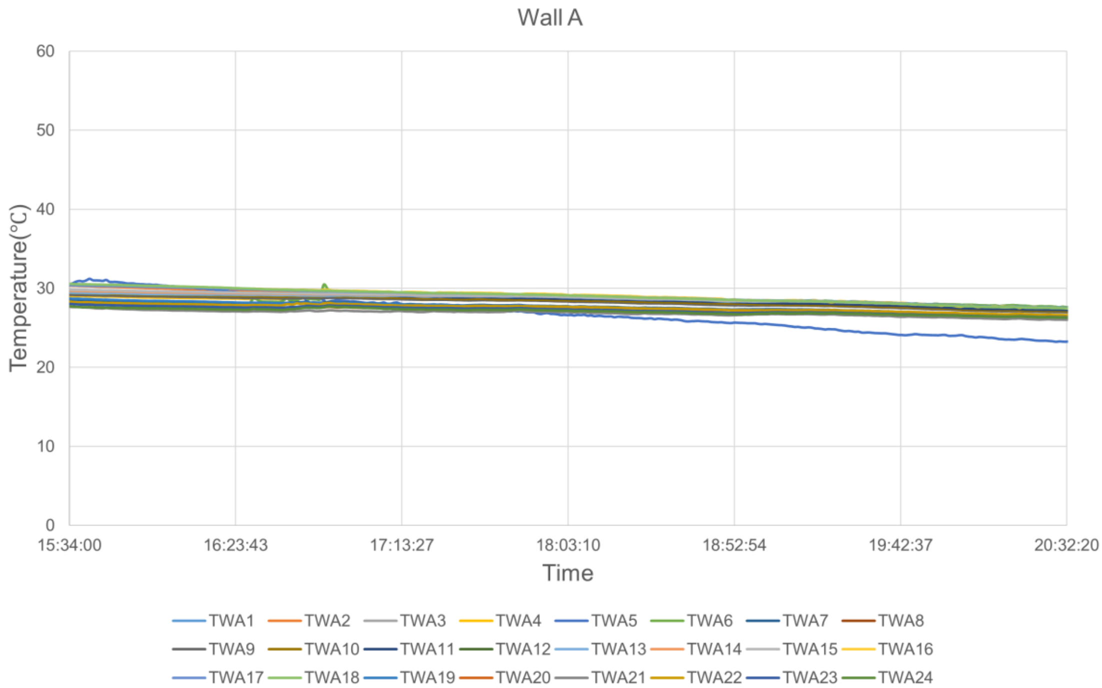


Figure 23. Temperature on instrument wall B

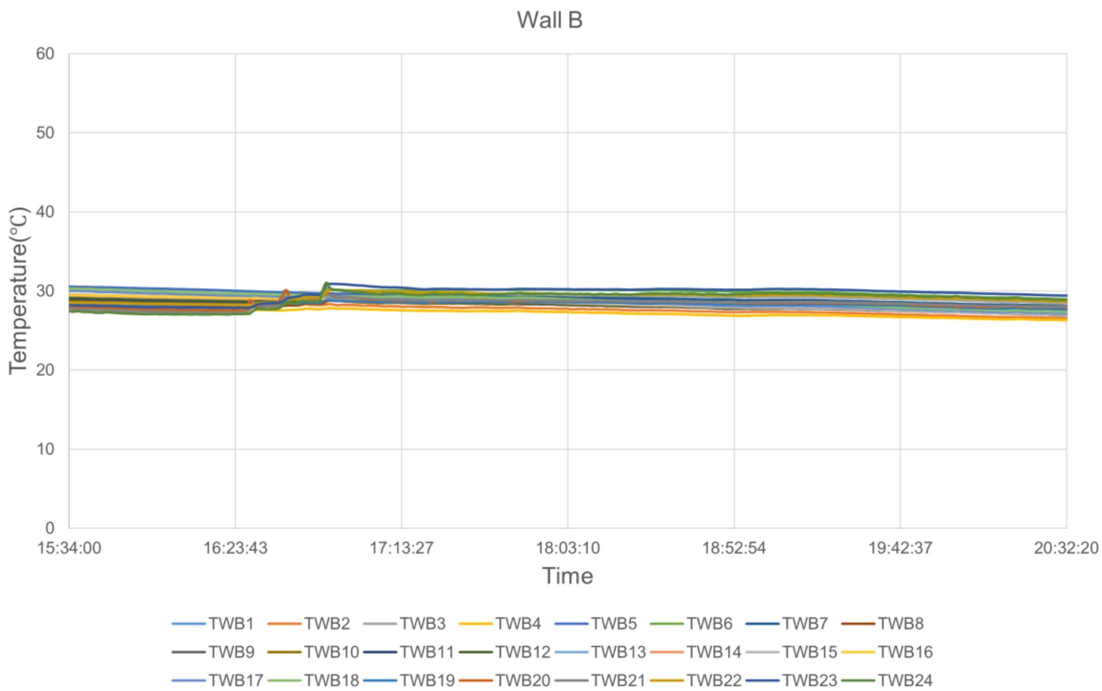
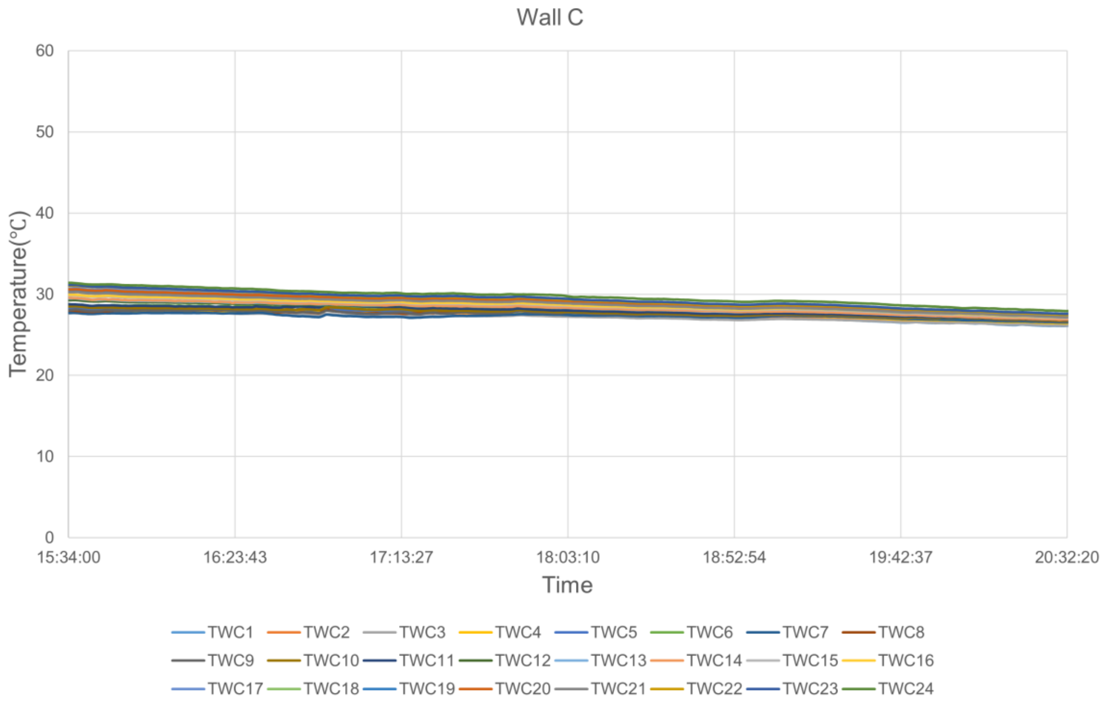


Figure 24. Temperature on instrument wall C



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)	2.14
	Total Smoke Released(m^2)	759.56
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. SRR curve

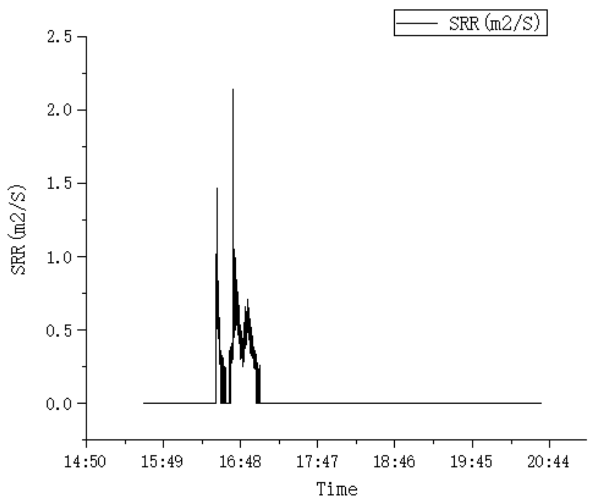
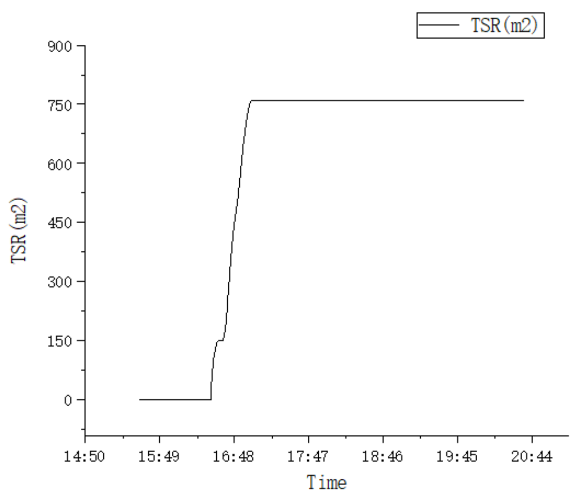
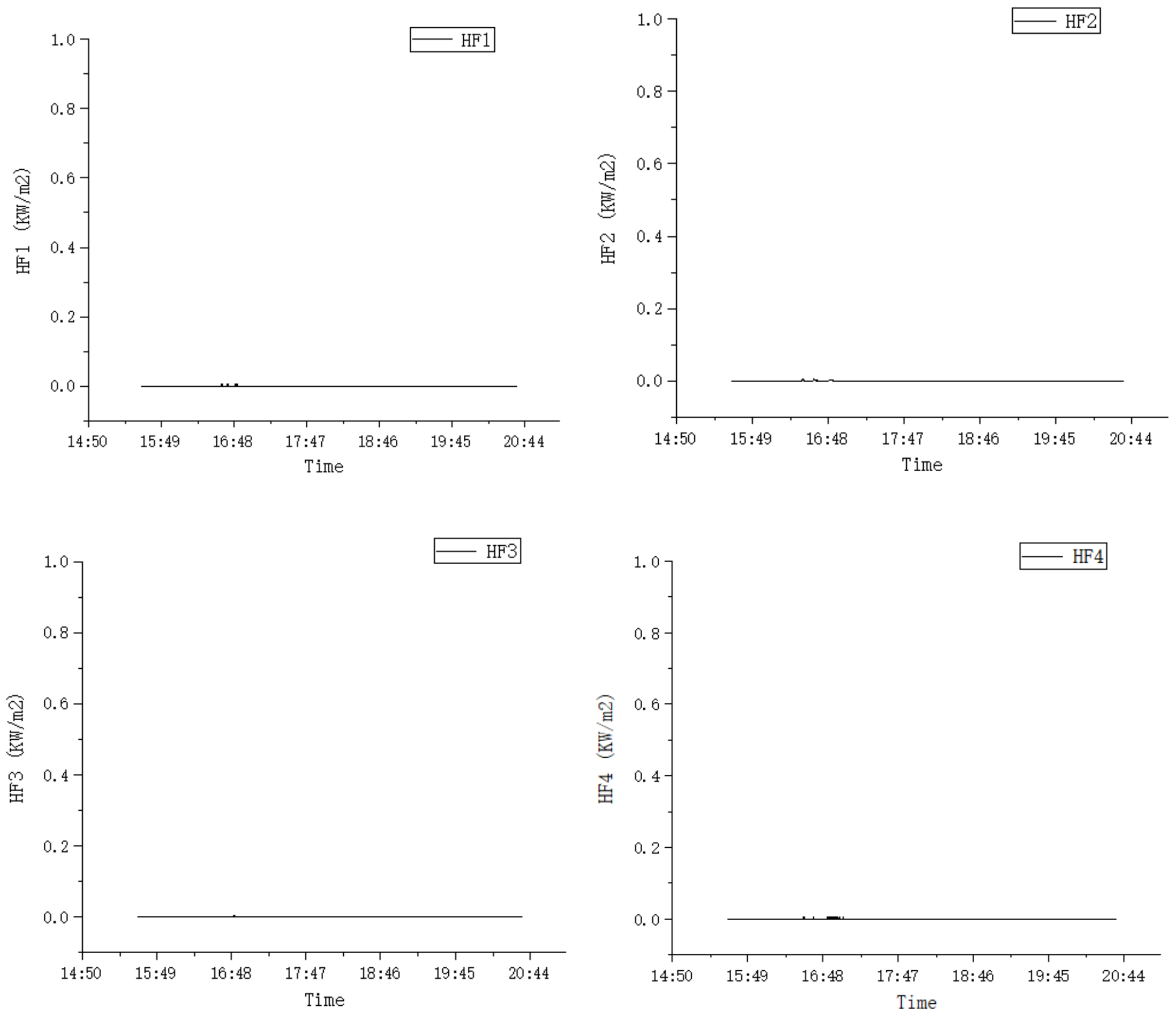


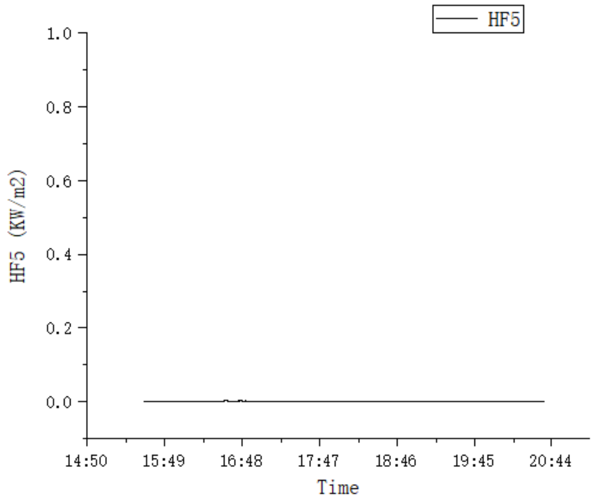
Figure 26. TSR curve

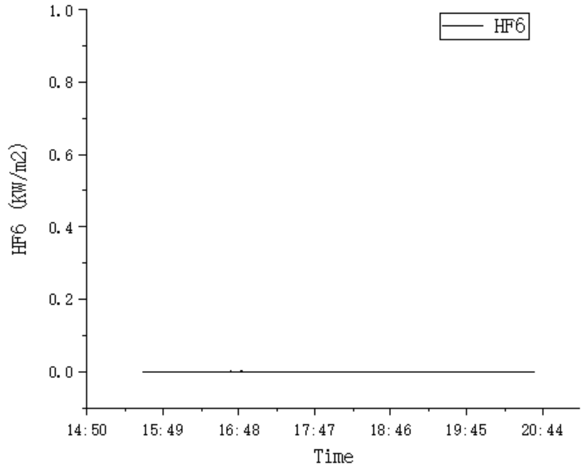


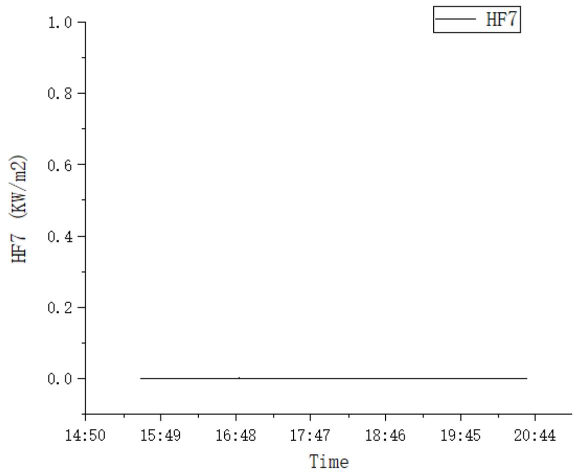
Maximum Heat Flux	
Number of Heat Flux Gauge	Maximum Heat Flux (kW/m^2)
HF 1	0.0061
HF 2	0.0048
HF 3	0.0056
HF 4	0.0060
HF 5	0.0055
HF 6	0.0031
HF 7	0.0035
HF 8	0.0038

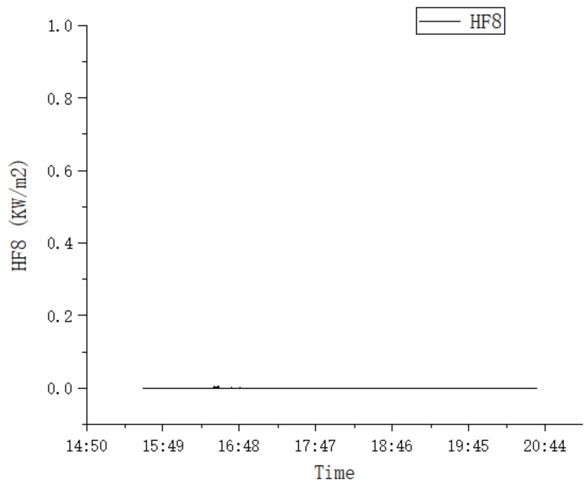
Figure 27. Heat Flux




HF5
1.0
0.8
0.6
0.4
0.2
0.0
HF5 (KW/m2)
14:50
15:49
16:48
17:47
18:46
19:45
20:44
Time


HF6
1.0
0.8
0.6
0.4
0.2
0.0
HF6 (KW/m2)
14:50
15:49
16:48
17:47
18:46
19:45
20:44
Time


HF7
1.0
0.8
0.6
0.4
0.2
0.0
HF7 (KW/m2)
14:50
15:49
16:48
17:47
18:46
19:45
20:44
Time


HF8
1.0
0.8
0.6
0.4
0.2
0.0
HF8 (KW/m2)
14:50
15:49
16:48
17:47
18:46
19:45
20:44
Time

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	306.53	No flaming
Fourier-Transform Infrared Spectrometer	Carbon Monoxide	Carbon Containing	26.47	No flaming
	Carbon Dioxide	Carbon Containing	217.63	No flaming
Solid-state Hydrogen Sensor	Hydrogen	Hydrogen	237.09	No flaming
Note: The collection time is from 15:34 to 20:40.				

Measurement Method	Gas Components		Total Volume of Gas (L)	
			Pre-Flaming	Post-Flaming
Fourier-Transform Infrared Spectrometer	Methane	CH_4	59.73	No flaming
	Ethylene	C_2H_4	56.57	No flaming
	Ethane	C_2H_6	35.52	No flaming
	Propylene	C_3H_6	26.99	No flaming
	Propane	C_3H_8	34.43	No flaming

Figure 28. Total Hydrocarbons

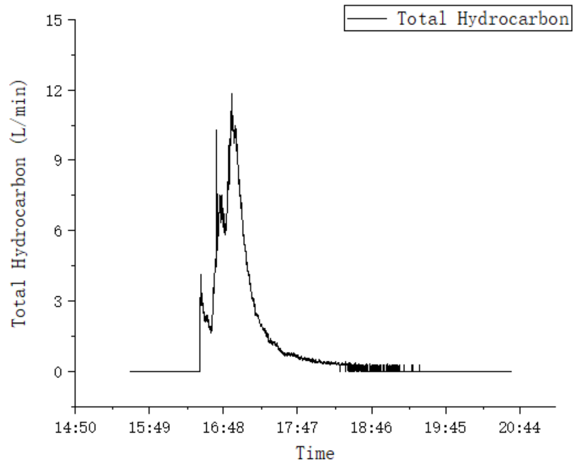
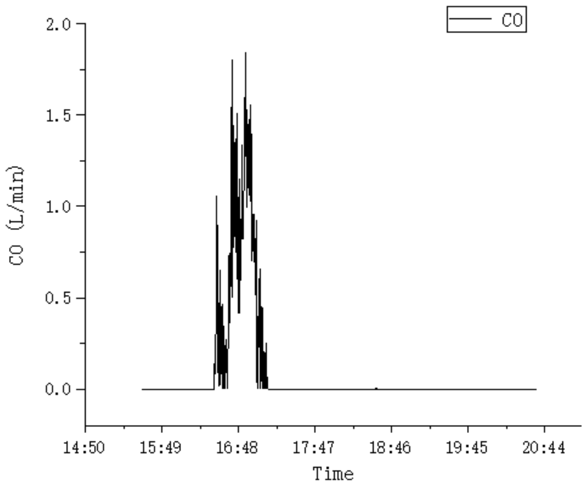


Figure 29. CO, CO2 concentration



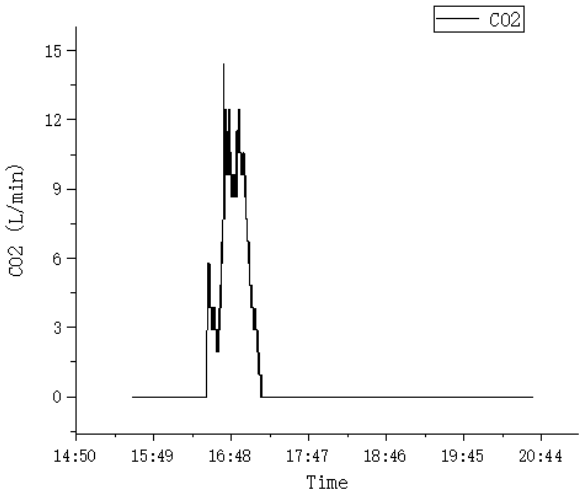


Figure 30. Hydrogen concentration

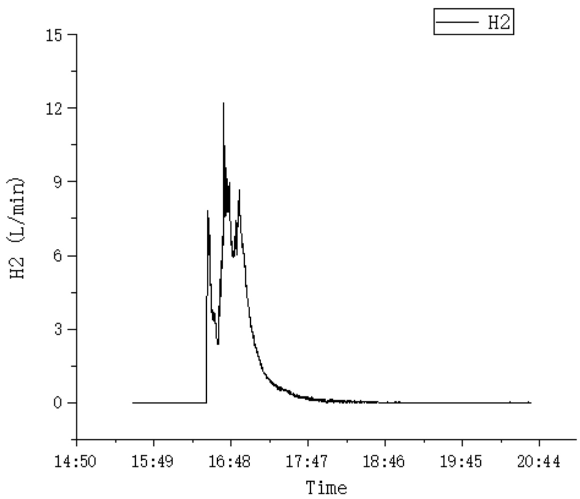
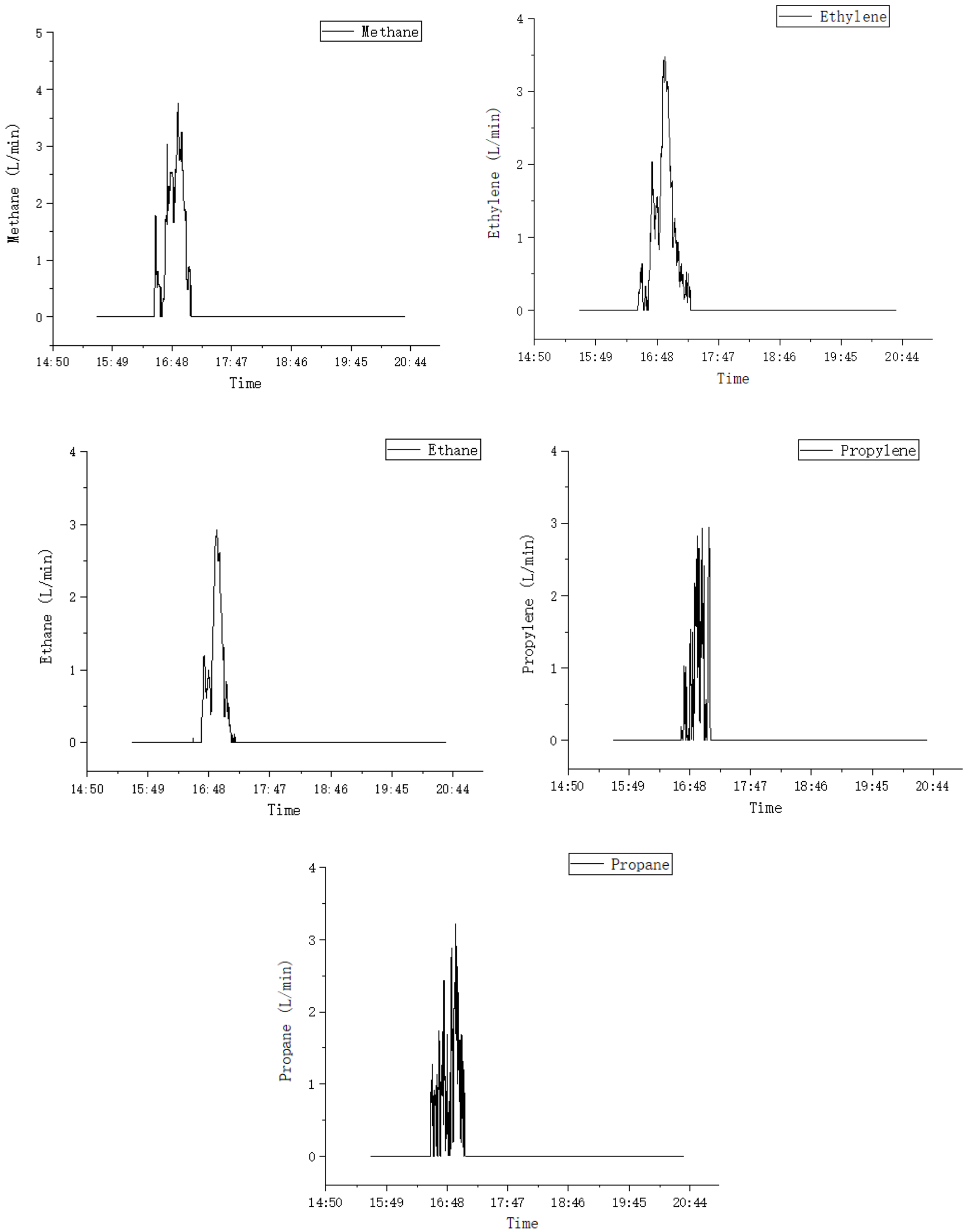


Figure 31. Hydrocarbon species



Attachment G: Sample Photos and Test Photos

Figure 32. Sample before test

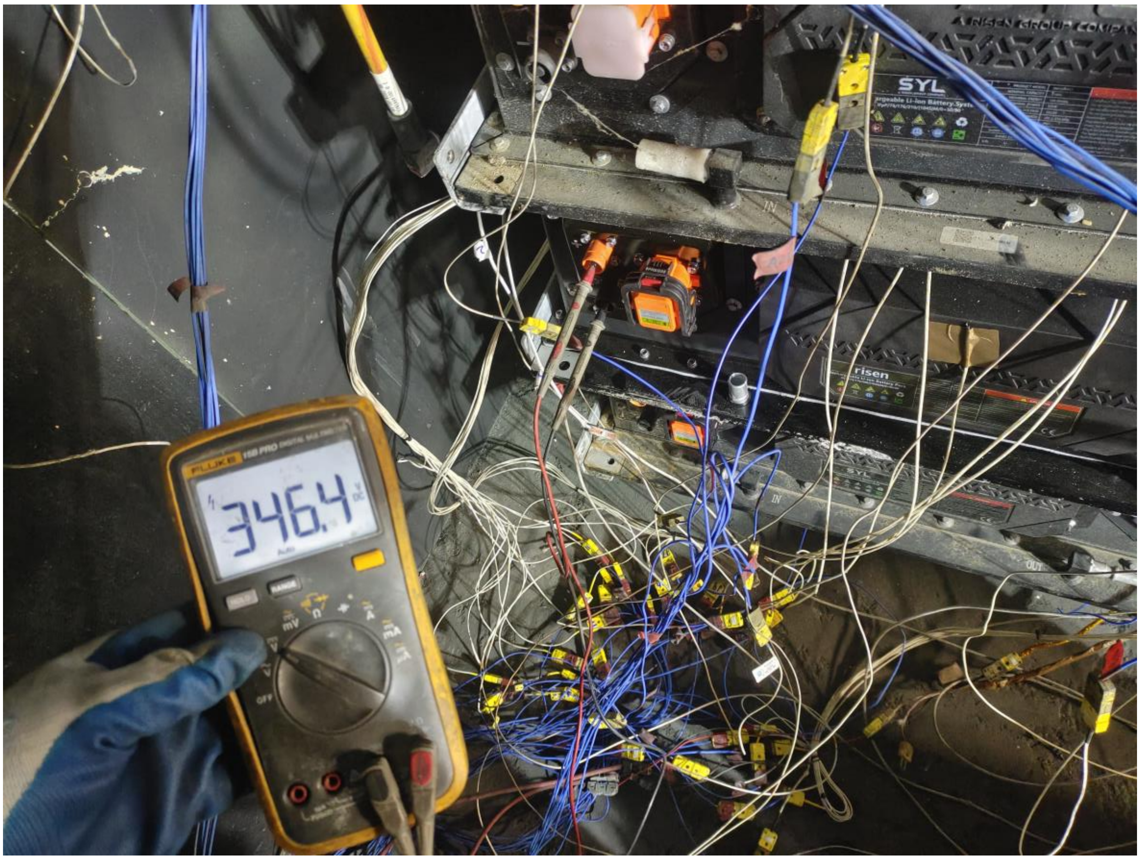


Figure 33. Test setup

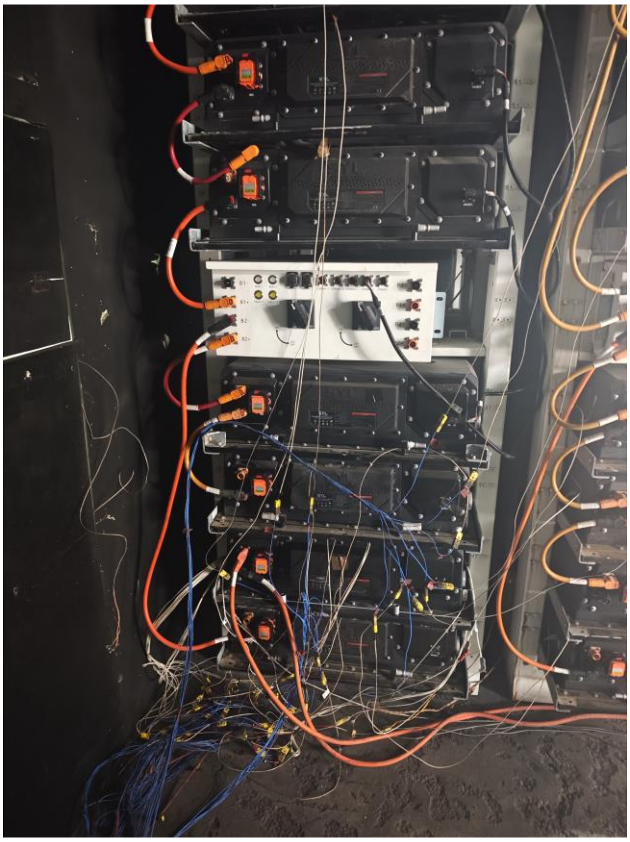


Figure 34. Smoke release during test

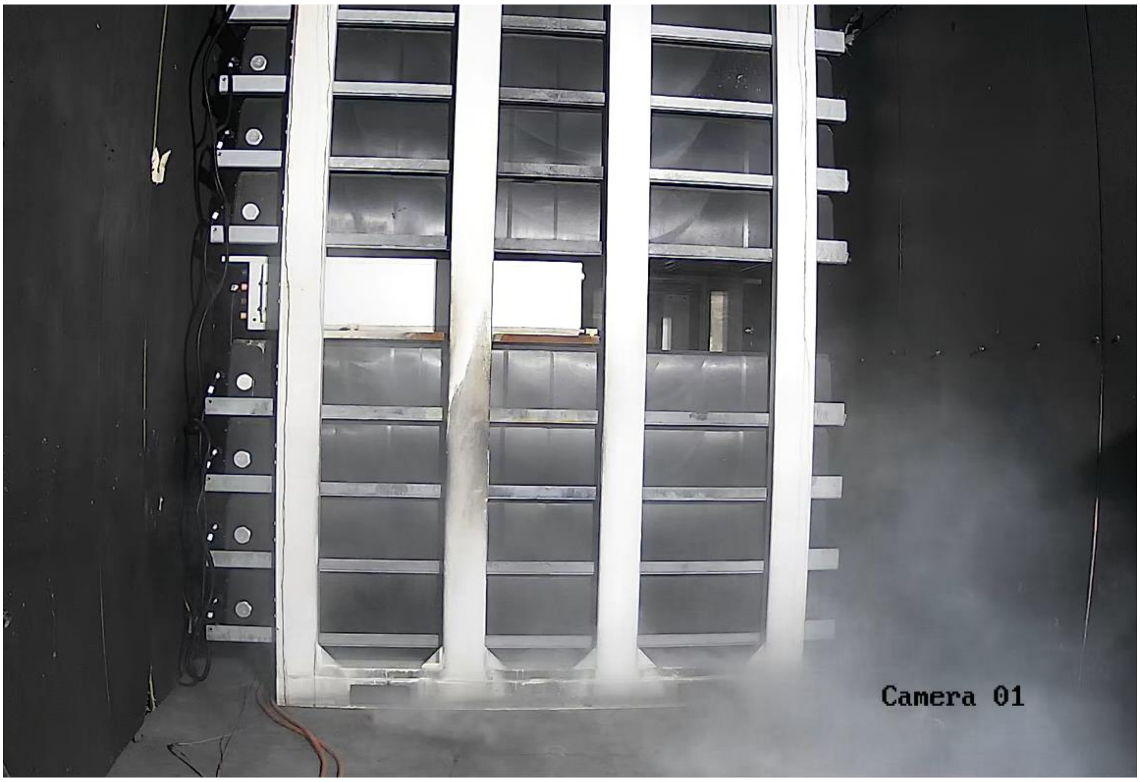
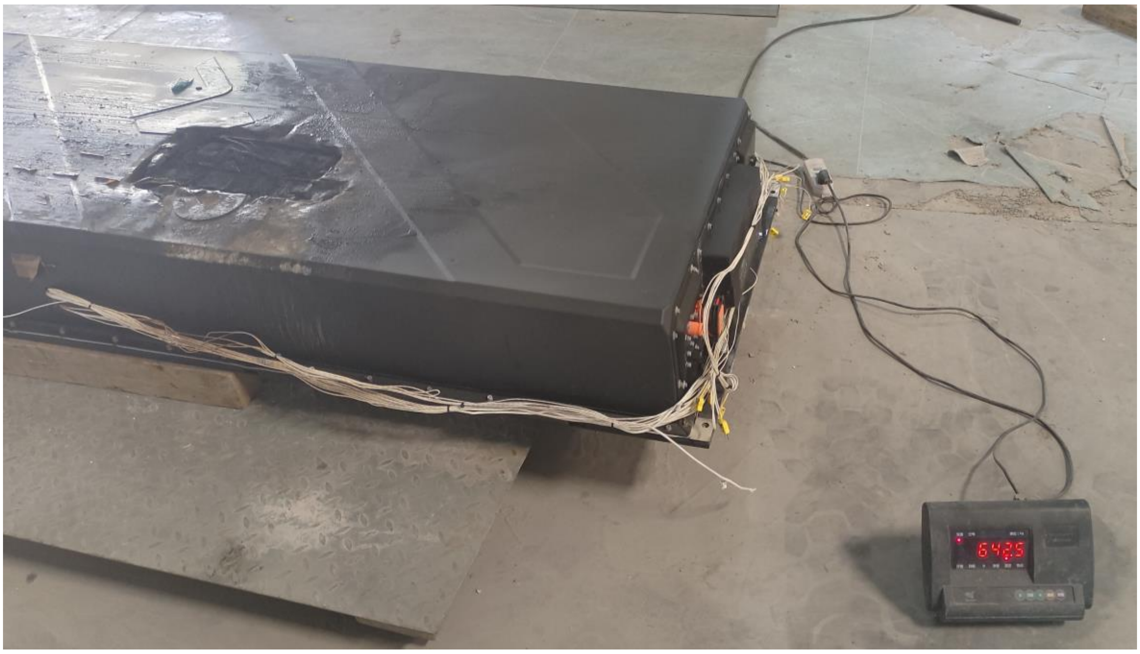


Figure 35. Photos after test



Attachment H: List of Test and Measurement Instruments

No.	Equipment	Model	Rating	Inventory no.	Cal. Expire date
1	Ambient temperature and humidity	SNDWAY SW-572	-30°C ~50°C, 20%RH~100%RH	12005577	2026.2.17
2	Data acquisition equipment	DAQ970A	3-slot cardcage with 6½ digit (22 bit) internal DMM 0.004% basic 1-year dcV accuracy; 0.06% acV accuracy	TY2020000138	2026.2.16
3	Electronic scale	XK3190-A12+E	0-500KG	65960494169	2026.2.16
4	Paramagnetic oxygen analyser	SERVOMEX4100	O2: paramagnetic sensor, range 0-25%, accuracy 0.02%, response time T90 < 7S	ZY2020000018-1	2026.3.4
5	Velocity probe	2671-25L-D-11-G2-E-N	4-20mA output, range 0-250pa, accuracy ± 1% F.S	ZY2020000018-2	2026.2.17
6	Photo detector	PDA36A2	Thorlabs optical receiver, wavelength range (350-1000) mm, gain adjustable, voltage output (0-10) V, instability < 0.1%	ZY2020000018-3	2026.2.16
7	Fourier-Transform Infrared Spectrometer	Atmos FIR	Spectral scanning range: 485 - 7500cm-1; Spectral repeatability: < 0.1cm-1	ZY2020000018-5	2026.2.16
8	Non-dispersive infrared carbon dioxide and carbon monoxide sensor	SERVOMEX4100	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	2026.2.16
9	Palladium-nickel thin-film solid state sensor	MODEL 2000	Range: 0-2000ppm, temperature less than 100 C, -90~110kPa	ZY2021000210	2026.2.16
10	Flame ionization detector	3010	Accuracy: 2.0%	19937	2026.2.16
11	Heat flux measurement equipment	MW88-JTC08C	0 ~ ± 99999 w / m2, - 250 ~ 980 °C, accuracy 5%, response time less than 0.1s,	ZY2020000010	2026.2.16
12	Thermopile	RS-WD-HW-1	0-200 °C, 4-20mA, response speed < 0.15s	28348141942	2026.2.16

13	Data acquisition equipment	TP700	Measuring range -60 °C to 1372 °C Measurement accuracy ± (0.05% rdg.+0.5°C) Display resolution 0.01°C	TY2211000716-2	2026.2.16
14	Data acquisition equipment	TP700	Measuring range-60 °C to 1372 °C Measurement accuracy ±(0.05% rdg.+0.5°C) Display resolution0.01°C	TY2020000217	2026.2.16
15	Multimeter	17b+	AC/DC voltage: 1000V； AC/DC current: 10A； Resistance: 40 ohms Frequency: 100kHz Temperature: 400 degrees Celsius	51631899WS	2026.4.06
16	Low cost metal thermocouple	K-type	(0-1000) °C	/	/
17	Film heater	/	Voltage 220V/900W, power cord length of 2 meters, outgoing from the 200mm side	/	/

Attachment I: Revision Information

New report, no revision information.

Appendix C

SYL USER MANUAL

risen

User Manual

eTron 5MWh Liquid-Cooled ESS
SU5016U1250KC-L&R

Version 01
Release Date July 1, 2025

Copyright

Trademarks

risen and other "Risen Storage" and "SYL" trademarks that may appear in this manual are owned by SYL (Ningbo) Battery Co., Ltd. All other trademarks or registered trademarks mentioned in this manual are owned by their respective owners.

Important Notes

Retain this manual in an easily accessible location for immediate reference during product operation or maintenance. While we make every effort to ensure the accuracy of this manual, both the product and documentation are subject to continuous improvement and updates. Should there be any discrepancies between the descriptions/illustrations herein and the physical product, the actual device specifications shall prevail.

About This Manual

Overview

This manual is specifically compiled for SYL BESS products. It contains key content such as important safety precautions, product introduction, transportation and storage, product installation, electrical connections, system commissioning, system maintenance, and system troubleshooting. These contents will provide clear guidance and strong guarantees for your installation and use, helping to prevent installation failures or subsequent malfunctions caused by improper operation or neglect of critical details.

Please ensure that you read this manual thoroughly and carefully before performing any practical operations. If you have any questions about the content provided in this manual, feel free to contact SYL for consultation at any time. We will do our best to answer your questions. For contact information, please refer to Chapter 9 Technical Support and After-Sales Service.

Target Group

This manual is applicable to product sales engineers, technical support engineers, and operators of energy storage systems. All installation and usage operations must be performed solely by qualified technical personnel. Qualified technical personnel must meet the following requirements:

- Have received specialized training, are familiar with relevant safety regulations of electrical systems, and possess the necessary knowledge and practical experience for performing related operations.
- Have read this manual thoroughly and carefully, are familiar with specific operational procedures, and have mastered relevant safety precautions.
- Have knowledge of relevant laws, regulations, and industry standards in the country or region where the project is located.

Symbol Explanations

This manual may contain the following symbols, which represent the following meanings:

⚠ DANGER
Indicates an imminently hazardous situation which, if not avoided, will result in death or serious personal injury.

⚠ WARNING
Indicates a moderately hazardous situation which, if not avoided, could result in death or serious personal injury.

CAUTION
Indicates a slightly hazardous situation which, if not avoided, may result in minor or moderate personal injury.

NOTICE
Indicates a potential risk which, if not avoided, may lead to equipment malfunction or property damage.

NOTE
Used to emphasize key points or provide supplementary explanations.

Note: Used to provide additional explanations for specific sections.

Underline: Indicates hyperlinked content that allows users to click and quickly navigate to relevant sections or directly access designated website pages.

Revision Record

Version 01 (2025-07-01)

First official release.

Table of Contents

1 Safety Precautions

1.1 Declaration

Before installing, operating, or maintaining the equipment, read this manual thoroughly and follow all safety precautions indicated on the equipment and in this manual.

When installing, operating, or maintaining the equipment, comply with local laws, regulations, and standards. The safety precautions in this manual are provided solely as a supplement to local laws, regulations, and standards.

The 'DANGER', 'WARNING', 'CAUTION', 'NOTICE', and 'NOTE' statements in this manual do not represent all safety requirements that must be followed and are provided solely as a supplement to all safety precautions. SYL assumes no liability for any damages resulting from failure to follow safety operation requirements or violation of safety standards for equipment design, production, and use.

1.2 General Safety

DANGER

- It is strictly prohibited to install, operate, or handle outdoor equipment and cables under adverse weather conditions such as lightning, rain, snow, or level 6 strong winds, including but not limited to activities such as equipment transportation, equipment/cable operation, plugging/unplugging signal ports connected to outdoor equipment, high-altitude operations, and outdoor installation.
- In case of a fire, immediately evacuate the building or equipment area, activate the fire alarm, and call the fire emergency number. Under no circumstances should you re-enter the burning building.

WARNING

- Before touching any conductor surfaces or terminals, measure the voltage at the contact points to verify no risk of electric shock.
- Strictly prohibited to perform installation, wiring, maintenance, or replacement on energized equipment.
- Strictly prohibited to make unauthorized alterations to the equipment's structure or installation sequence under any circumstances.

risen

⚠ CAUTION
● Comply with the requirements of this manual, use appropriate tools, and properly operate them.

⚠ NOTICE
● When performing operations such as transportation, transfer, installation, wiring, and maintenance, you must comply with the laws, regulations, and relevant standards of the country and region where the operations take place. ● Permission from the local power department of the country and region must be obtained before grid-connection work can be carried out. ● You should be fully familiar with the composition and working principle of the entire energy storage system, as well as the relevant standards of the country and region where the project is located. ● In case of paint scratches during the transportation and installation of the equipment, timely repairs must be made to prevent the scratched parts from being exposed to the outdoor environment for a long time.

NOTE
● It is strictly prohibited to conduct reverse engineering, decompilation, disassembly, disassembly (in the software-related sense), adaptation,

implantation, or other derivative operations on the equipment software. ● It is forbidden to study the internal implementation of the equipment, obtain the source code of the equipment software, steal intellectual property rights, etc. in any way. ● Do not disclose the results of any equipment software performance tests.

1.3 Personnel Safety

⚠ NOTICE
● Personnel responsible for installing and maintaining the equipment must undergo rigorous training, understand all safety precautions, master correct operating methods, and possess the knowledge and experience required to operate the relevant equipment. ● Only qualified professionals or trained personnel are permitted to install, operate, and maintain the equipment. ● Only qualified professionals are allowed to remove safety devices and conduct maintenance on the equipment. ● Personnel operating the equipment, including operators, trained personnel, and professionals, must possess the special operation qualifications required by the country and region where the project is located, such as high-voltage operation, working at heights, and special equipment operation

qualifications.

- Replacement of the equipment and its components, including software, must be carried out by professionals or authorized personnel.

Note:

- **Qualified professionals:** Individuals who have received training or possess experience in equipment operation, and are fully aware of potential hazard sources and the degree of hazard severity during equipment installation, operation, and maintenance.
- **Trained personnel:** Individuals who have undergone relevant technical training and have necessary experience, can recognize hazards posed by specific operations, and take measures to minimize risks to themselves or others.
- **Operators:** Personnel who may come into contact with the equipment, excluding trained personnel and qualified professionals.

1.4 Electrical Safety

General Requirements

WARNING

Before making electrical connections, ensure the equipment is undamaged. Failure to do so may result in electric shock or fire.

- All electrical connections must comply with the electrical standards of the country and region where the equipment is located.
- Permission from the local power department of the country and region must be obtained before grid-connected power generation can be carried out.
- Cables provided by the user should meet the requirements of local laws and regulations.
- When performing high-voltage operations, please use dedicated insulated tools.

Grounding Requirements

- For equipment that requires grounding, the protective grounding wire must be installed first during installation and removed last when disassembling the equipment.
- It is prohibited to damage the grounding conductor.
- Do not operate the equipment without the grounding conductor installed.
- Equipment shall be provided with permanent protective grounding. Before operating the equipment, check its electrical connections to ensure the equipment is reliably grounded.

DC Operation

⚠ WARNING
It is prohibited to install or remove the power cable with the power on. When the power cable core comes into contact with the conductor, arcs or sparks will be generated, which may lead to fire or personal injury.

- Before making electrical connections to the equipment, if there is a possibility of coming into contact with live parts, the corresponding disconnection device at the previous stage of the equipment must be switched off.

- Before connecting the power cord, make sure to confirm that the labels and markings on the power cable are correct, and then proceed with the connection.
- If the equipment has multiple inputs, all inputs of the equipment should be disconnected. You can only operate the equipment after the equipment is completely powered off.

Wiring Requirements

- Using cables in high-temperature environments may cause aging and damage to the insulation layer. The distance between the cables and the periphery of heat-generating devices or heat source areas should be at least 50 mm.
- Cables of the same type should be bundled together. Cables of different types should be laid at least 30 mm apart. It is prohibited to wind or cross them with each other.
- Cables must be firmly connected, have good insulation, and be of appropriate specifications.
- At the positions where cables pass through pipes or wire holes, protection measures must be taken to prevent the cables from being damaged by sharp edges, burrs, etc.

Anti-static requirements

⚠ NOTICE
The static electricity carried by the human body may cause irreversible damage to

electrostatically sensitive components on the single board of the energy storage system, such as large-scale integrated circuits (LSI). Therefore, when touching the PCB board, you must wear anti-static equipment throughout the process, such as anti-static gloves and anti-static wristbands. At the same time, it is strictly prohibited to wear clothing that easily generates static electricity, such as clothing made of acrylic or chemical fiber materials, to ensure the stable operation of the system and the safety of the components.

1.5 Battery Safety

Declaration

SYL shall not be liable for equipment malfunctions, component damage, personal safety accidents, property damage, etc., caused by the following reasons:

- Damage to the battery, such as capacity loss or irreversible damage, caused by the user's failure to charge in a timely manner resulting in overdue storage.
- Battery damage, drops, leakage, etc., caused by improper operation or failure to connect the battery as required.
- Damage caused by over-discharge of the battery due to the customer's failure to power on in a timely manner after on-site installation and system connection.
- User's failure to properly set the battery operation management parameters.
- If the user or a third-party changes the battery usage scenario without informing our company. For example, connecting additional loads to the battery on their own, or mixing

the batteries provided by our company with other batteries, including but not limited to: mixing with batteries of other brands, mixing with batteries of different rated capacities, etc.

- Direct damage to the battery caused by the fact that the on-site equipment operating environment or external power parameters cannot meet the environmental requirements for normal operation. This includes the actual operating temperature of the battery being too high or too low, and the unstable power grid situation with frequent power outages.
- Abuse of the battery system, including but not limited to exceeding the rated current rate during operation and forced charging at low temperatures.
- The user does not properly maintain the battery in accordance with the maintenance manual.
- The battery gets stolen.
- The battery has gone beyond the warranty period.

Basic Requirements

⚠ DANGER
● Do not expose the battery to high-temperature environments or around heat-generating equipment such as open flames and transformers. Overheating of the battery may cause fire or explosion. ● Do not disassemble, modify, or damage the battery (e.g., inserting foreign objects, immersing in water or other liquids) to prevent battery short circuits, fires, or explosions. ● The battery energy storage system has a high fire risk. Before performing

battery operations, the following safety risks must be fully considered:

- The battery electrolyte is flammable, toxic, and volatile.
- Battery thermal runaway can generate various flammable and harmful gases.
- The accumulation of flammable gases produced after battery thermal runaway poses a risk of fire and explosion.

- Batteries should be stored independently within their original packaging. Avoid storing them together with other items, leaving them exposed to the open air, or stacking them to excessive heights.
- Batteries that have gone past their warranty period are not allowed to be used anymore.
- Under normal circumstances, do not take off the battery's original packaging. In case the battery needs to be recharged, it should be done by professional staff following the specified procedures. After the recharge is finished, the battery must be put back into its packaging.
- When handling batteries, they should be transported in the direction specified by the battery requirements. Inversion and tilting are strictly prohibited.
- Batteries should be protected from impact.
- Do not perform welding, grinding, or similar operations near the battery to prevent sparks or arcs from causing fire hazards.
- Use the battery within the operating temperature range specified in this manual. Refer to Section 2.3.1 Battery for the battery's operating temperature range.

- Do not use damaged batteries, such as those that have been dropped, collided, or have case dents. Damaged batteries may release flammable gases. Do not store damaged batteries near undamaged products.
- Damaged batteries should not be stored in areas containing flammable materials, and non-professional personnel should keep away.
- During storage, damaged batteries should be monitored to ensure there are no signs of smoke, fire, electrolyte leakage, or overheating.

Personal Safety

- During equipment operation, appropriate personal protective equipment (PPE) shall be worn. In case of malfunctions that may cause personal injury or equipment damage, immediately cease operation, report to the responsible personnel, and take timely and effective protective measures.
- Before using tools, ensure proper use methods are mastered to avoid personal injury or equipment damage.
- During equipment operation, the enclosure temperature is high, posing a risk of burns. Do not touch.
- To ensure personal safety and proper operation, reliable grounding shall be implemented before use.
- When a battery malfunctions, its surface temperature may exceed safe touch limits, presenting a burn risk. Avoid contact.

- Do not open or damage the battery. Released electrolyte may cause harm to skin and eyes. Avoid contact.
- Do not place unrelated items on top of the equipment or insert them into any part of the equipment.
- Do not store flammable items around the equipment.
- Batteries shall not be exposed to fire to prevent explosion and endanger personal safety.
- Do not immerse battery modules in water or other liquids.
- Never short-circuit battery terminals, as this may cause combustion.
- Batteries may pose risks of electric shock and large short-circuit currents. When using batteries, observe the following precautions:
  - Use tools with insulated handles.
  - Wear insulated gloves and shoes.
  - Do not place tools or metal parts on top of the battery.
  - Disconnect the charging power supply before connecting or disconnecting battery terminals.
  - Check if the battery is accidentally grounded. If so, remove the power supply from the ground.
- Do not use water or cleaning agents to clean the internal and external electrical components of the cabinet.
- Do not lean on the equipment or stand/sit on top of it.
- Do not damage any module of the equipment.

Battery Installation

- Before installing the battery, check whether the packaging is intact. Batteries with damaged packaging must not be used directly.
- During the battery installation process, pay attention to the positive and negative terminals. It is prohibited to short-circuit the positive and negative terminals of the battery.
- During the installation process, use a torque wrench to ensure that the screws are tightened without loosening, and check them regularly.
- After installing the equipment, remove the empty packaging materials in the equipment area, such as cartons, foam, plastics, and cable ties.

Hazards and Toxicity

⚠ DANGER
● Contact between battery terminals and other metals may cause overheating or electrolyte leakage. Since the electrolyte is flammable, immediately remove the battery from fire in case of leakage. ● Vapors generated by burning batteries may irritate the eyes, skin, and throat.

Battery Abnormalities and Emergency Measures

⚠ DANGER
● When electrolyte leakage occurs or there is an unusual odor, avoid contact with the leaked liquid or gas. Non-professionals should not approach. Please contact professional personnel immediately for handling. Professional personnel should wear goggles, rubber gloves, gas masks, protective clothing, etc. to prevent the hazards caused by electrolyte spillage. ● The electrolyte is corrosive and contact may cause skin irritation and chemical burns. If exposed to battery electrolyte, take the following measures: ■ Inhalation: Immediately evacuate personnel from the contaminated area. After moving away, inhale fresh air and seek medical attention. ■ Eye contact: Flush eyes with plenty of water for at least 15 minutes. Do not rub and seek immediate medical help. ■ Skin contact: Wash the affected area with copious amounts of water and soap. Seek medical attention immediately. ■ Ingestion: Seek immediate medical attention.

Fire Emergency Measures

⚠ DANGER
● In case of fire, disconnect the system power supply when it is safe to do so

- Firefighters should avoid contact with high-voltage components during fire suppression. Otherwise, there may be a risk of electric shock.
- Excessive battery temperature may cause battery deformation and damage, as well as electrolyte spillage and toxic gas release. In such cases, wear respiratory protective equipment and do not approach to prevent skin irritation and chemical burns.

Flood Emergency Measures

⚠ DANGER

- Power off the system when it is safe to ensure personal safety.
- If any part of the battery is submerged in water, do not touch it to avoid an electric shock.
- Do not use flood-damaged batteries. Contact a battery recycling company for proper disposal.

Battery Drop Emergency Measures

⚠ DANGER

- When installing the battery, if it drops or sustains severe impact, internal damage to the equipment may occur. In such cases, do not continue to use it to avoid safety risks such as cell leakage or electric shock hazards.

- If a dropped battery exhibits distinctive odor, damage, smoke, or fire, immediately evacuate nearby personnel, alert emergency services, and contact professionals. Trained personnel should use fire-fighting equipment to extinguish flames while ensuring safety.
- If a dropped battery shows no visible deformation or damage, and there is no noticeable odor, smoke, or fire, contact professionals to transport the battery to an open and safe location or coordinate with a recycling company for disposal.

Battery Recycling and Disposal

- Follow local laws and regulations for proper disposal of used batteries. Do not dispose of batteries as household waste. Improper battery disposal may cause environmental pollution.
- If a battery leaks or becomes damaged, contact technical support or a battery recycling company for proper disposal.
- When a battery reaches the end of its service life, contact a battery recycling company for proper disposal.
- Avoid exposing used batteries to high temperatures or direct sunlight.
- Avoid exposing used batteries to high humidity or corrosive environments.

1.6 Handling, Transportation, and Storage Safety

⚠ WARNING
● Do not allow direct exposure to rain or snow to prevent water ingress. ● Avoid dropping or subjecting batteries to mechanical impact. ● Do not invert, tilt, or tip over batteries. ● Handle with care to prevent battery damage or short circuits, which could lead to accidents. ● Comply with national and regional laws, regulations, and industry standards for handling, transportation, and storage.

1.7 Maintenance and Replacement

⚠ DANGER
The equipment operates with high voltage, which can lead to electric shock accidents. These accidents may result in severe personal injury, even loss of life, or significant property damage. Before performing any maintenance tasks, it is essential to first cut off the equipment's power supply and strictly follow the safety guidelines outlined in this manual and other relevant documentation.

- Familiarize yourself with and understand the contents of this manual before performing maintenance on the equipment, and ensure that appropriate tools and testing equipment are available.

- Before conducting maintenance, cut off the equipment's power supply. Follow the instructions on the time-delay discharge label, wait the specified time to ensure the equipment is completely powered off, and then proceed with operations.
- During maintenance, prevent unauthorized personnel from entering the work area. Erect temporary warning signs or install barriers for isolation.
- If the equipment malfunctions, contact our company immediately for after-sales service. Contact information is provided in Chapter 9 Technical Support and After-Sales Service.
- The equipment must be fully repaired before powering up again. Failure to do so may cause the fault to escalate or equipment damage.
- Do not open the equipment without authorization. This poses a risk of electric shock, and resulting malfunctions will not be covered under warranty.
- Operators and maintenance personnel, as well as professional technicians, must receive adequate training on safe equipment operation and maintenance. Operations should be performed under sufficient preventive measures and with personal protective equipment (PPE).
- When moving or rewiring the equipment, first disconnect the power input. After internal energy dissipation is complete and a multimeter confirms no hazardous voltage on the DC bus and internal components to be repaired, maintenance may commence.
- Battery repairs must be performed or supervised by personnel familiar with batteries and required preventive measures.
- Replace the battery with the same type of battery.

- After maintenance operations, immediately inspect to ensure no tools or other components are left inside the equipment.
- When the equipment is not in use for an extended period, the battery should be stored and recharged according to the instructions in this manual.

2 Product Introduction

2.1 Product Information

Introduction

This product is a highly integrated containerized battery energy storage system solution. It integrates key components such as batteries, battery management systems (BMS), and Golden Shield (GS) within a standard 20-foot container, enabling high integration and modularity. This design streamlines transportation, installation, and rapid deployment, significantly reducing project construction timelines. The energy storage system delivers ultimate safety and stability alongside exceptional performance, providing real-time responsiveness to dynamic power demands and precise control of charging/discharging processes to optimize energy utilization efficiency. It plays a pivotal role in applications like photovoltaic-storage synergy and grid peak shaving with frequency regulation, laying a robust foundation for building a stable and efficient energy infrastructure.

Basic Information

Model	Applicable Regions
SU5016U1250KC-L (Container A)	UL
SU5016U1250KC-R (Container B)	UL

System Parameters

Parameter	Value
Dimensions	L: 6058mm
	W: 2438mm
	H: 2896mm
Weight	40.5±0.5t
Operating Ambient Temperature Range	-30~50℃ (-22~131℉)
Charge/Discharge Rate	0.25C
Operating Ambient Humidity Range	0~95%RH
Corrosion Protection Grade	C4
IP Rating	IP55
Cooling Method	Intelligent liquid cooling solution
Fire Suppression Configuration	Fire Detection and Alarm System
	Ventilation and Air-Exchange System
	Aerosol Fire Suppression System

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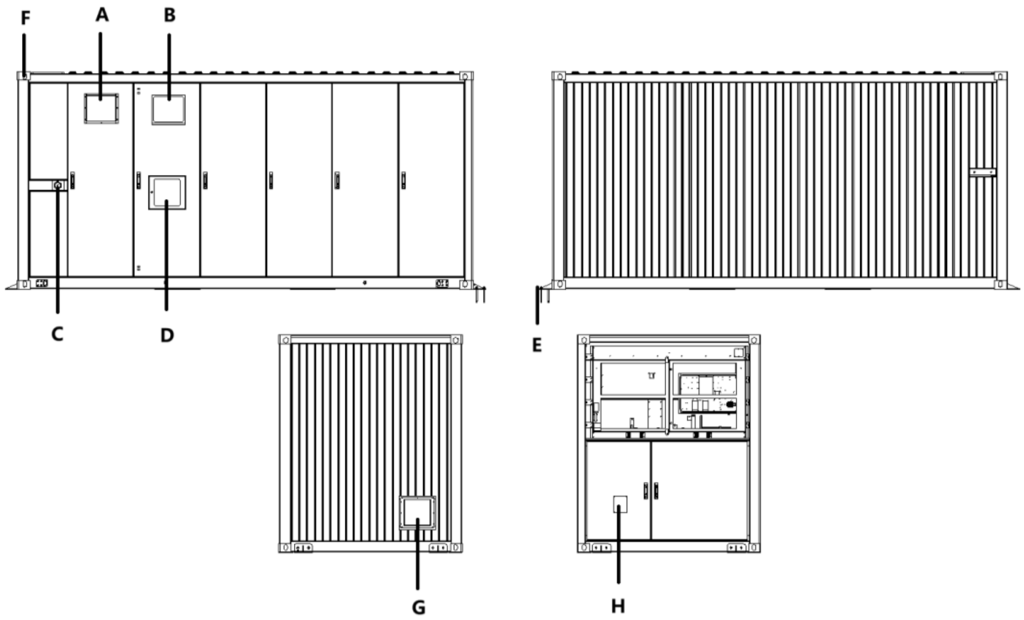
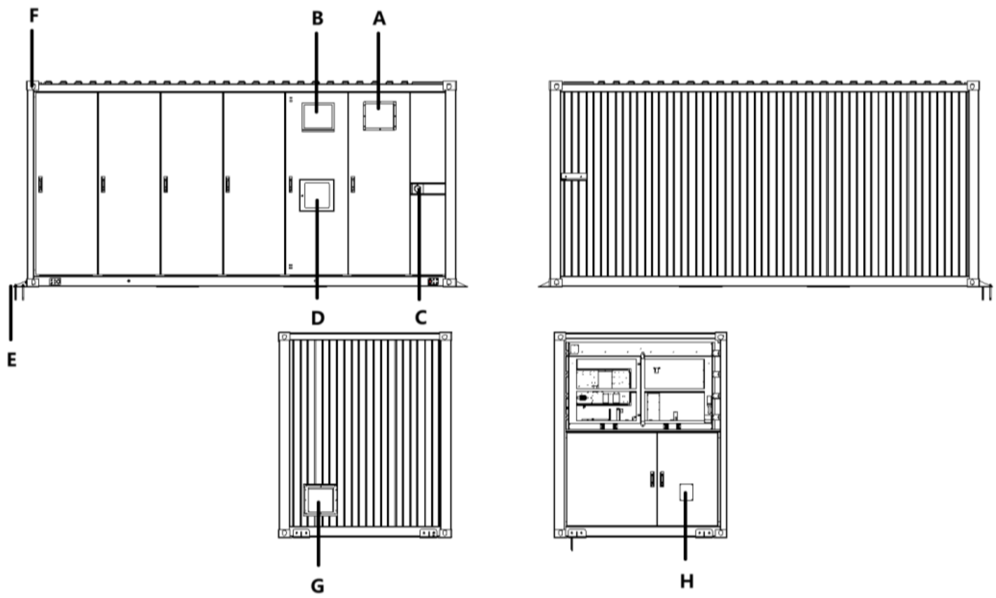
	Water-Based Fire Suppression System
Allowable Operating Altitude	≤4000m
Noise Level	≤80dB@1m
Wind Load	66m/s
Snow Load	40psf
Seismic Grade	Zone 4
Cell Specifications	3.2V/314Ah
Battery Configuration	416S12P
Key Components	3 battery arrays
	1 BAU
Rated Energy	5015.96kWh
Rated Power	526kW
Rated Voltage	DC 1331.2V
Operating Voltage Range	DC 1123.2~1497.6V

2.2 Design

2.2.1 Appearance



SU5016U1250KC-L (Container A)



SU5016U1250KC-L (Container B)

Figure 2-1 Product Appearance

No.	Components	Quantity	Function
A	FSS exhaust fan	1	Vent the combustible gas inside the container.
G	FSS air inlet	1	
B	Audible and visual alarm	1	When the fire suppression system in the container is triggered, it emits audible and visual alarms and the sound of an alarm bell.
	Alarm bell	1	
C	FSS water supply port	1	Connect to an external water source to provide an emergency water supply for the Water-Based Fire Suppression System.
D	System emergency stop button	1	Used to shut down the energy storage system in emergencies.
	FSS emergency stop button	1	Used to stop the discharge of fire suppressant in emergencies.
	FSS disable switch	1	Used for preventing unintended discharge of fire suppressant during system commissioning or maintenance.
	Emergency discharge button	1	Used for manually discharging the fire suppressant in emergencies.
E	Fastener	4	Used for connecting and fixing the container to the foundation.

F	Top corner casting	4	Used for container lifting.
H	Container nameplate	1	Displays technical parameters of the container, production date, and other information.

2.2.2 Marks on Products

Marks	Explanation
	Live Electricity Sign
	Warning Sign
	Caution: Heavy Load
	Caution: Chemicals
	Warning: Explosive Hazard
	Caution: Hot Surface
	Caution: Wet Floor
	No Open Flames
	Do Not Damage Batteries

	Keep Out of Reach of Children
	Height Limit Sign
	UN3536 Marking
	Class 9 Dangerous Goods Transport Marking
	Left Door Opening
	Right Door Opening
	Grounding Symbol
	User Manual Available
	Wear Safety Goggles
	Wear Protective Gloves
	Wear Ear Protector
	First Aid Sign
	Emergency Eyewash Station

 	Recyclable Symbol
	WEEE Recycling Symbol

2.3 Key Components

2.3.1 Battery

2.3.1.1 Cell

Parameter	Value	Image
Chemical Composition	Lithium Iron Phosphate (LFP)	 (For reference only)
Form Factor	Prismatic	
Dimensions	W: 174mm	
	H: 207mm	
	T: 71mm	
Weight	5.6±0.1kg	
Rated Capacity	314Ah	
Rated Energy	1004.8Wh	
Rated Voltage	DC 3.2V	

Operating Voltage Range	DC 2.5~3.65V	
Operating Temperature Range	Charge: 0~60°C (32~140°F)	
	Discharge: -30~60°C (-22~140°F)	

2.3.1.2 Battery Module

A battery module is composed of multiple cells connected in series and is equipped with one battery module management unit (BMU).

Parameter	Value	Image
Configuration	104S1P	 (For reference only)
Key Components	104 cells	
	1 BMU	
Dimensions	W: 790mm	
	H: 243mm	
	D: 2170mm	
Weight	650±10kg	
Rated Capacity	314Ah	
Rated Energy	104.4992kWh	
Rated Voltage	DC 332.8V	

Operating Voltage Range	DC 280.8~374.4V

2.3.1.3 Battery Cluster

A battery cluster is composed of multiple battery modules connected in series and is equipped with one battery cluster management unit (BCU).

Parameter	Value
Configuration	416S1P
Key Components	4 battery modules
	1 BCU, located in the switchgear
Rated Capacity	314Ah
Rated Energy	417.9968kWh
Rated Voltage	DC 1331.2V
Operating Voltage Range	DC 1123.2~1497.6V

2.3.1.4 Battery Array

A battery array is composed of multiple battery clusters connected in parallel and is managed by the battery array management unit (BAU).

Parameter	Value
Configuration	416S4P
Key Components	4 battery clusters
	2 switchgears, each containing 2 BCUs
	1 BAU, located in the distribution panel
Rated Capacity	1256Ah
Rated Energy	1671.98kWh
Rated Power	526kW
Rated Voltage	DC 1331.2V
Operating Voltage Range	DC 1123.2~1497.6V

2.3.2 Battery Management System (BMS)

The battery energy storage system (BESS) employs a multi-tiered battery management system (BMS) for system monitoring and control. Each BMS comprises multiple battery module management units (BMUs), multiple battery cluster management units (BCUs), and one or multiple battery array management units (BAUs).

Figure 2-2 Battery Array Management Unit (BAU) (For reference only)

2.3.2.1 Battery Management Units and Functions

The BMU can be used to detect voltage and temperature and perform cell balancing. The BCU can manage BMUs, detect cluster voltage and cluster current, and execute protection functions by switching DC contactors. The BAU can manage BCUs and communicate with Golden Shield (GS).

Function		BMU	BCU	BAU
Measurement	Cell Voltage	✔		
	Cell Temperature	✔		
	Cluster Voltage		✔	
	Cluster Current		✔	

Calculation	SOC		✔	✔
	SOH		✔	✔
	Power Prediction		✔	✔
Control	Contactor Control		✔	
	Cell Balancing	✔	✔	
Communication	CAN2.0	✔	✔	✔
	RS485		✔	✔
	Ethernet			✔

2.3.2.2 Battery Management System Architecture

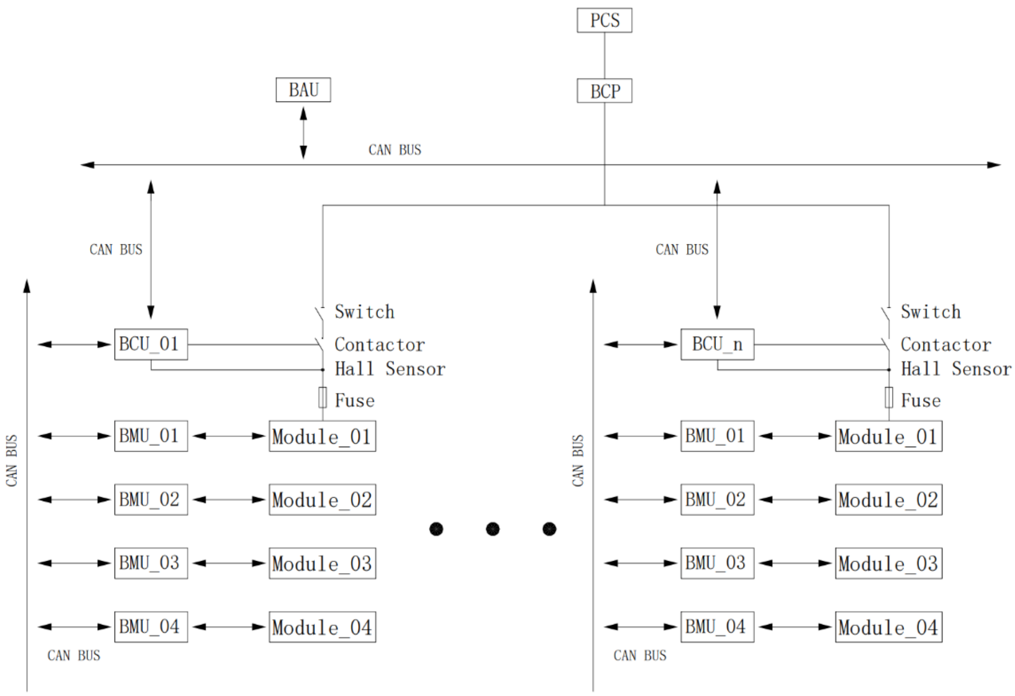


Figure 2-3 BMS Architecture

2.3.3 Golden Shield

To provide a universal communication port for battery systems equipped with the supervisory control and data acquisition (SCADA) system or the EMS and to free the EMS from basic system protection, a system controller, namely the Golden Shield (GS) shown in the following figure, is integrated and deployed in the BESS.

Figure 2-4 Golden Shield

2.3.3.1 Features and Functions

- Integration of battery system control, including the BMS, cooling devices, BCP, etc.
- Provide a universal communication port for battery systems equipped with SCADA or EMS.
- As a communication adapter, convert various communication protocols (such as RS485, CAN, dry contacts, etc.) of the balance of system (BOS) like BMS, PCS, HVAC, FSS into one communication protocol of the EMS for easy integration.
- Implement basic system protection to prevent equipment, such as batteries and PCS, from being damaged during operation.
- Record data for a short period for troubleshooting.

2.3.3.2 Communication Topology

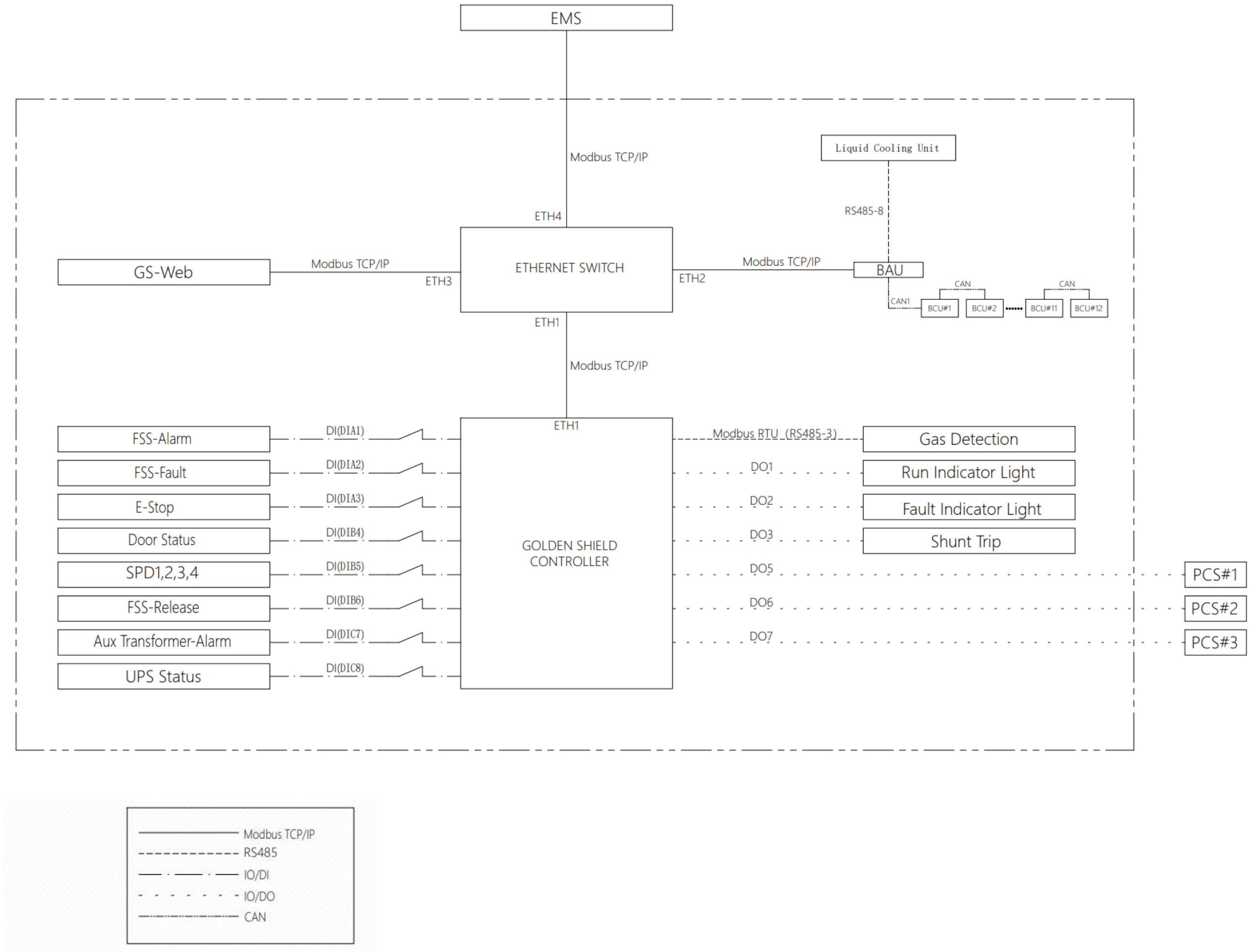


Figure 2-5 Golden Shield Communication Topology

2.4 Fire Suppression System

2.4.1 Precautions

⚠ DANGER
● If there is visible fire or even an explosion at the site, it is prohibited to approach the container for manual emergency discharge operation. ● When the equipment activates automatic fire suppression, it releases a large amount of gas that rapidly consumes oxygen inside the container through chemical reactions. Operators must not enter the container during this period to avoid the risk of death by asphyxiation.

⚠ NOTICE
● The container is equipped with an automatic fire suppression system. The FSS buttons must not be triggered casually under non-emergency circumstances. ● It is necessary to adhere to the fire suppression codes and regulations of the country and region where the project is situated. ● Fire suppression equipment should be inspected and maintained on a regular basis to ensure all functional parameters are normal.

NOTE
If users intend to utilize the Water-Based Fire Suppression System integrated into

the ESS (where applicable), they shall comply with the laws, regulations, standards, and codes of the project's location, and independently design and construct supporting fire wastewater treatment solutions and facilities based on the actual project conditions. It is necessary to ensure that such solutions and facilities fully meet the requirements regarding legality, safety, and long-term effectiveness. SYL assumes no liability for any matters related to fire wastewater treatment.

2.4.2 Fire Suppression System Overview

The fire suppression system is based on core subsystems such as the Fire Detection and Alarm System, Ventilation and Air-Exchange System, Aerosol Fire Suppression System, and Water-Based Fire Suppression System. Through seamless integration with the fire alarm control panel and the Golden Shield controller, it establishes a protection system covering the entire process of fire early warning, risk prevention, and fire response. Relying on a multi-layered protection mechanism, it provides all-dimensional fire safety for energy storage systems. It can implement efficient fire suppression in stages for different phases of fire germination, development, and spread, minimizing losses to the energy storage system.

2.4.3 Fire Suppression System Components

- **Fire Detection and Alarm System**

  Smoke detectors and heat detectors are deployed at key positions inside the container to monitor smoke concentration and temperature in real time. When the detected value exceeds the preset safety threshold, an early warning signal is immediately sent to the fire alarm control panel to achieve early and accurate identification of fire hazards and intervention.

- **Ventilation and Air-Exchange System**

Combustible gas detectors monitor the concentration of combustible gases inside the container in real time. When the concentration reaches the set safety threshold, it immediately sends an early warning signal to the fire alarm control panel and automatically activates the mechanical ventilation devices. Through forced convection, accumulated combustible gases are discharged to control the concentration within a safe range, reducing the risk of deflagration at the source.

- **Aerosol Fire Suppression System**

It can quickly achieve total flooding protection inside the container. Through a dual fire-extinguishing mechanism of chemical inhibition of combustion chain reactions and physical oxygen isolation, it rapidly suppresses the spread of initial fires, effectively addressing electrical fires and battery thermal runaway.

- **Water-Based Fire Suppression System**

As the ultimate fire-extinguishing measure, it can quickly connect to an external water source through the FSS water supply port, activate the water sprinkler devices to precisely cool and reduce the temperature in the open fire area, rapidly extinguish the open fire, and continue sprinkling to prevent lithium battery re-ignition. Meanwhile, a physical isolation barrier is constructed through dense sprinkling to block the spread of fire, creating safe conditions for subsequent emergency response.

2.4.4 Fire Suppression System Logic Diagram

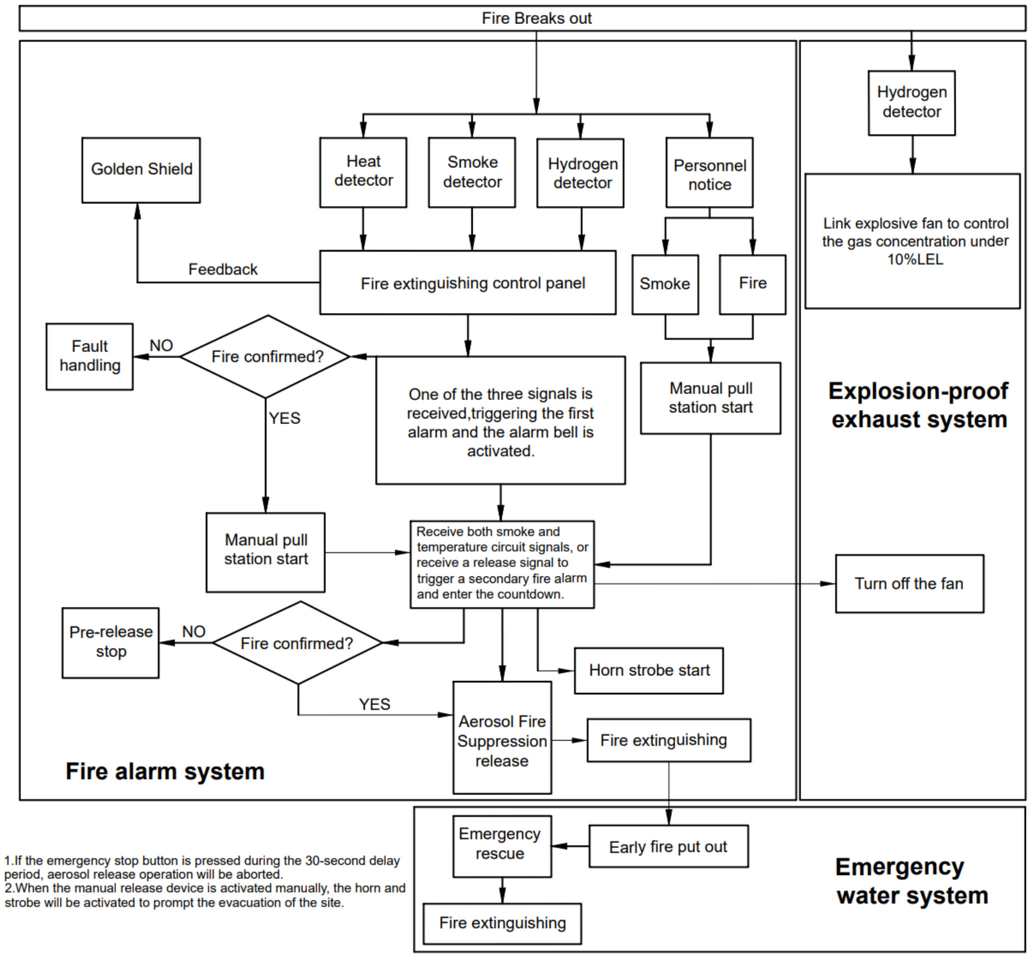


Figure 2-6 Fire Suppression System Logic Diagram

2.4.5 Water Supply for Water-Based Fire Suppression System

⚠ NOTICE
The piping of the Water-Based Fire Suppression System shall remain dry under

normal conditions. External water source connection via the FSS water supply port is strictly permitted only during emergency situations (e.g., fire incidents).

A FSS water supply port is pre-reserved on the right side near the Battery Connection Panel (BCP) end, approximately 1400mm above the bottom corner casting. On-site personnel may consider pre-connecting the water supply pipeline based on actual conditions.

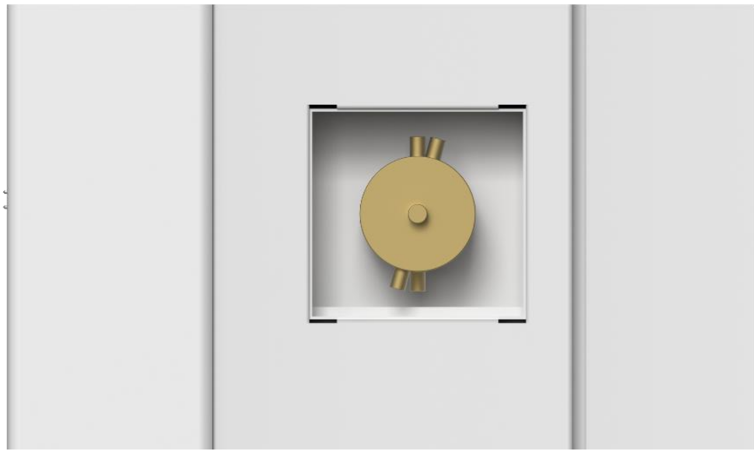


Figure 2-7 FSS Water Supply Port

2.4.6 Post-Discharge Handling Measures for Aerosol Fire Suppression System

2.4.6.1 Precautions

⚠ DANGER
● Flammable gases may be present inside the container. It is strictly prohibited to carry open flames, heat sources, or lit cigarettes into the hazardous area to prevent re-ignition or explosion. ● Toxic gases may be present. Before entering, personal protective measures must be taken, and respiratory protective equipment complying with local

regulations must be worn to ensure life safety and health.

- After firefighting, professional firefighters must assess the internal safety risks. The container door can only be opened after confirming that no hazards exist.

⚠ NOTICE
During the handling process, portable fire extinguishers must be equipped throughout to prevent re-ignition.

2.4.6.2 Handling Measures

Ventilation and Inspection

- After the aerosol fire suppression device is discharged, keep the protected area airtight for 10 minutes or more. Ventilation or opening doors, windows, fire doors, or other openings is prohibited during this period.
- Thoroughly ventilate the area using ventilation systems, fans, or by opening windows before entering. Wear respiratory protective equipment throughout the process to avoid inhaling toxic substances and aerosol fire extinguishing agents.
- Conduct a comprehensive inspection after entering to confirm the fire is extinguished and there are no localized heat sources or re-ignition points.

Residue Handling

- In high-humidity environments, dehumidification must be performed after ventilation to prevent residues from absorbing moisture, which could corrode metals and electronic devices or cause circuit board short-circuits.

- For aerosol fire extinguishing agent residues remaining after ventilation, promptly inspect and completely remove them:
    1. For aerosol residues on equipment and circuit board surfaces, use a lint-free cloth to gently press and absorb the liquid.

       Note: Directly wiping circuit boards is prohibited to avoid scratches or component damage. Paper products are forbidden to prevent fiber residue.
    2. Gently brush off particulate matter and dried liquid residues with a toothbrush.
    3. Use compressed air to quickly blow in a single direction for a short time to remove remaining dust and fine residues.

Dismantling and Disposal

- The casing of the aerosol fire suppression device may remain hot for a period of time after activation. Wear protective gloves and follow standard procedures when dismantling—do not touch directly.
- Dispose of the dismantled aerosol fire suppression device in accordance with local regulations.
- Contact us as soon as possible to replace the aerosol fire suppression device and re-commission it. For contact information, please refer to Chapter 9 Technical Support and After-Sales Service.

2.5 Thermal Management System

2.5.1 Precautions

⚠ CAUTION

- No blocking of air inlets and outlets for the thermal management system.
- Caution: risk of burns. The surfaces of the thermal management system reach high temperatures during operation and remain hot for a period after shutdown.

2.5.2 Liquid Cooling System Parameters

Parameter	Value
Cooling Capacity	25kW
Heating Capacity	19kW
Supply Voltage	AC 480V±10%
	60±3Hz
	3P
Maximum Operating Current	30A
Operating Ambient Temperature Range	-30~55℃ (-22~131℉)
Refrigerant Type	R513A
Coolant Type	50% Ethylene Glycol Aqueous Solution
Coolant Temperature	5~35℃ (41~95℉)

Coolant Replenishment Method	Automatic
IP Rating	Whole unit: IPX5
	Electrical control box: IP56
Corrosion Protection Grade	C4M
Permissible Operating Altitude	0~4000m **Note:** When exceeding 1000m, for every additional 1000m, derate by 5%~8%.
Noise Level	≤73dB@1m

3 Transportation and Storage

3.1 Handling and Transportation

3.1.1 Precautions

WARNING

- Do not expose to direct rain or snow to prevent water ingress.
- Avoid dropping or mechanical impact.
- Do not tilt or invert.

Note: In case of any of the above anomalies, refer immediately to the emergency measures in Section 1.5 Battery Safety for resolution.

NOTICE

This product is certified under UN38.3 (Section 38.3 of the Sixth Revised Edition of the *Recommendations on the Transport of Dangerous Goods: Manual of Tests and Criteria*) and *SN/T 0370.2-2009 Rules for the Inspection of Export Dangerous*

Goods Packaging-Part 2: Performance Testing, and is classified as Class 9 dangerous goods.

NOTE
Energy storage systems are subject to various external conditions such as temperature, transportation, and storage. Their specifications shall be based on the date of manufacture.

3.1.2 Handling

WARNING
● Energy storage systems must comply with the laws, regulations, and industry standards of the country and region where they are located during handling operations. ● During handling operations, handle with care. Rough handling may cause battery short circuits or damage inside the enclosure, and may also result in battery leakage, rupture, fire, or explosion.

3.1.3 Transportation

Transportation Preparation

- Before commencing transportation, batteries must be inspected. Batteries shall be intact without visible damage, abnormal odors, smoke, fire, etc. If any of these conditions occur, transportation is prohibited, and emergency measures must be initiated immediately. For specific emergency measures, refer to Section 1.5 Battery Safety.
- Before commencing transportation, the outer packaging of the product must be inspected to ensure it is secure.
- Before commencing transportation, ensure the product and its outer packaging comply with the requirements of transportation vehicles (e.g., trucks, vessels).

Transportation Requirements

- During transportation, the product must be fully protected against moisture.
- For sea transportation, comply with the *International Maritime Dangerous Goods Code* (IMDG CODE).
- For road transportation, comply with the *European Agreement concerning the International Carriage of Dangerous Goods by Road* (ADR) or *Regulations Concerning Road Transportation of Dangerous Goods* (JT/T 617).
- Meet the regulatory requirements of the country of departure, transit countries, and country of destination.
- Comply with other applicable international dangerous goods transportation regulations.

3.2 Storage

3.2.1 Precautions

NOTICE
● Storage environments must meet local regulations and standard requirements. ● For extended storage, qualified personnel must perform inspections and tests before returning the battery to service. ● When storing batteries, place them according to packaging labels and ensure proper orientation. Do not invert or tilt. ● When stacking battery packages, comply with stacking limits specified on the outer packaging. ● Handle batteries with care during handling to avoid damage.

NOTE
● During storage, relevant data records (e.g., temperature, humidity, storage environment) must be maintained in accordance with the product storage requirements in this manual. ● During storage, battery maintenance must be performed according to the maintenance requirements in this manual. For details, refer to Section 7.2 Battery System Maintenance.

- Long-term storage of batteries is not recommended. Long-term storage of lithium-ion batteries causes irreversible capacity loss. After 12 months of storage at the recommended temperature, the typical irreversible capacity loss is 3% to 6%.

3.2.2 Storage Requirements

- Recommended storage ambient temperature: ≤35°C.
- Recommended storage ambient humidity: <60% RH.
- Recommended battery system/spare battery modules storage SOC: 30%~50%. During storage, all external power-consuming devices must be disconnected. Perform regular inspections, maintain detailed inspection records, and promptly address any abnormal conditions.
- Store in a dry, clean, and well-ventilated warehouse to prevent dust and moisture ingress and ensure no short circuits.
- Avoid contact with corrosive organic solvents or gases to prevent battery corrosion and rust.
- Avoid direct sunlight.
- During storage, if any questions arise, please contact the after-sales service for consultation and handling. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.

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4 Product Installation

4.1 Precautions

⚠ WARNING
● Battery energy storage systems are high-voltage devices classified as dangerous goods. Improper operation by unqualified personnel may result in severe consequences such as electric shock, combustion, or explosion. ● Battery energy storage systems must be installed and maintained by qualified technical personnel and used strictly in accordance with relevant safety regulations.

4.2 Pre-Installation Inspection

4.2.1 Outer Packaging Inspection

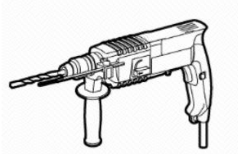
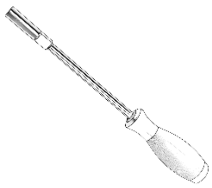
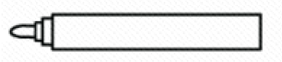
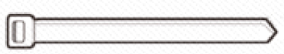
Before opening the outer packaging of the product, inspect it for visible damage (e.g., tears, cracks, or other signs of potential internal damage) and verify the product model. If packaging irregularities or model discrepancies are found, contact us immediately. Contact information is provided in Chapter 9 Technical Support and After-Sales Service.

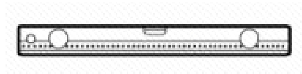
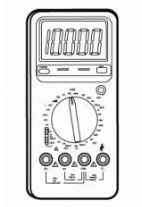
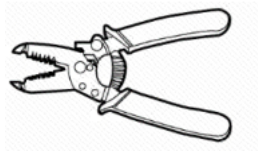
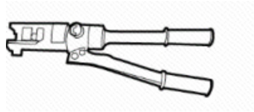
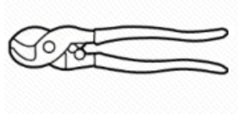
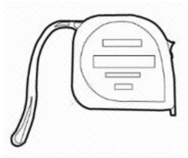
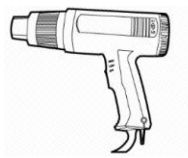
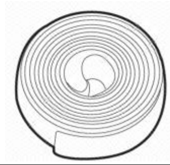
4.2.2 Delivered Items Inspection

After opening the outer packaging of the product, inspect the container itself and internal equipment for integrity and visible damage. Refer to the *Packing List* to check whether the spare parts and accessories provided are complete and intact. If any damage to the container/equipment or missing spare parts are found, contact us immediately.

4.3 Pre-Installation Preparation

4.3.1 Tools and Instruments

Name	Purpose	Image
Electric Drill and Φ16 Drill Bit	For making holes in expansion bolts.	
Screwdriver and Socket Set	For the installation of grounding wires, power cables, rubber conduits, and forklift hole covers.	
Torque Wrench	For confirming the torque of fasteners.	
Marker Pen	For torque markings.	
Zip Ties	For cable fixation.	

Level meter	For leveling the container.	
Multimeter	For continuity testing.	
Wire Stripper	For removing insulation from the ends of cables.	
Hydraulic Pliers	For crimping terminals and cables.	
Cable Cutter	For cutting cables.	
Tape Measure	For measuring dimensions.	
Heat Gun	For shrinking heat shrink tubing.	
Heat Shrink Tubing	For protecting wire and terminal connections.	
Cold Crimp Terminal Pliers	For crimping terminals and cables.	

4.3.2 Personal Protective Equipment

Name	Purpose	Image
Insulating Gloves	For electrical insulation protection.	
Insulating Shoes	For electrical insulation protection.	
Safety Goggles	For arc flash protection.	
Dust Mask	For dust protection.	

Note: Personal protective equipment of Category 1 or higher shall be worn.

4.3.3 Accessories

Name	Specifications	Purpose
Stainless Steel Shims	As required	For leveling the base.
Expansion Bolts	Recommended: M16×100	For connecting the foundation and container fasteners.
Steel Wire Rope	As required	For crane lifting.

Shackles	As required	For crane lifting.
Fasteners	Standard specifications	For connecting and securing the foundation and the container.
Assembly Bolts	M16×30 (property class 8.8)	For fastener installation.
Copper Cable Lug	Hole diameter compatible with M10 bolts	For grounding cable fabrication.
Grounding Cable	Crimping cross-sectional area≥3/0AWG	For equipment grounding.
Assembly Bolts	M10×25 (property class 8.8)	For grounding cable installation.
Fireproofing Mud	Standard specifications	For sealing cover plates.

4.4 Installation Requirements

4.4.1 Installation Environment Requirements

- Installation environments must comply with relevant international, national, and regional laws, regulations, and standards.
- For areas prone to natural disasters (e.g., floods, debris flows, earthquakes, typhoons), appropriate preventive measures must be implemented during installation.
- Install in a dry, well-ventilated environment and securely fasten equipment to a solid, flat

support surface.

- Ensure the installation location is clean, free of excessive infrared radiation, organic solvents, and corrosive gases.
- Keep the installation location away from ignition sources and heat sources. Do not store flammable or explosive materials near the equipment.
- Avoid water accumulation at the installation location. Keep it away from water sources to prevent water ingress.
- During operation, the heat dissipation area generates high temperatures. Avoid installing the equipment in easily accessible locations.
- Do not block vents or cooling systems during operation to prevent overheating and fire hazards.
- Never place the equipment in environments with flammable/explosive gases or fumes, and avoid any operations in such environments.

Note:

- The operation and service life of the energy storage system are related to the operating temperature. Install the equipment in an environment with a temperature equal to or better than the ambient temperature conditions.
- When the cell temperature is low, the system automatically derates charging power. If the cell temperature is below 0°C/32℉ before system startup, the minimum cell temperature must be heated to above 0°C/32℉ before charging begins.

4.4.2 Installation Foundation Requirements

- The container bottom must be supported by a concrete foundation with sufficient strength to provide adequate support for the container body.
- Use a level meter to measure the foundation levelness, ensuring it is ≤5mm, particularly on the eight mounting surfaces. If the levelness exceeds 5mm, level it out with stainless steel shims. A levelness ≥5mm may cause long-term issues such as equipment frame deformation, insufficient door sealing leading to water ingress, door malfunctions, or liquid-cooling pipe leakage.

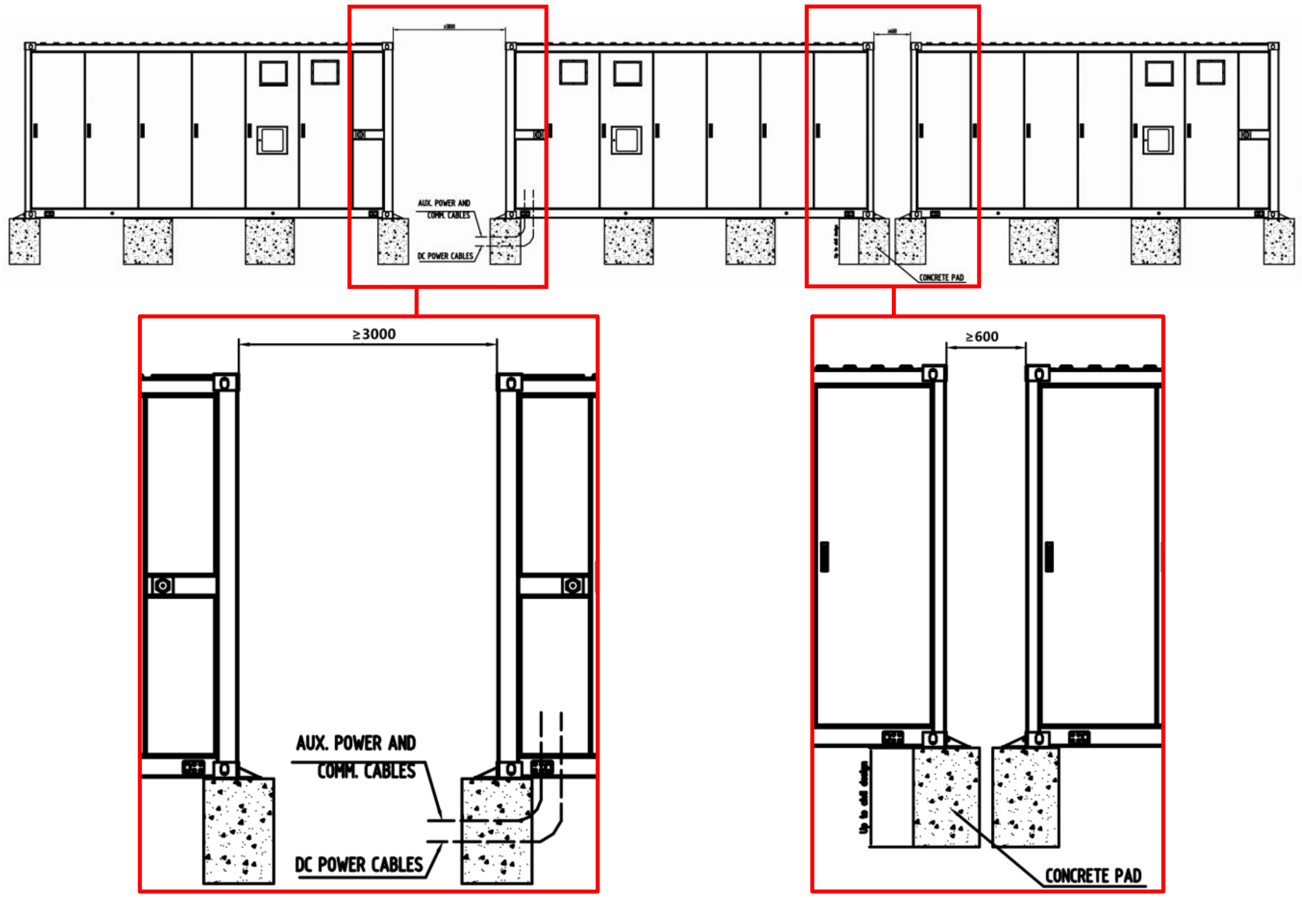


Figure 4-1 Front View of Installation Foundation (Unit: mm)

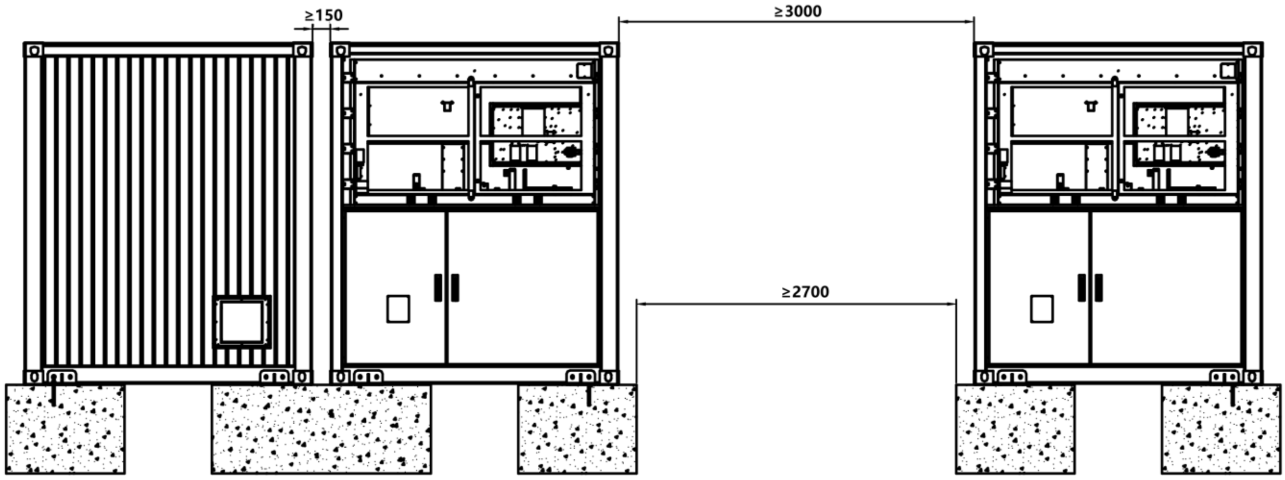


Figure 4-2 Left View of Installation Foundation (Unit: mm)

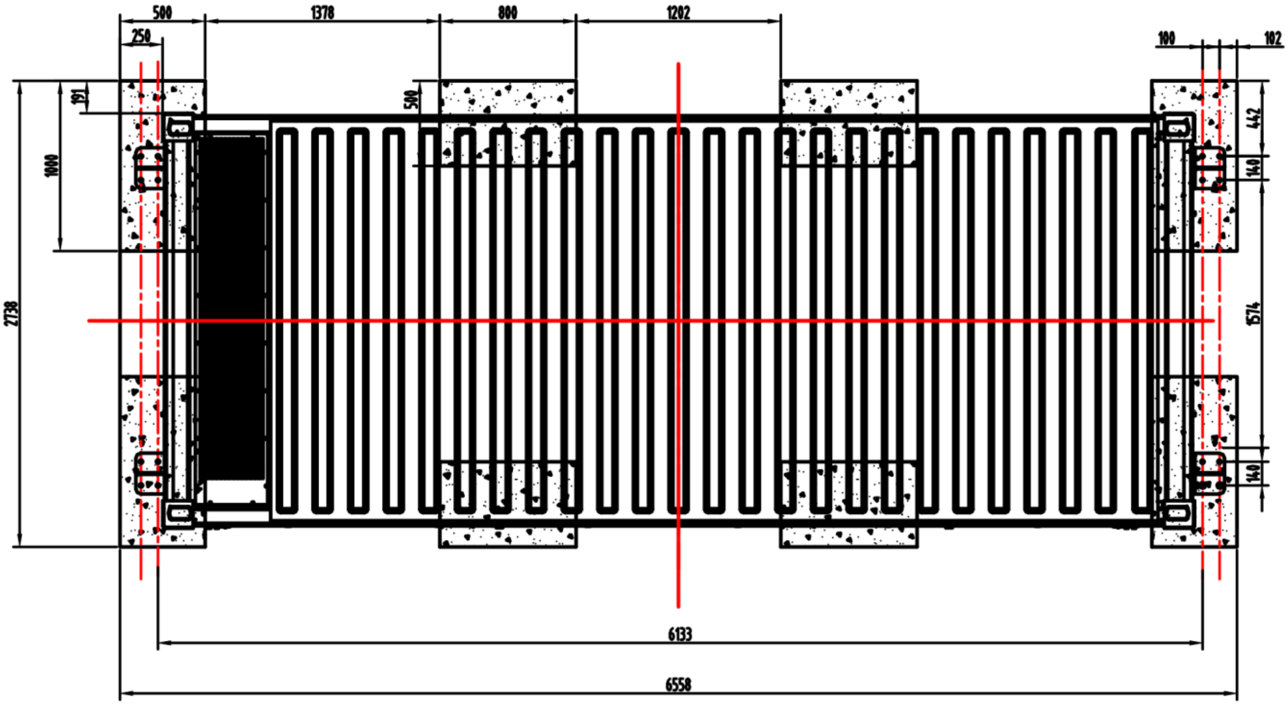
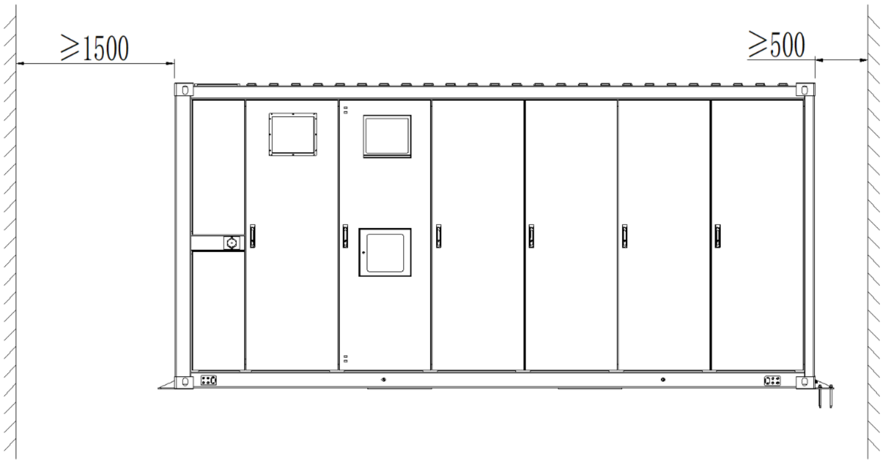


Figure 4-3 Top View of Installation Foundation (Unit: mm)

4.4.3 Installation Space Requirements

⚠ WARNING
When installing the equipment, ensure that there are no flammable or explosive materials in the vicinity and leave sufficient space for heat dissipation and safe separation.



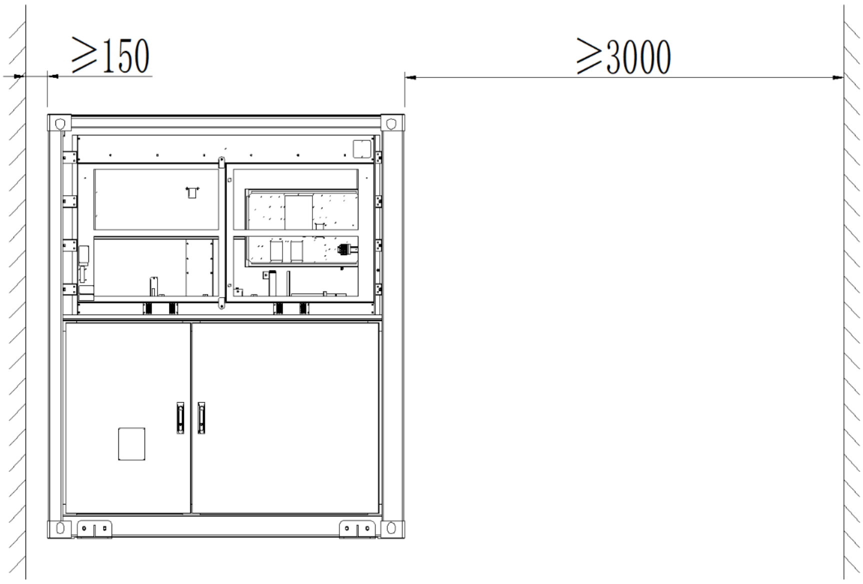


Figure 4-4 Single Container Installation Space Requirements (mm)

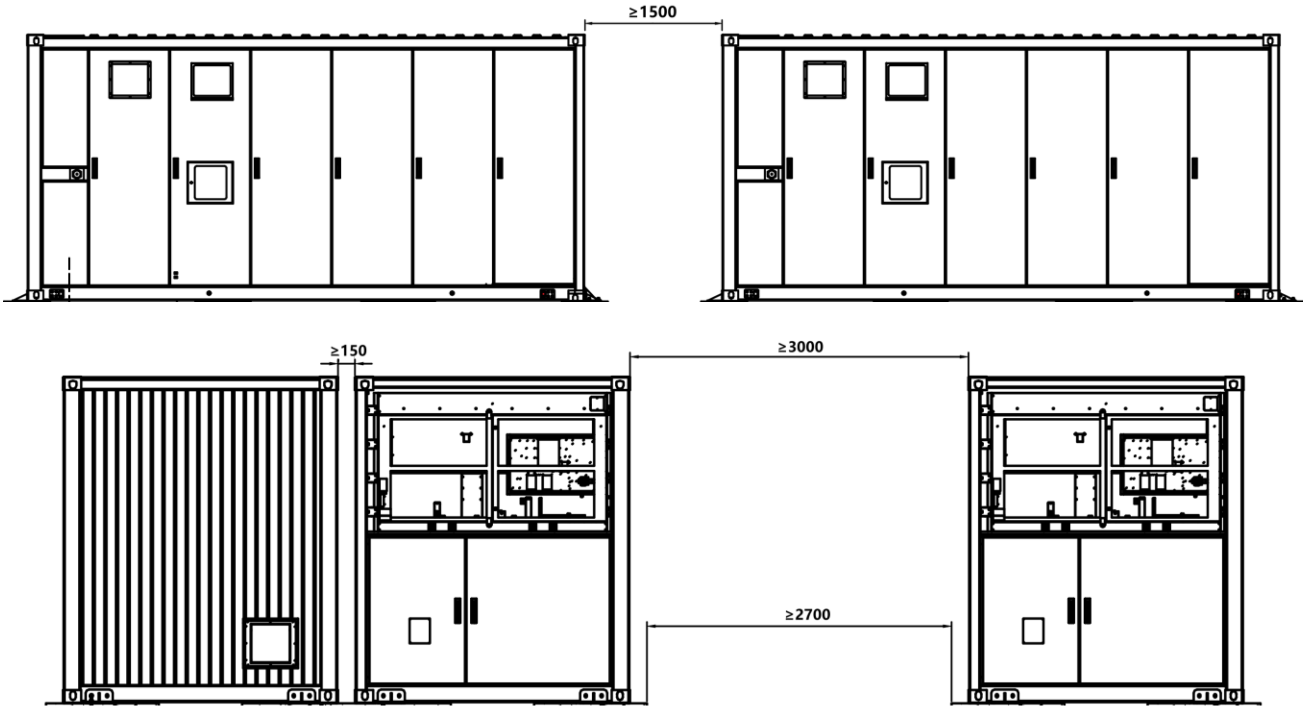


Figure 4-5 Installation Space Requirements for Multiple Container A Units (mm)

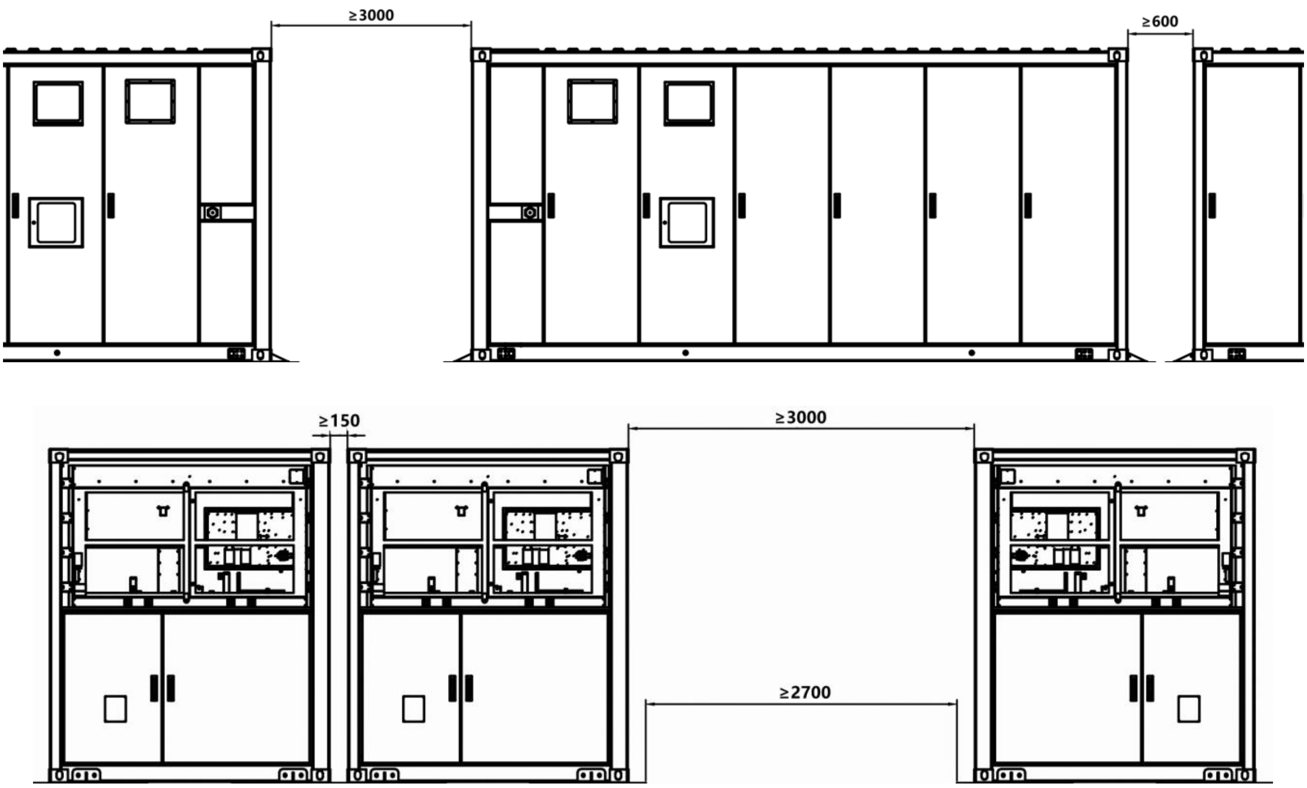


Figure 4-6 Installation Space Requirements for Multiple Container A and Container B Units (mm)

4.5 Equipment Installation

4.5.1 Equipment Lifting

⚠ WARNING

- During crane operations, no personnel are allowed within a 5m to 10m radius of the operation area.
- Never stand under the crane boom or beneath lifted/moving machinery to prevent injury or fatality.
- Lifting angles must be ≥60°. Ensure no personnel or obstacles are present in the vicinity before lifting.
- Suspend lifting operations during adverse weather conditions such as wind force ≥ Beaufort scale 6, heavy rain, snow, or fog.
- Immediately halt operations if abnormal conditions occur, including unusual noises, deformation, or weld cracks in the equipment.

⚠ CAUTION

- Select an appropriate crane based on site conditions and the weight of the product.
- Equip 4 steel wire ropes and 4 shackles according to the dimensions and weight of the product, ensuring they have suitable lengths and load-bearing capacities for safe and reliable operation.

- Lifting or lowering processes must be conducted at a constant speed, ensuring acceleration ≤0.1g (i.e., ≤0.98 m/s²).

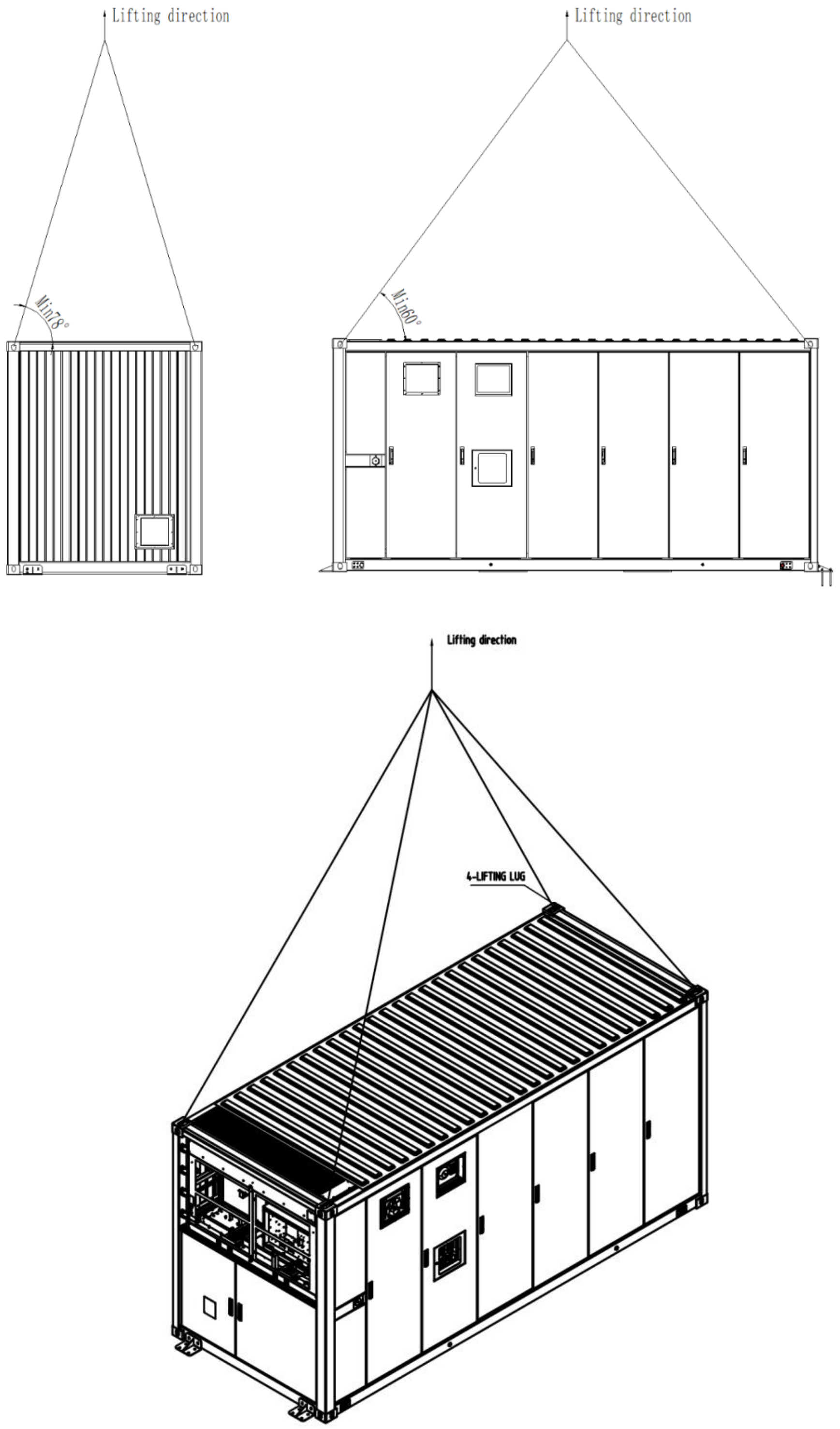


Figure 4-7 Container Lifting

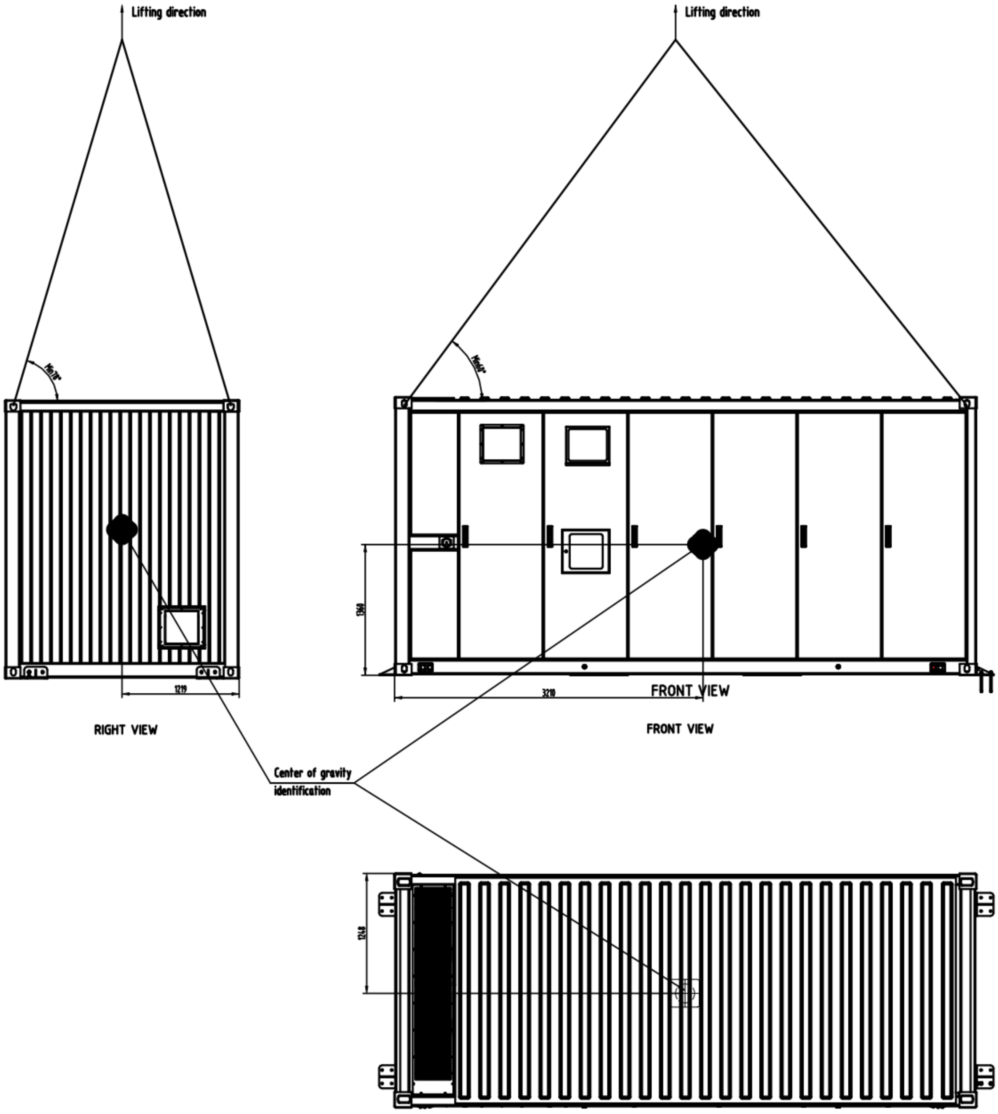


Figure 4-8 Container's Center of Gravity

4.5.2 Equipment Fixing

⚠ NOTICE
Before lifting the equipment, ensure the foundation levelness meets requirements (i.e., foundation levelness ≤5mm), particularly on the eight mounting surfaces. If the foundation levelness exceeds 5mm, use stainless steel shims for leveling.

4.5.2.1 Equipment Leveling

1. After the container is placed, use a level to measure the levelness of the eight mounting surfaces. The levelness must be ≤5mm. If it exceeds 5mm, use stainless steel shims for leveling.
2. After leveling, perform open/close operations on all container doors to ensure smooth movement. If doors do not operate smoothly, re-adjust the leveling until all doors function properly.

4.5.2.2 Installation of Fasteners

1. Determine the positions of expansion bolt fixing holes and drill holes to embed M16×100 expansion bolts.
2. Install the fasteners on the foundation. A single container requires 4 fasteners.
3. Use M16×30 assembly bolts to secure the fasteners to the container. Tightening torque: 127.50~150.00N·m.

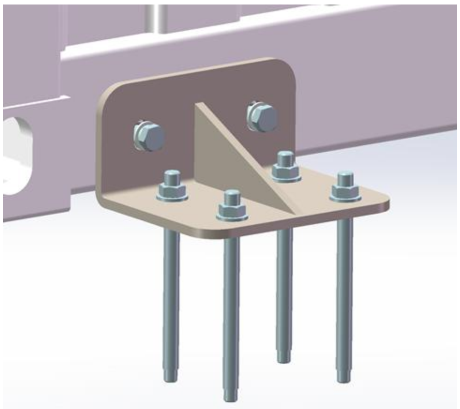


Figure 4-9 Fastener Installation

4.5.3 Equipment Grounding

The container is equipped with two grounding terminals on its side, either of which can be selected for grounding based on site requirements. Each grounding terminal features a layout of two rows and two columns with a total of four fastening points, supporting horizontal or vertical orientations for grounding cable arrangements to meet diverse on-site installation needs.

Installation of Grounding Cables

1. Grounding Cable Fabrication: Use a copper cable lug with a hole diameter compatible with M10 bolts, crimped with a cable with a cross-sectional area of not less than 3/0AWG to form the grounding cable.
2. Secure the grounding cable with M10×25 assembly bolts. Tightening torque: 37.49~44.10N·m.

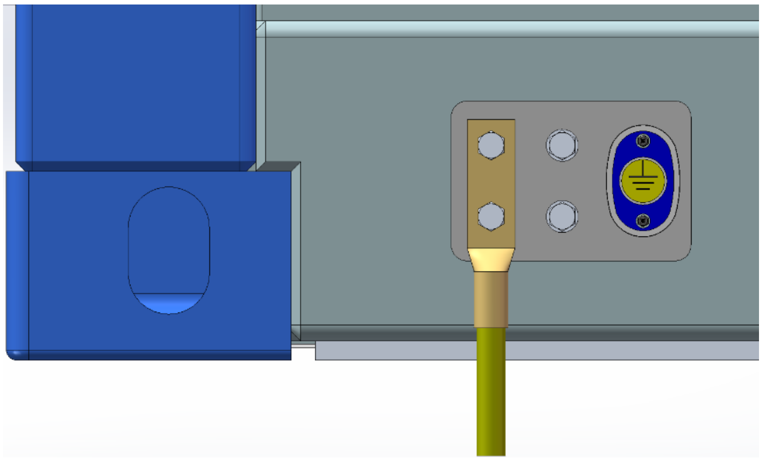


Figure 4-10 Vertical Grounding Cable Connection

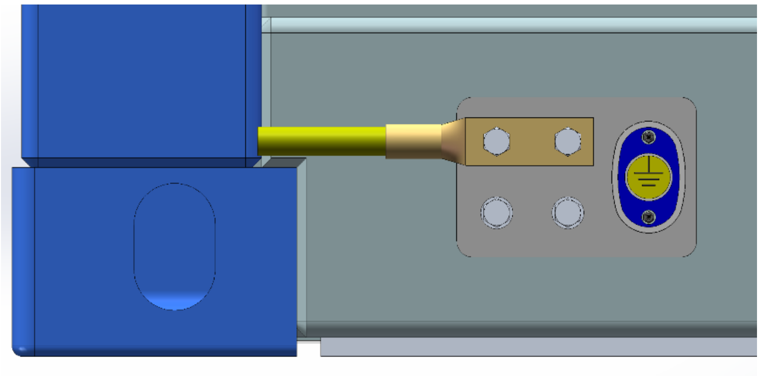


Figure 4-11 Horizontal Grounding Cable Connection

4.5.4 Wiring and Sealing

For external wiring operations, refer to the content described in Section 5.4 Auxiliary Power Supply Cable Connection and Section 5.5 PCS Power Cable Connection. The bottom of the BCP has pre-reserved cable inlet/outlet areas for power cables and auxiliary power cables, located below the connection panel and distribution panel, as shown in the figure below. Aluminum cover plates are installed for sealing at these two cable inlet/outlet areas during shipment. On site, drill holes in the cover plates as needed, and after wiring, seal the cover plates with the fireproofing mud provided in the package to ensure the internal sealing of the BCP.

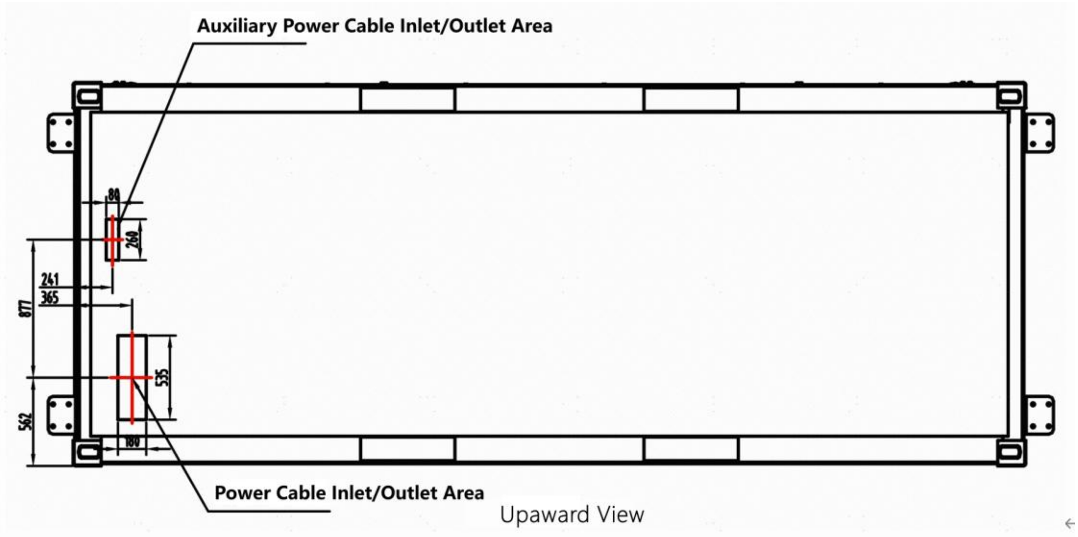


Figure 4-12 Cable Inlet/Outlet Areas

4.6 Post-Installation Inspection

- Use a level to check the levelness of the eight mounting surfaces, ensuring that the levelness is ≤5mm.
- Perform open and close operations on all container doors to ensure smooth movement without abnormal noise.
- Inspect the tightness of each container fastener to confirm the secure connection between the container and the foundation.
- Check the grounding cable for a secure connection and verify effective grounding using a multimeter.
- Ensure the bottom cover plate is tightly sealed with fireproofing mud after wiring.

5 Electrical Connection

5.1 Precautions

⚠ DANGER

- Before performing electrical connections, fully read Chapter 1 Safety Precautions of this manual and follow all requirements therein.
- Never touch live parts.

⚠ WARNING

- Electrical connection operations must be performed by qualified electrical personnel.
- Operators must wear personal protective equipment (PPE) during electrical connections.

> ⚠ **CAUTION**
>
> Tools used for battery power connection installation shall be insulated or shall minimize exposed metal areas. At least the handle portion must be insulated.

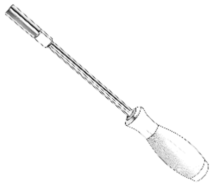
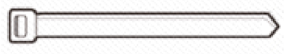
> ⚠ **NOTICE**
>
> Equipment damage resulting from incorrect wiring shall not be covered under the equipment warranty.

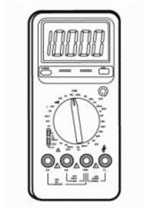
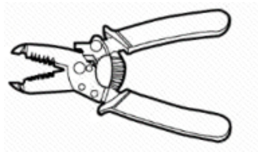
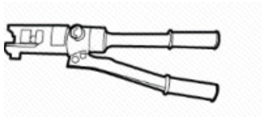
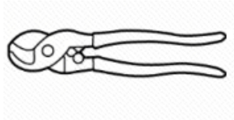
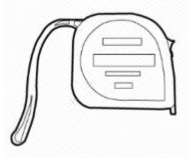
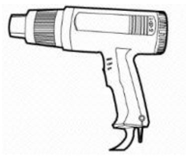
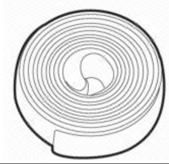
5.2 Pre-Connection Inspection

- Ensure that both AC and DC sides are not energized.
- Before connecting the cables, if the auxiliary power supply is supplied by a station-level transformer, it is necessary to confirm that the voltage between the neutral wire and the ground wire on the line side of the auxiliary power supply inlet is lower than 2V.

5.3 Pre-Connection Preparation

5.3.1 Tools and Instruments

Name	Purpose	Image
Screwdriver and Socket Set	For cable installation.	
Zip Ties	For cable fixation.	

Multimeter	For continuity testing.	
Wire Stripper	For removing insulation from the ends of cables.	
Hydraulic Pliers	For crimping terminals and cables.	
Cable Cutter	For cutting cables.	
Tape Measure	For measuring dimensions.	
Heat Gun	For shrinking heat shrink tubing.	
Heat Shrink Tubing	For protecting wire and terminal connections.	
Cold Crimp Terminal Pliers	For crimping terminals and cables.	

5.3.2 Personal Protective Equipment

Name	Purpose	Image
Protective Clothing	For electrical insulation protection.	
Insulating Gloves	For electrical insulation protection.	
Insulating Shoes	For electrical insulation protection.	
Safety Goggles	For arc flash protection.	

Note: Personal protective equipment of Category 1 or higher shall be worn.

5.3.3 Accessories

Name	Specifications	Purpose
Cable	Cross-sectional area≥ 6AWG	Connecting to the auxiliary power copper busbar terminals of the distribution panel.
Copper Cable Lug	Hole diameter compatible with M8 bolts	For cable fabrication.
Assembly Bolts	M8 (property class 8.8)	For cable connection.

Cable	Cross-sectional area≥ 1/0AWG	Connecting to the PCS power cable interfaces of the connection panel.
Copper Cable Lug	Hole diameter compatible with M12 bolts	For cable fabrication.
Assembly Bolts	M12 (property class 8.8)	For cable connection.
Network cable	CAT7	For Ethernet communication port connection.
Cable	Cross-sectional area 18AWG	Connecting to the PCS dry contact interface.
Tubular Terminal	Suitable for crimping cables with a cross-sectional area of 18AWG	Cable fabrication.

5.4 Auxiliary Power Supply Cable Connection

Connect the N, L1, L2, and L3 terminals as per the markings on the auxiliary power supply copper busbar of the distribution panel. Use 4 cables, each with a cross-sectional area of not less than 6AWG, to separately connect the interfaces. The cable ends shall be crimped with copper cable lugs compatible with M8 bolt hole diameters and secured with M8 assembly bolts. Tightening torque: 20.83~24.50N·m.

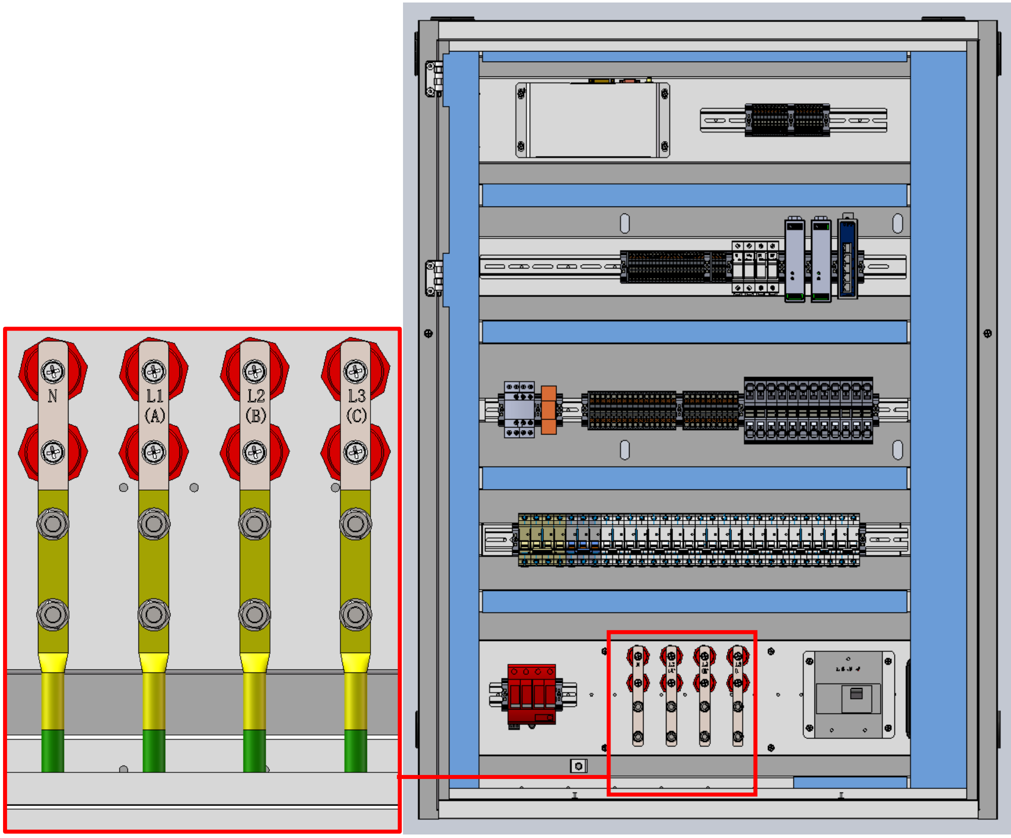


Figure 5-1 Auxiliary Power Supply Copper Busbar Cable Connection

5.5 PCS Power Cable Connection

Connect the PCS power cable interfaces on each copper busbar of the connection panel according to the polarity markings. Each interface area shall be connected using 2 cables, each with a cross-sectional area of not less than 1/0AWG. The cable ends shall be crimped with copper lugs compatible with M12 bolt holes and secured with M12 assembly bolts. Tightening torque: 66.73~78.50N·m.

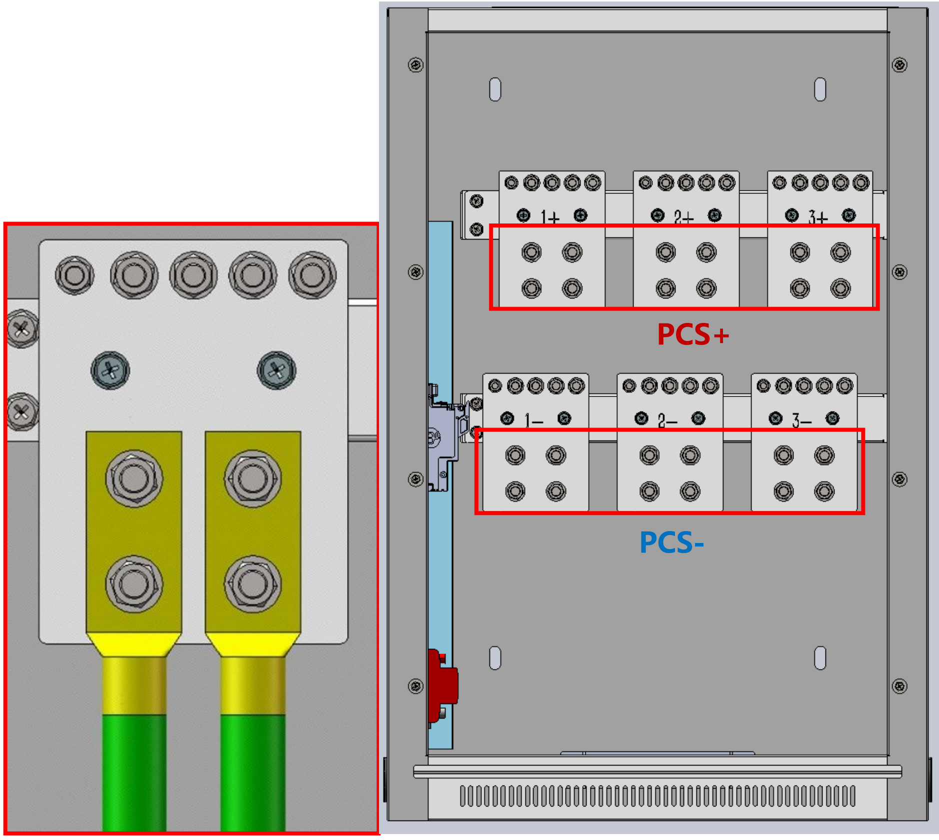


Figure 5-2 Connection Panel Copper Busbar Cable Connection

5.6 Ethernet Communication Port Connection

As shown below, the distribution panel provides multiple Ethernet communication ports inside.

Use CAT7 network cables to connect them to other devices.

Mark	Name	Description
1	ETH1	Ethernet communication port, connected to Golden Shield.
2	ETH2	Ethernet communication port, connected to BAU.

3	ETH3	System debugging Ethernet port.
4	ETH4	Ethernet communication port, connected to EMS.
5	ETH5	Reserved Ethernet port.

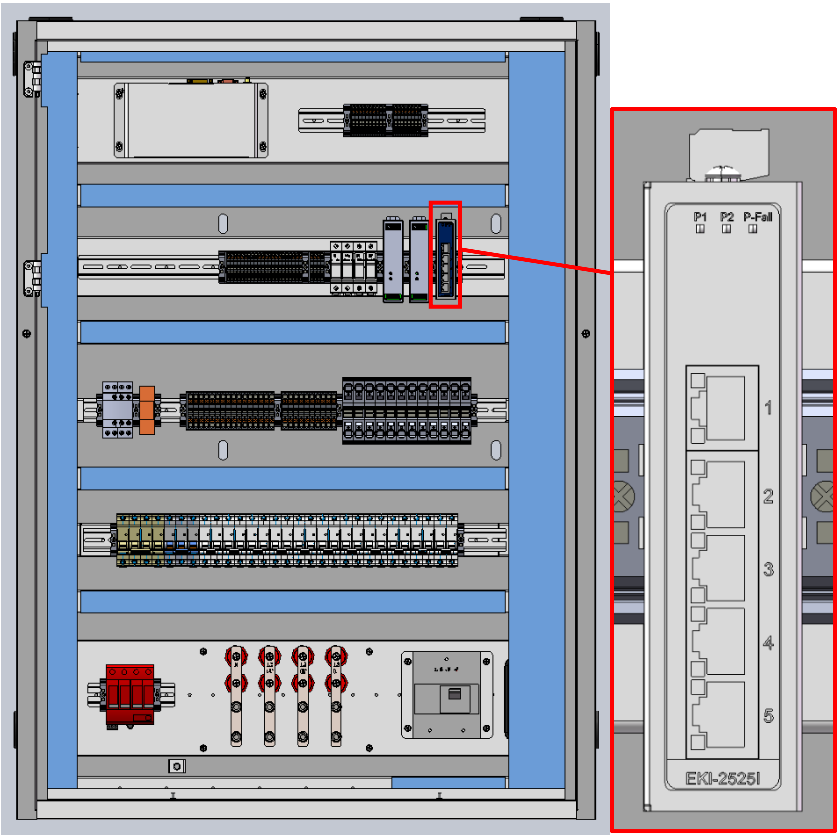
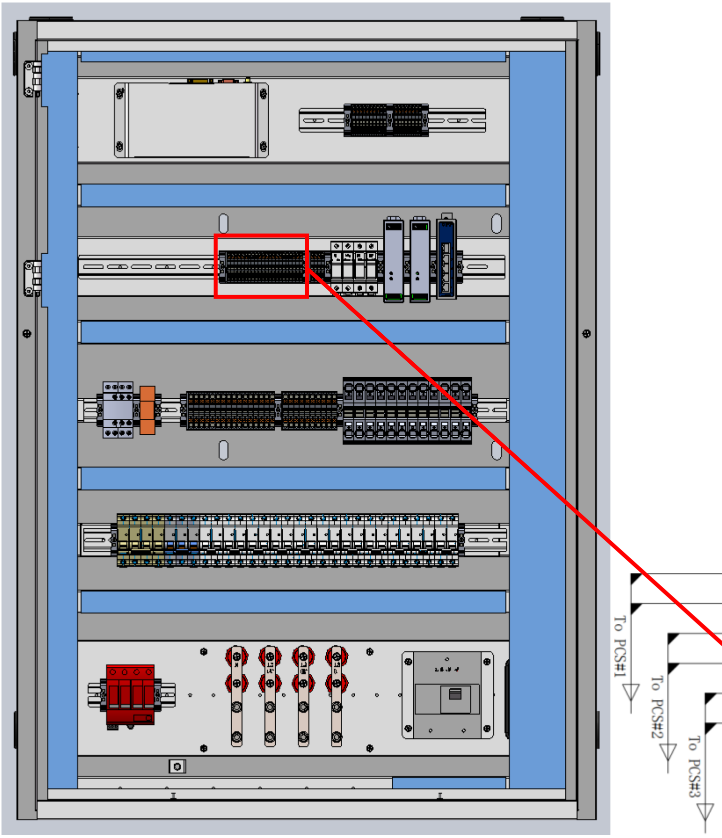


Figure 5-3 Ethernet Communication Port

5.7 Reserved PCS Dry Contact Interface

As shown in the figure, XT6-17 to XT6-22 are reserved PCS dry contact interfaces (shutdown signals), which can be selected for connection according to the actual PCS conditions. It is recommended to use cables formed by crimping tubular terminals onto cables with a cross-sectional area of 18AWG for connection.



XT6	DC 24V(PT 2.5)		
Lower End (-2)	Front View		Upper End (-1)
GS:D01-1	1	24V+	U1:24V+
GS:D02-3	2	24V+	RT2:1
GS:D03-5	3	24V+	RT3:1
	4	24V+	RT4:1
	5	24V+	
HD2:X2	6	24V-	U1:24V-
HD3:X2	7	24V-	BAU:J1-2
KA1:13	8	24V-	GS:GND
	9	24V-	NS:V1-
	10	24V-	
FSS Alarm:C	11	COMA	GS:COMA
FSS Fault:C	12	COMA	ES:12
SQ:2	13	COMB	GS:COMB
SPD1:11-C	14	COMB	FSS Release:C
TB1:T2	15	COMC	GS:COMC
KM1:13	16	COMC	
	17	PCS#1	GS:D05-1
	18	PCS#1	GS:D05-2
	19	PCS#2	GS:D06-3
	20	PCS#2	GS:D06-4
	21	PCS#3	GS:D07-5
	22	PCS#3	GS:D07-6

Figure 5-4 Reserved Dry Contact for PCS Emergency Stop Signal

5.8 Panel and Functions

5.8.1 Battery Module Panel

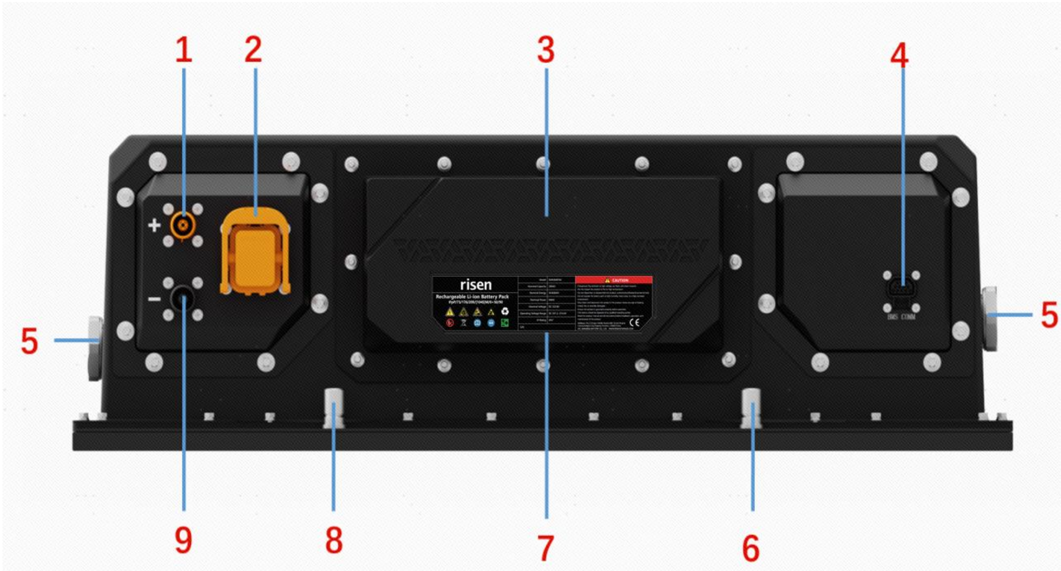


Figure 5-5 Battery Module (For reference only)

No.	Name	Description
1	+	Positive terminal of the battery module.
2	MSD	Manual service disconnect switch. Remove it before transportation and install it before operation.
3	BMU	BMU mounting panel
4	BMS COMM	Supplies power for BMU communication, including a 24V power source and CAN communication.
5	Explosion-proof valve	Balances the pressure difference between the

		inside and outside of the battery module.
6	Coolant outlet	Battery module liquid cooling coolant outlet.
7	Nameplate	Display battery module parameters.
8	Coolant inlet	Battery module liquid cooling coolant inlet.
9	-	Negative terminal of the battery module.

5.8.2 Switchgear Panel

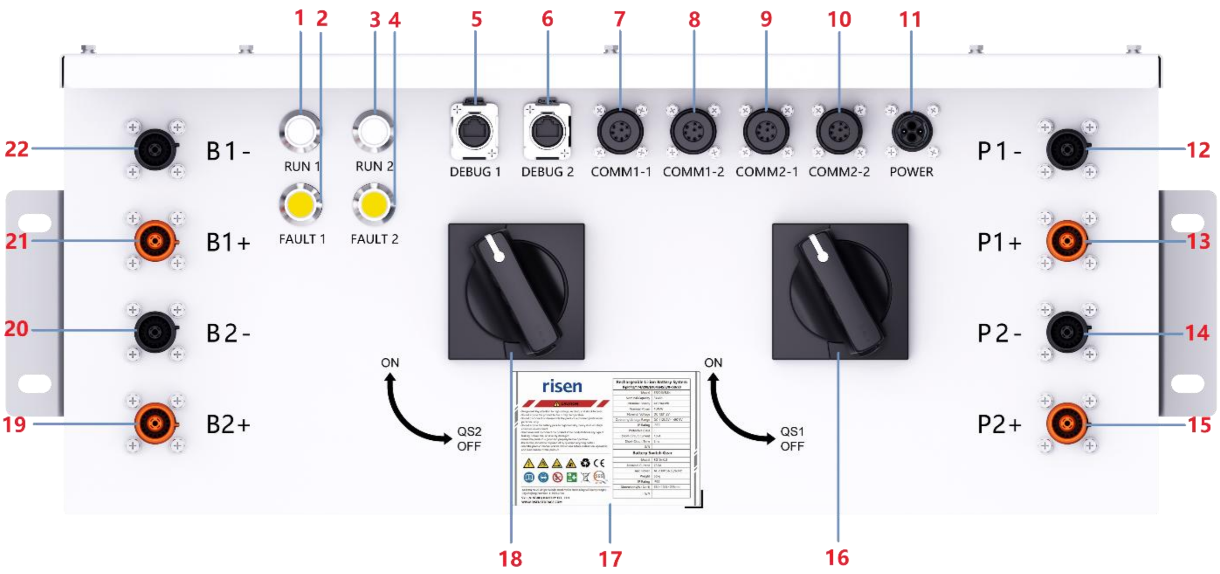


Figure 5-6 Switchgear Panel

No.	Name	Description
1	RUN1	Cluster 1 operation indicator.
2	FAULT1	Cluster 1 fault indicator.
3	RUN2	Cluster 2 operation indicator.

4	FAULT2	Cluster 2 fault indicator.
5	DEBUG1	BCU1 debug interface.
6	DEBUG2	BCU2 debug interface.
7	COMM1-1	Inter-cluster communication: Connect to COMM2-1 of the previous cluster's switchgear or to BAU.
8	COMM1-2	Intra-cluster communication: Connect to all BMUs in the cluster.
9	COMM2-1	Inter-cluster communication: Connect to COMM1-1 of the next cluster's switchgear or to the terminal resistor.
10	COMM2-2	Intra-cluster communication: Connect to all BMUs in the cluster.
11	POWER	BMS AC 220V auxiliary power input.
12	P1-	BCP Negative: Connect to DC Bus Negative.
13	P1+	BCP Positive: Connect to DC Bus Positive.
14	P2-	BCP Negative: Connect to DC Bus Negative.
15	P2+	BCP Positive: Connect to DC Bus Positive.
16	QS1	Circuit Breaker 1: Connect and disconnect Main Circuit 1.
17	Nameplate	Display switchgear parameters.

18	QS2	Circuit Breaker 2: Connect and disconnect Main Circuit 2.
19	B2+	Battery Positive: Connect to the nearest battery module Positive below the switchgear.
20	B2-	Battery Negative: Connect to the farthest battery module Negative below the switchgear.
21	B1+	Battery Positive: Connect to the farthest battery module Positive above the switchgear.
22	B1-	Battery Negative: Connect to the nearest battery module Negative above the switchgear.

5.9 Post-Connection Inspection

- Check all wiring points to ensure that the cables are firmly connected and there are no missing or loose connections.
- Ensure that the wiring terminals are firmly and reliably connected.

6 System Commissioning

6.1 Precautions

⚠ WARNING
● Operations related to system commissioning must be performed by qualified electrical personnel. ● Do not touch any original equipment or metal components before powering on.

6.2 Pre-Commissioning Inspection

6.2.1 Cable Connection

- After checking all wiring points, ensure that no cables are missing or loose.
- Maintain a safe distance and ensure that wiring terminals are firmly and reliably connected.

6.2.2 System Setup

Before powering on, carefully check the following items and ensure all electrical connections comply with this manual's requirements.

- The container enclosure has been effectively grounded.
- The system emergency stop button is in the normal state.
- All AC circuit breakers inside the distribution panel are switched off, i.e., all are in the "OFF" position. At this time, all indicator lights on the distribution panel are off.
- All isolating switches in the switchgear are in the "ON" position. At this time, all indicator lights on the switchgears are off.
- Manual service disconnects (MSDs) of all battery modules are inserted and properly locked.
- Ensure the automatic exhaust valve of the liquid cooling unit is in the open position.

6.3 Power-On Commissioning

6.3.1 Wiring Diagram for Auxiliary Power Supply

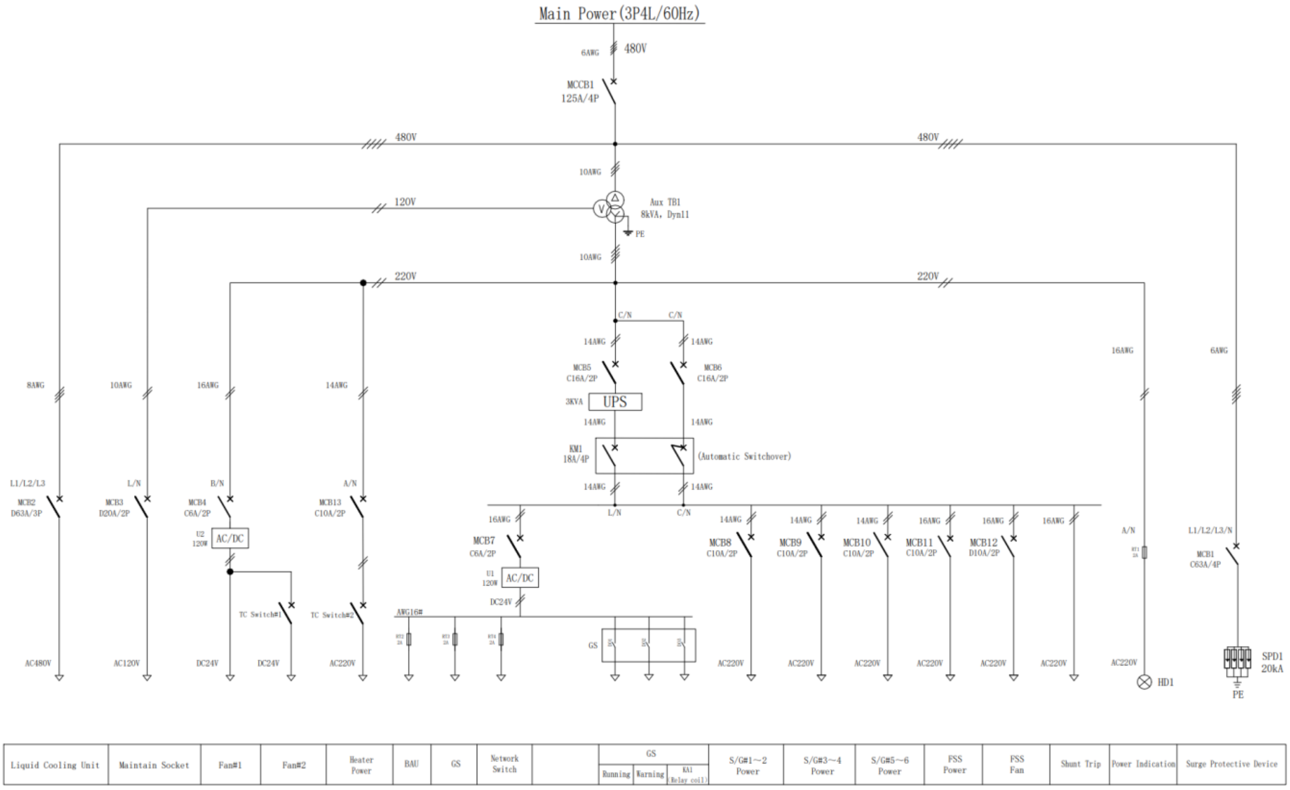


Figure 6-1 Wiring Diagram for Auxiliary Power Supply

6.3.2 Circuit Breakers and Control Objects

Circuit Breaker	MCCB1	MCB1	MCB2	MCB3
Control Object	480V Power Supply	Surge Protective Device	Liquid Cooling Unit	Socket

MCB4	MCB5	MCB6	MCB7	MCB8
Fan	UPS	UPS Bypass	Switch Mode Power Supply	Switchgear 1&2
MCB9	MCB10	MCB11	MCB12	MCB13
Switchgear 3&4	Switchgear 5&6	FSS	FSS Fan	Heater

6.3.3 Auxiliary Power Supply

1. When powering up the ESS for the first time, ensure the UPS is properly connected to its internal battery, then start the UPS via cold start (battery-powered).
2. Close the MCB7 Switch Mode Power Supply. When DC 24V outputs normally, devices such as GS, network switch, and BAU are powered up.

Figure 6-2 GS-web Maintenance Mode Switch

3. Connect the computer to the GS-web port on the container or the distribution panel network switch via a network cable. Enter 192.168.1.136 in the computer browser to access the GS-web terminal, and change the GS operation mode from normal mode to maintenance mode (as shown in Figure 6-2).

   Note: Exit the maintenance mode after normal operation. This change will automatically revert to normal mode when the GS is powered down.

4. After the 480V 3P4L power supply is properly connected, measure the voltage between the neutral wire and the ground wire at the line side of the MCCB1. Ensure that the voltage is less than 2V before closing the MCCB1 480V power supply switch.

   Note: If the voltage between the neutral wire and the ground wire at the line side of the MCCB1 is greater than or equal to 2V, it is strictly prohibited to close the MCCB1 power supply switch.

5. Close the MCB1 AC surge protective device switch. The AC surge protective device operates normally.
6. Close the MCB5 UPS power switch. The UPS operates normally and switches to utility mode.
7. Close the MCB6 UPS bypass power switch. When the UPS malfunctions, it can be automatically switched to the bypass mode.
8. Close the MCB4 fan power switch and MCB13 heater power switch. The fans and heater are powered normally.
9. Close the MCB8, MCB9 and MCB10 switchgear power switches. The switchgears' AC

power supply operates normally, and the power indicator green light is on.

10. Open the fire alarm control panel. After completing the 24V backup power connection, close the MCB11 FSS power supply switch, and the fire alarm control panel will be powered normally.
11. Close the MCB12 FSS fan power switch. The fan is powered normally.
12. Close MCB2. The liquid cooling unit operates after the power supply is applied.
13. Close the MCB3 socket power switch. The socket of the container is powered normally.
14. The auxiliary power supply procedure for Container B is the same as that for Container A. Repeat steps 1 to 13 to supply auxiliary power to Container B. The auxiliary power supply for both Container A and Container B is now complete.

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6.3.4 Operational Status Overview

After the auxiliary power supply is powered normally, the operation status information of the energy storage system (Figure 6-3), all battery clusters (Figure 6-4), and auxiliary devices such as HVAC (Figure 6-5) can be viewed on the GS-web terminal.

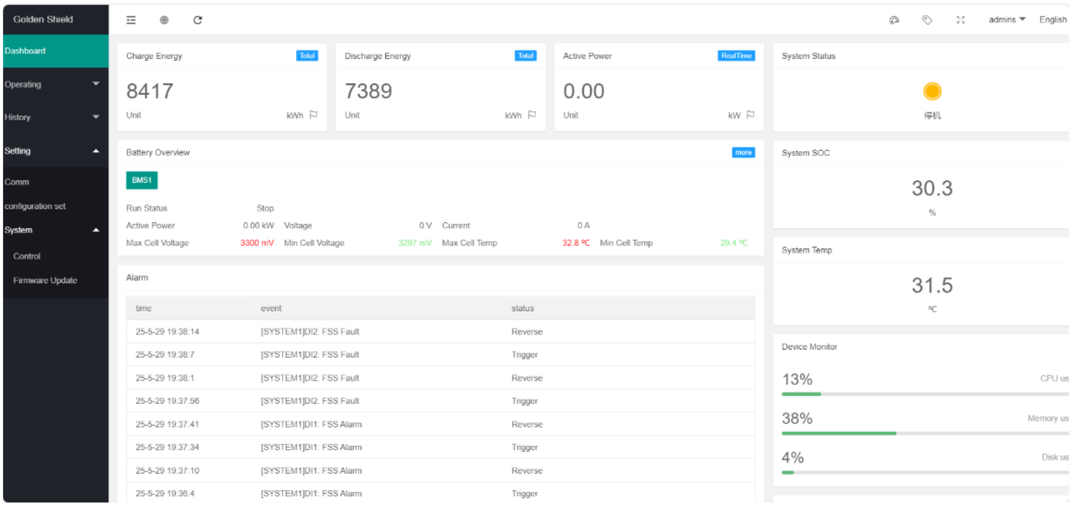


Figure 6-3 Operational Status Overview of the ESS

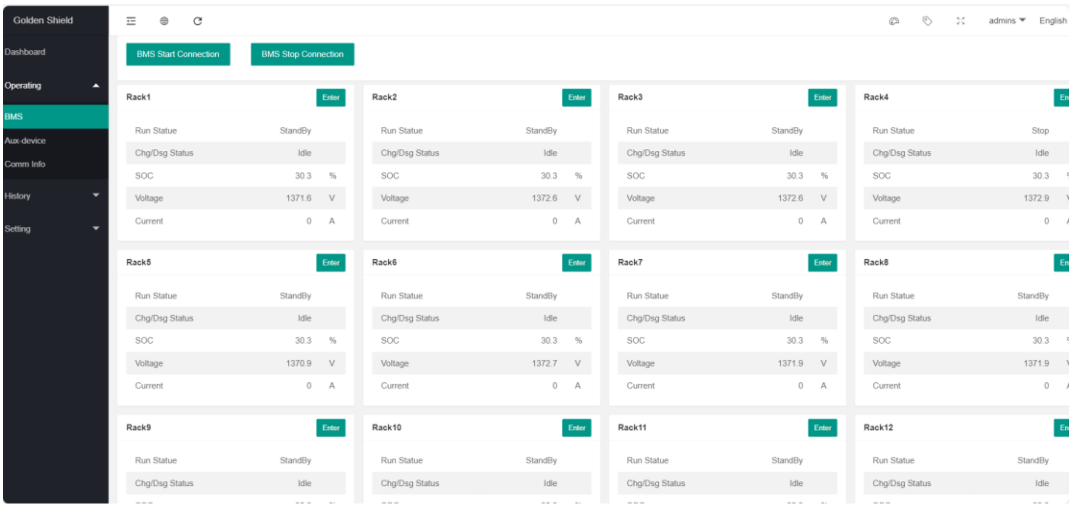


Figure 6-4 Operational Status Overview of the Battery Clusters

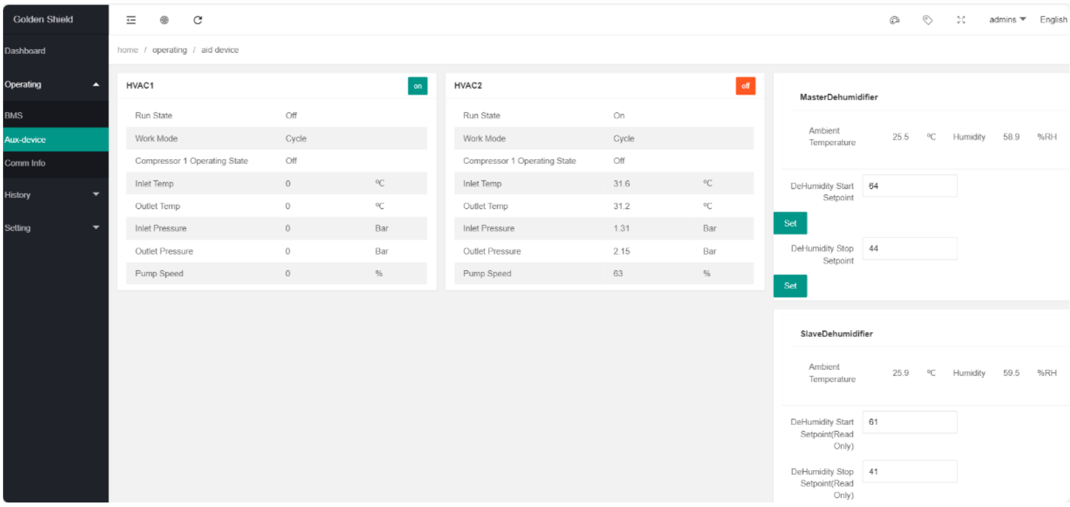


Figure 6-5 Operational Status Overview of Auxiliary Devices

6.3.5 High-Voltage DC Power On/Off Operations

NOTE
● When the energy storage system is in standby state under non-maintenance mode, charging and discharging operations cannot be performed. ● When the energy storage system is in operation state, the active power and reactive power parameters of PCS will be automatically set to 0.

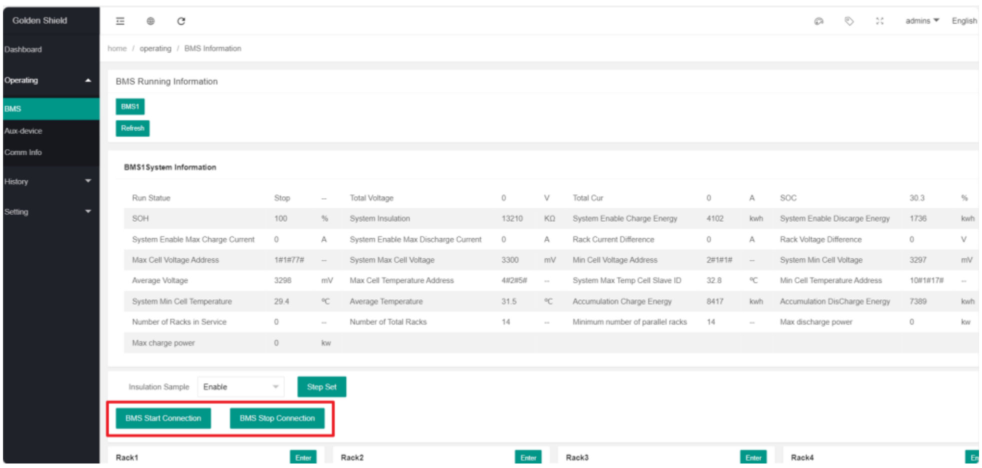


Figure 6-6 BMS Real-time Operational Information

When communication is normal and there are no alarms, perform high-voltage DC power on/off operations for the battery array via the GS web interface, as shown in Figure 6-6.

- Click the "BMS Start Connection" button. All contactors in the switchgear of battery clusters will close, completing the DC side power-on. The battery system is now in a charge/discharge enabled state.
- Click the "BMS Stop Connection" button. All contactors in the switchgear of battery clusters will open, completing the DC side power-off. The battery system cannot perform charge/discharge operations at this time.

Note: During charging or discharging, do not manually turn off the energy storage system. Failure to follow this instruction may damage contactors or isolating switches.

6.3.6 Powering Off the Auxiliary Power Supply

1. Disconnect MCB7, MCB8, MCB9, and MCB10 in sequence.
2. Disconnect MCB2, MCB4 and MCB13.
3. Disconnect MCB11 and MCB12.
4. Disconnect MCB5 and MCB6, turn off the UPS power supply.
5. Disconnect MCB3, turn off the socket power.
6. Disconnect MCB1 and MCCB1, turn off the 480V 3P4L power supply.

7 System Maintenance

7.1 Precautions

⚠ DANGER
Before performing system maintenance, carefully read and strictly follow the safety precautions listed in Section 1.7 Maintenance and Replacement.

Declaration

- The maintenance cycles mentioned in this manual are the minimum requirements. If the Authority Having Jurisdiction (AHJ) at the project location specifies more stringent cycle requirements, its regulations shall be complied with.
- This chapter does not fully and exhaustively describe all system maintenance requirements. Applicable maintenance management systems shall be developed in compliance with the laws, regulations, and standards of the country or region where the project is located.
- The system maintenance content described in this chapter is for reference only. In case of

discrepancies between the maintenance specifications provided by the equipment manufacturer and the content of this chapter, the maintenance specifications provided by the equipment manufacturer shall take precedence.

Maintenance Personnel

⚠ NOTICE
● Personnel responsible for operating and maintaining the equipment must undergo rigorous training, understand all safety precautions, master correct operation and maintenance methods, and possess the knowledge and experience required for maintaining relevant equipment. ● Only qualified professionals or trained personnel are permitted to operate and maintain the equipment. ● Only qualified professionals are allowed to remove safety devices and overhaul equipment. ● Replacement of equipment and components (including software) must be performed by qualified professionals or authorized personnel.

Qualified maintenance personnel shall meet any of the following requirements:

- Have received training provided by the manufacturer and obtained a certification for the relevant equipment issued by the manufacturer.
- Have obtained relevant certifications from an accredited certification body accepted and

recognized by the AHJ.

- Are registered, licensed, or certified by the authorities of the country or region where the project is located to service the relevant equipment.

7.2 Battery System Maintenance

7.2.1 Precautions

⚠ WARNING

- Incorrect operation may lead to serious personal injury or property damage.
- Be cautious of hazardous voltages in battery modules and be aware of the risk of short circuits.
- If a rapid temperature rise in cells is detected, cease operation immediately and seek assistance promptly.
- In the event of emergencies such as short circuits, fires, or electric shocks, remain calm, stop charging immediately, apply appropriate emergency measures, and seek professional help.

⚠ CAUTION

- Ensure a dry and well-ventilated environment is selected, and operations are conducted in designated areas.
- Keep the work area free of debris, especially metal fragments or liquids that

may cause short circuits.

- Verify that the balancer settings match the cell recharging requirements.
- Before performing recharging operations, inspect the external condition of cells for damage, dents, swelling, or liquid leakage.
- When charging battery modules, never wear metal jewelry like necklaces, rings, or watches.

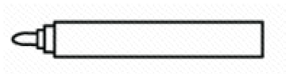
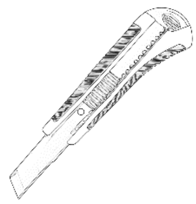
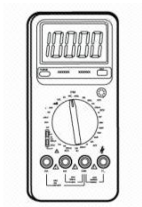
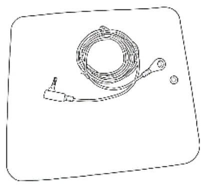
NOTICE

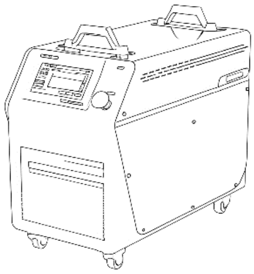
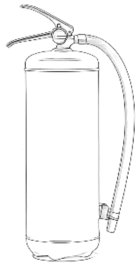
- Conduct safety training for operators in advance to familiarize personnel with the chemical properties and potential risks of cells, and understand emergency handling procedures.
- When temporarily storing cells, handle them with care to avoid impact, extrusion, or puncture. Terminals must be protected to prevent positive-negative short circuits.
- Regularly inspect and maintain equipment related to cell use to ensure normal operation. If cell issues or equipment damage are detected, take appropriate measures immediately (e.g., discontinue use, repair, or replacement).
- Follow the instructions strictly during operations to ensure compliance with specifications at every step.
- At least two personnel must be present during maintenance, and all must

wear PPE.

- Long-term storage of energy storage systems without use may cause irreversible battery damage. Ensure regular maintenance!

7.2.2 Tools and Instruments

Name	Purpose	Image
Electric Screwdriver Kit	For battery module installation and removal.	
Marker Pen and Labels	For recording inspection and maintenance dates.	
Utility Knife	For removing outer packaging.	
Multimeter (0.1mV precision)	For measuring insulation resistance, voltage, AC internal resistance, and other data.	
Grounding Mat	For electrostatic protection.	

Charger	For charging, discharging, and voltage balancing of batteries.	
Fire Extinguisher	For preventing thermal runaway in LFP batteries due to short circuits.	

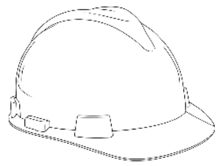
Recommended Charger Specifications

Parameter Name	Value
Input Voltage	AC 100~240V
	50/60Hz
Operating Temperature Range	-10~40℃（14~104℉）
Operating Humidity Range	＜80% RH
Storage Temperature Range	-20~80℃（-4~176℉）
Storage Humidity Range	＜80% RH
Charging Mode	Supports constant current charging mode
DC Output Voltage Range	0~500V
DC Output Current Range	0~200A

Voltage Stability	≤0.2%
Current Stability	≤0.5%
Load Stability	≤0.5%
Ripple and Noise	≤1% (RMS)
Display Accuracy	±0.5%
(Optional) Human-Machine Interface	Charging voltage, charging current, charging capacity, charging time, and other data can be read from the charging interface.

7.2.3 Personal Protective Equipment

Name	Purpose	Image
Protective Clothing	For electrical insulation protection.	
Insulating Gloves	For electrical insulation protection.	
Insulating Shoes	For electrical insulation protection.	
Safety Goggles	For arc flash protection.	

Safety Helmet	For head protection.	
Anti-static Wrist Strap	For electrostatic protection.	

Note: Personal protective equipment of Category 1 or higher shall be worn.

7.2.4 Terminology

- **Normal Operation:** Refers to the continuous and alarm-free operation of the system in accordance with the conditions agreed upon in the agreement.
- **Intermittent Operation:** Indicates that the operating frequency of the system is not fixed, and a continuous operation cannot be guaranteed.
- **Long-term Idle Operation:** Refers to the system not being started and operated for more than six consecutive months.
- **Voltage Difference at the End of Charging/Discharging:** Refers to the voltage difference between the cell with the highest voltage and the cell with the lowest voltage within the battery system or battery module when charged/discharged to its maximum/minimum cutoff voltage.
- **A Full Charge-Discharge Cycle:** Refers to the cycle in which the battery system or battery module is first charged to its maximum cut-off voltage and then discharged to its minimum cut-off voltage.

- **Round-trip Efficiency:** The ratio of discharge energy to charging energy, typically expressed as a percentage.
- **Spare Battery Module:** Refers to the battery modules independently purchased by customers from Risen Storage and not pre-installed in energy storage systems.

7.2.5 Maintenance Requirements

System in Normal Operation

- The system must undergo an SOC calibration and voltage balancing, with voltages adjusted to the normal range prior to its first operation.
- Conduct charge-discharge activation on the system once every 12 months to prevent potential battery damage.
- Perform routine inspection of the system once every 12 months, maintain detailed inspection records, and promptly address any detected abnormal conditions.
- If the system operates in a shallow charging and discharging state continuously for more than 6 months (i.e., the state of charge (SOC) is not 0% at the end of discharge and not 100% at the end of charge), an SOC calibration must be performed for the system.

System in Intermittent Operation

- For a system unused within six consecutive months, conduct a charge-discharge activation when restarting to prevent potential battery damage.
- When the system remains unused for more than 6 consecutive months, adjust its SOC to

30%~50% before storage and promptly disconnect all power-consuming devices.

- Perform routine inspection of the system once every 3 months, maintain detailed inspection records, and promptly address any detected abnormal conditions.
- Conduct charge-discharge activation on the system once every 3 months to prevent potential battery damage.
- Before reusing a system that has been unused for an extended period, it must undergo at least one charge-discharge activation to activate the battery and restore it to optimal performance.

System in Long-term Idle Operation

- When the system has no immediate plans for use or will transition to an unused state, adjust its SOC to 30%~50% before storage and promptly disconnect all power-consuming devices.
- Perform routine inspection of the system once every 3 months, maintain detailed inspection records, and promptly address any detected abnormal conditions.
- Conduct charge-discharge activation on the system once every 3 months to prevent potential battery damage.
- Before reusing a system that has been unused for an extended period, it must undergo at least one charge-discharge activation to activate the battery and restore it to optimal performance.
- Before reusing a system that has been unused for an extended period, an SOC calibration

must be performed on the system.

Spare Battery Modules

- Perform routine inspection of the spare parts once every 3 months, maintain detailed inspection records, and promptly address any detected abnormal conditions.
- Perform charge-discharge activation on the spare battery modules once every 6 months.
- The recommended SOC for long-term storage of spare battery modules is 30%~50%.

7.2.6 Inspection Items

Item	Checklist
Power-On Check	Check all devices and the host computer interface, record parameters such as total voltage, individual cell voltage, cell temperature, cell voltage difference, etc., and observe for any anomalies.

7.2.7 Abnormal Condition Handling

	Abnormal Condition	Handling Solution
Battery System	An abnormal voltage difference among cells is detected at the end of charging/discharging in the battery system.	Perform voltage balancing until the voltage difference at the end of charging/discharging for all cells in the system meets the requirements.
	The voltage of any single cell in	The battery module containing the cell may

	the battery system is lower than 2V.	be permanently damaged. Contact the after-sales service promptly for handling. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.
	Cell temperature within the battery module exceeds the average temperature by 5°C or more during charging/discharging.	1. Inspect the cell temperature acquisition harness for aging, disconnection, damage, pin retraction, cold solder joints, etc. If any issues are found, repair or replace the harness. 2. Check the AC internal resistance of the cell, verify that the internal resistance is less than 1.8mΩ. If it is greater than or equal to 1.8mΩ, replace the entire battery module containing the abnormal cell.
Spare Battery Modules	The voltage of any single cell in the battery module is lower than 2V.	1. The module may be permanently damaged. Contact the after-sales service promptly for handling. For contact information, refer to Chapter 9 Technical Support and After-Sales Service. 2. Repack the module completely in its original packaging and store it in a

	separate area to avoid placing it together with functional modules.
The voltage of any single cell in the battery module is 2~3V (inclusive).	1. Conduct charge-discharge activation on the battery module. 2. If an abnormal voltage difference among cells at the end of charging/discharging is detected in the battery module, perform voltage balancing until the voltage difference at the end of charging/discharging for all cells in the module meets the requirements.
Cell temperature within the battery module differs from the average temperature by 5°C or more.	1. Inspect the cell temperature acquisition harness for aging, disconnection, damage, pin retraction, cold solder joints, etc. If any issues are found, repair or replace the harness. 2. Check the AC internal resistance of the cell, verify that the internal resistance is less than 1.8mΩ. If it is greater than or equal to 1.8mΩ, replace the entire battery module containing the abnormal cell.

7.2.8 Pre-Maintenance Checks

Item	Checklist
Wiring Harness Check	Inspect the wiring harness for aging, disconnection, damage, pin retraction, cold solder joints, etc. If any issues are found, repair or replace the harness.
Insulation Check	Use an insulation meter to test the insulation resistance between the positive/negative terminals and the grounding point. The insulation resistance of the battery module must be greater than 10MΩ. If it is less than or equal to 10MΩ, immediately stop all subsequent operations and contact the after-sales service for handling. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.

7.2.9 Charge-Discharge Activation

Steps

1. Discharge the battery system or spare battery modules at 0.25P until reaching the cut-off voltage.
2. Stand idle for a duration adjusted based on actual conditions.
3. Charge the battery system or spare battery modules at 0.25P until reaching the cut-off voltage.
4. Stand idle for a duration adjusted based on actual conditions.
5. Discharge the battery system or spare battery modules at 0.25P until reaching the cut-off

voltage.

6. Stand idle for a duration adjusted based on actual conditions.
7. Charge the battery system or spare battery modules at 0.25P until the SOC reaches 30%~50%.

7.2.10 Voltage Balancing

Spare Battery Modules

- When the voltage difference at the end of charging among the cells in the battery module is ≤250 mV, it is within the normal range, and no voltage balancing is required. When the voltage difference at the end of charging does not meet the above conditions, perform the following voltage balancing steps:
    1. Perform a full charge on the battery module at rated power until the voltage reaches the maximum protection value, then stop. Record the voltage data of all cells in the battery module at the moment of charging termination.
    2. Allow the battery cluster to stand idle for 30 minutes after charging termination.
    3. Export the recorded voltage data at the moment of charging termination and compile it into a table. Use a scatter plot to identify the serial numbers and quantity of cells with voltage differences exceeding the normal range, then perform individual charging on each out-of-range cell one by one.
    4. For all high-voltage cells (i.e., cells with a voltage difference at the end of charging ≥ 250 mV), use a balancer to discharge them at a constant current of 5A until their

voltage drops to 30 mV below the average voltage of non-high-voltage cells in the battery module. After discharging, let the cells stand idle for 30 minutes.

5. Continue charging the battery module at rated power until the voltage reaches the maximum protection value, then stop. Re-collect and evaluate the voltage data at the moment of charging termination to verify the balancing effect. If any cell still has a voltage difference at the end of charging ≥250 mV, repeat Step 4 and continue charging until all cells in the battery module have a voltage difference at the end of charging <250 mV. The balancing process is then completed.
6. After confirming that the voltage differences at the end of charging of all cells in the battery module meet the requirements, perform a full charge-discharge cycle at rated power. Then, verify the charge-discharge energy data to ensure they comply with the standards specified in the technical agreement.

- When the voltage difference at the end of discharging among cells in the battery module is ≤300 mV, no voltage balancing is required. If the voltage difference at the end of discharging does not meet the above conditions, perform the following voltage balancing steps:

1. Perform a full discharge on the battery module at rated power until the voltage reaches the minimum protection value, then stop. Record the voltage data of all cells in the battery module at the moment of discharging termination.
2. Allow the battery cluster to stand idle for 30 minutes after discharging termination.
3. Export the recorded voltage data at the moment of discharging termination and

compile it into a table. Use a scatter plot to identify the serial numbers and quantity of cells with voltage differences exceeding the normal range, then perform individual charging on each out-of-range cell one by one.

4. For all low-voltage cells (i.e., cells with a voltage difference at the end of discharge ≥ 300 mV), use an equalizer to charge them at a constant current of 5A until their voltage exceeds the average voltage of non-low-voltage cells in the battery module by 30 mV. After charging, let the cells stand idle for 30 minutes.
5. Continue to fully discharge the battery module at rated power until the voltage reaches the minimum protection value, then stop. Re-collect and evaluate the voltage data at the moment of discharge termination to confirm the balancing effect. If any cell still has a voltage difference at the end of discharging ≥300 mV, repeat Step 4 and continue individual charging until all cells in the battery module have a voltage difference at the end of discharging <300 mV.
6. After confirming that the voltage differences at the end of discharge of all cells in the battery module meet the requirements, perform a full charge-discharge cycle at rated power. Then, verify the charge-discharge energy data to ensure they comply with the standards specified in the technical agreement.

Battery System

- When the voltage difference at the end of charging among cells in the system is ≤380 mV, it is within the normal range, and no voltage balancing is required. If the voltage difference at the end of charging does not meet the above conditions, perform the following voltage balancing steps:

1. Perform a full charge on the system at rated power until the voltage reaches the maximum protection value, then stop. Record the voltage data of all cells in the system at the moment of charging termination.
2. Allow the battery system to stand idle for 30 minutes after charging termination.
3. Export the recorded voltage data at the moment of charging termination and compile it into a table. Then, use a scatter plot to confirm the numbers and quantity of the cells whose voltage differences exceed the normal range. Next, charge the out-of-range single cells one by one.
4. For all high-voltage cells (i.e., cells with a voltage difference at the end of charging ≥ 380 mV), use a balancer to discharge them at a constant current of 5A until their voltage drops to 30 mV below the average voltage of non-high-voltage cells in the system. After discharging, let the cells stand idle for 30 minutes.
5. Continue charging the system at rated power until the voltage reaches the maximum protection value, then stop. Re-collect and evaluate the voltage data at the moment of charging termination to confirm the balancing effect. If any cell still has a voltage difference at the end of charging ≥380 mV, repeat Step 4 and continue individual charging until all cells in the system have a voltage difference at the end of charging <380 mV.
6. After confirming that the voltage differences at the end of charging of all cells in the

system meet the requirements, perform a full charge-discharge cycle at rated power. Then, verify the charge-discharge energy data to ensure they comply with the standards specified in the technical agreement.

- When the voltage difference at the end of discharging among cells in the system is ≤480 mV, it is within the normal range, and no voltage balancing is required. When the voltage difference at the end of discharging is >480 mV, and the discharge energy and round-trip efficiency meet the requirements of the technical agreement, voltage balancing may not be performed. If the voltage difference at the end of discharging does not meet any of the above conditions, perform the following voltage balancing steps:

1. Perform a full discharge on the system at rated power until the voltage reaches the minimum protection value, then stop. Record the voltage data of all cells in the system at the moment of discharging termination.
2. Allow the battery system to stand idle for 30 minutes after discharging termination.
3. Export the recorded voltage data at the moment of discharging termination and compile it into a table. Then, use a scatter plot to confirm the numbers and quantity of the cells whose voltage differences exceed the normal range. Next, charge the out-of-range single cells one by one.
4. For all low-voltage cells (i.e., cells with a voltage difference at the end of discharge ≥ 480 mV), use a balancer to charge them at a constant current of 5 A until their voltage exceeds the average voltage of non-low-voltage cells in the system by 30 mV. After charging, allow the cells to stand idle for 30 minutes.

5. Continue discharging the system at rated power until the voltage reaches the minimum protection value, then stop. Re-collect and evaluate the voltage data at the moment of discharge termination to confirm the equalization effect. If any cell still has a voltage difference at the end of discharge $\geq$480 mV, repeat Step 4 and continue individual charging until all cells in the system have a voltage difference at the end of discharge <480 mV.
6. After confirming that the voltage differences at the end of discharge of all cells in the system meet the requirements, perform a full charge-discharge cycle at rated power. Then, verify the charge-discharge energy data to ensure they comply with the standards specified in the technical agreement.

7.2.11 SOC Calibration

Steps

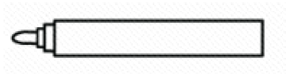
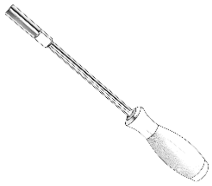
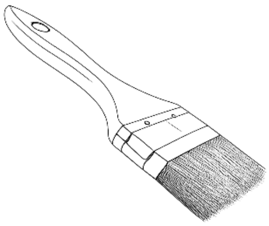
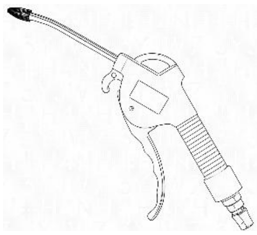
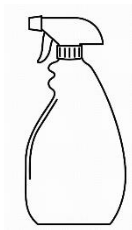
1. Discharge the battery system at rated power until reaching the cut-off voltage.
2. Stand idle for a duration adjusted according to actual conditions. The recommended idle time is greater than 1 hour.
3. Charge the battery system at rated power until reaching the cut-off voltage.

7.3 Fire Suppression System Maintenance

NOTE
● The maintenance cycles below are for reference only. The actual maintenance cycles shall be adjusted according to the natural environment at the project location. If the natural environment is harsh, the maintenance cycles should be shortened. ● To ensure the normal operation of the detector, it should be replaced promptly after it reaches the service life specified by the manufacturer.

NOTE
When the energy storage system is in long-term storage, the battery of the fire suppression system needs to be regularly charged according to the ambient temperature. ● Storage ambient temperature: -20~40℃/-4~104℉, recommended storage ambient temperature: 20~30℃/68~86℉. ● Recharging cycle: below 25℃/77℉ (once every six months), 25~30℃/77~86℉ (once every four months), 30~35℃/86~95℉ (once every three months), 35~40℃/95~104℉ (once every two months). ● Maximum storage time: 18 months (at 25℃/77℉).

7.3.1 Tools and Instruments

Name	Purpose	Image
Marker Pen and Labels	For recording inspection and maintenance dates.	
Screwdriver and Socket Set	For installation and removal of components.	
Brush	For removing dust.	
Air Blower	For blowing away dust.	
High-Purity Alcohol/Non-Corrosive Cleaner	For removing stubborn dirt.	

7.3.2 Maintenance Items

Item	Frequency	Checklist	Abnormal Condition Handling
FSS air inlet	Every 6 months	Visual inspection for deformation or damage.	Repair or replace deformed and damaged FSS air inlets.

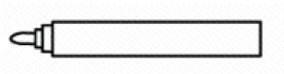
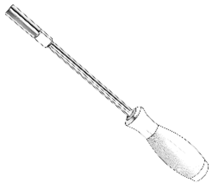
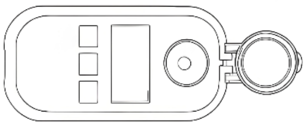
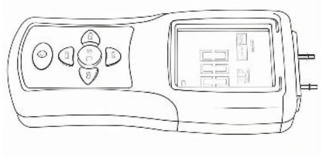
		Check for dirt, dust, or blockages.	Remove dirt, dust, and blockages.
FSS exhaust fan	Every 6 months	Visual inspection for deformation or damage.	Repair or replace deformed and damaged FSS exhaust fans.
		Check for dirt, dust, or blockages.	Remove dirt, dust, and blockages.
Smoke Detector	Every 6 months	Visual inspection for deformation or damage.	Repair or replace detectors with physical damage or abnormal operation.
		Observe if the status indicator light blinks every 1-3 seconds (normal operation).	
		Check for dirt, dust, or blockages.	Remove dirt, dust, and blockages.
Heat detector	Every 6 months	Visual inspection for deformation or damage.	Repair or replace detectors with physical damage or abnormal operation.
		Observe if the status indicator light blinks every 1-3 seconds (normal operation).	
		Check for dirt, dust, or blockages.	Remove dirt, dust, and blockages.

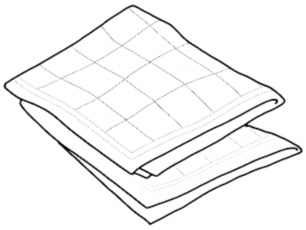
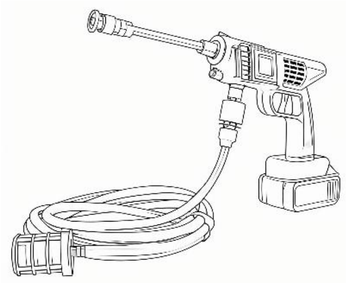
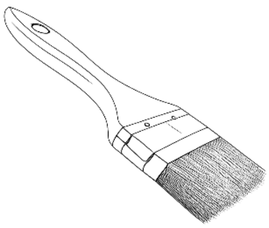
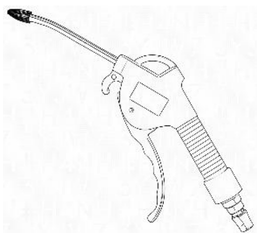
Combustible Gas Detector	Every 6 months	Visual inspection for deformation or damage.	Repair or replace detectors with physical damage or abnormal operation.
		Conduct a functional test. If failed, inspect and calibrate as needed.	
		Check for dirt, dust, or blockages.	Remove dirt, dust, and blockages.
Water-Based Fire Suppression System Piping	Every 12 months	Visual inspection for deformation or damage.	Repair or replace deformed and damaged piping.
Sprinkler Head	Every 12 months	Visual inspection for deformation or damage.	Repair or replace deformed and damaged sprinkler heads.
FSS Water Supply Port	Every 12 months	Visual inspection for deformation or damage.	Repair or replace the deformed and damaged FSS water supply port.

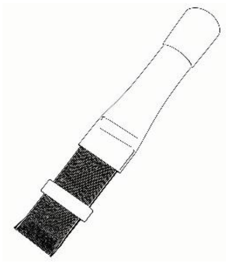
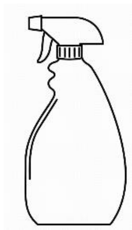
7.4 Thermal Management System Maintenance

NOTE
The maintenance cycles below are for reference only. The actual maintenance cycles shall be adjusted according to the natural environment at the project location. If the natural environment is harsh, the maintenance cycles should be shortened.

7.4.1 Tools and Instruments

Name	Purpose	Image
Marker Pen and Labels	For recording inspection and maintenance dates.	
Screwdriver and Socket Set	For installation and removal of components.	
Coolant Tester	For checking the concentration of coolant.	
Air Pressure Gauge	For measuring air pressure.	

Clean Cloth	For wiping dirt.	
Low-pressure water gun	For cleaning dust from the condenser. **Note:** ● The water pressure must be below 2.2 Mpa to avoid damaging the condenser fins. ● It is not recommended to use the water gun to rinse other components.	
Brush	For removing dust.	
Air Blower	For blowing away dust.	
Vacuum cleaner	For removing dust.	

Fin comb	For straightening fins.	
High-Purity Alcohol/Non-Corrosive Cleaner	For removing stubborn dirt.	

7.4.2 Daily Maintenance

Item	**Checklist**	**Inspection Method**	**Abnormal Condition Handling**
Operating Data	The current, voltage, inlet and outlet coolant temperature/pressure and other data during chiller operation.	Visual inspection	The inlet and outlet coolant temperature and pressure can be viewed and obtained via the HMI. In case of abnormal data, please locate the fault and handle it according to Section 8.3.4 Liquid Cooling System Fault.
Running Sound	The chiller operates without abnormal vibration and noise. Mainly observe	Visual and auditory inspection	In case of abnormal operation, please locate the fault and handle it according to Section 8.3.4 Liquid Cooling System

	the operation of the following parts: ● Compressor ● Fan ● Circulating water pump		Fault.
Pipeline Reliability	The refrigeration system has no refrigerant leakage.	Visual inspection	When a leak is detected, promptly contact the after-sales service for repairs. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.
	The coolant circulation system has no leakage.		

7.4.3 Regular Maintenance

7.4.3.1 Fan Maintenance

Item	Checklist	Frequency	Inspection Method	Abnormal Condition Handling
Operational Reliability of Fan	There is no dust in the fan and no foreign matter blockage at the tuyere.	Every 6 months	Visual inspection	Clean up the dust with a brush after 1 min of power off. Clean the foreign matters at the tuyere.

	The fan blades are not damaged, and the fan rotates smoothly without abnormal noise.			After power off for at least 1 min, fasten the fixing screws of the fan and check whether there is any internal cable or other objects interfering with the rotation of the fan. If the fan fails, please replace it.

7.4.3.2 Electric Control System Maintenance

Item	**Checklist**	**Frequency**	**Inspection Method**	**Abnormal Condition Handling**
Reliability of Power Cable and Power Terminal of Wiring Panel	No looseness of electrical cables and terminals.	Every 6 months	Visual inspection	Tighten the loose cables with a screwdriver after 1 min of power off.
	There is no aging, damage, abnormal heating and other abnormalities in the power cable.			Replace the power cables after 1 min of power off.

	There is no dust at the wiring panel.			Clean up the dust with a brush after 1 min of power off.
Normal Operation of Circuit Breaker	Automatic turned off when the circuit is abnormal (such as short circuit).	Every 6 months	Visual inspection	Replace or maintain the circuit breaker after 1 min of power off. The circuit breaker is located at the power cable wiring position in the electrical control box.

7.4.3.3 Expansion Tank Maintenance

Item	Checklist	Frequency	Inspection Method	Abnormal Condition Handling
Operating Nitrogen Pressure	The nitrogen pressure is maintained at 0.3~0.5 bar.	Every 6 months	Air pressure gauge	Fill the expansion tank with nitrogen after at least 1 min of power off.

Air Pressure Measurement Steps

1. After cutting off the power and waiting for at least 1 min, turn off the maintenance ball valve connected to the chiller and drain the coolant.
2. Unscrew the end cover and use a air pressure gauge to check the pressure of the expansion tank. When the pressure is below 0.3 bar, nitrogen needs to be filled to increase the pressure to stabilize at 0.3~0.5 bar.
3. Restore the end cover and replenish the coolant.

7.4.3.4 Coolant Maintenance

Item	Checklist	Frequency	Inspection Method	Abnormal Condition Handling
Coolant	● Concentration meets range requirements ● The PH value and the concentration of each electrolyte meet the requirements. ● No dirt, precipitation, algae, etc.	Every 6 months	Coolant tester and visual inspection	Replace the coolant at least 1 minute after power off.

Coolant Specification Requirements

Color	Odor	PH@20℃ /68℉	Conductivity@25℃/77℉	Reserve alkalinity	Turbidity
Blue	No irritating odor	7.5~9.5	2000~4000 μS/cm	>1.5 mL	<5 NTU

Cu	Al	Fe	Si	Chlorine ion	Sulfate ions	Total hardness
<5 mg/L	<5 mg/L	<5 mg/L	<10 mg/L	<20 mg/L	<50 mg/L	<20 mg/L

Coolant Replacement Steps

1. Cut off the power and wait at least 1 minute.
2. Use a drain hose to connect the drain port.
3. Open the ball valves at the coolant drain port to drain the coolant to the coolant storage tank. After draining, close the valve and remove the drain pipe.
4. Remove the filter element of the filter for cleaning or replacement.
5. Add the coolant, check the PH value and electrolyte concentration of the coolant.
6. After the coolant replenishment is completed, close the ball valve at the coolant filling port and remove the pipe.

7.4.3.5 Condenser Maintenance

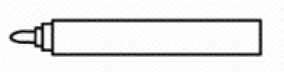
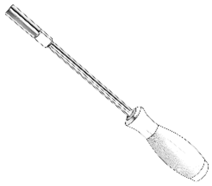
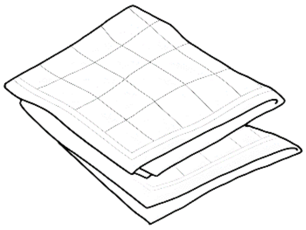
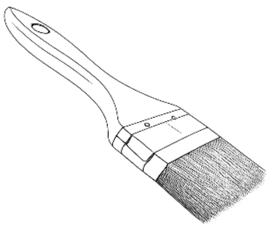
⚠ NOTICE
The edges of the condenser blades are sharp. Please wear gloves during maintenance.

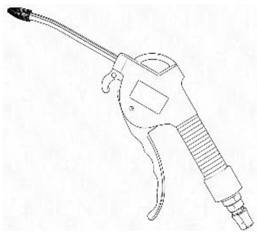
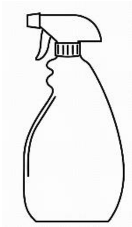
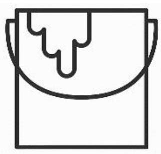
Item	Checklist	Frequency	Inspection Method	Abnormal Condition Handling
Condenser Cleanliness	Condenser is free from dust and foreign matter blockage.	Every 6 months (should be shortened during sandstorm season)	Visual inspection	Clean the condenser with air blower or a vacuum with a brush head after at least 1 min of power off.
	Fins are not seriously deformed.			Use tools such as a fin comb to correct it after at least 1 min of power off.

7.5 Container Maintenance

NOTE
The following maintenance cycles are for reference only. The actual maintenance cycle should be adjusted according to the natural environment of the equipment location. If the natural environment is severe, the maintenance cycle should be shortened.

7.5.1 Tools and Instruments

Name	Purpose	Image
Marker Pen and Labels	For recording inspection and maintenance dates.	
Screwdriver and Socket Set	For installation and removal of components.	
Clean Cloth	For wiping dirt.	
Brush	For removing dust.	

Air Blower	For blowing away dust.	
High-Purity Alcohol/Non-Corrosive Cleaner	For removing stubborn dirt.	
Paint	For repainting the damaged painted surface.	

7.5.2 Maintenance Items

Item	Frequency	Checklist	Abnormal Condition Handling
Container Exterior	Every 12 months	Check for dirt, dust, or foreign objects.	Remove dirt, dust, and foreign objects.
		Check for any damage to the exterior surface, such as cracks, deformation, fractures, holes, etc.	Repair the damaged exterior surface.
		Check for any component issues, such as missing parts, loose connections, or	Repair or replace components with issues.

		protrusions.	
Container Interior	Every 12 months	Check for dirt, dust, foreign objects, or condensation.	Remove dirt, dust, foreign objects, and condensation.
		Check for any damage to the interior wall lining, floor, and threshold, such as cracks, deformation, fractures, or holes.	Repair the damaged interior wall lining, floor, and threshold.
		Check for any component issues, such as missing parts, loose connections, or protrusions.	Repair or replace components with issues.
Painted Surface	Every 12 months	Check for any damage to the painted surface, such as topcoat peeling or primer damage.	After rust removal, repaint the damaged areas on the painted surface.
Door Lock and Hinges	Every 12 months	Inspect the door lock and hinges for proper function.	Repair or replace malfunctioning door locks and hinges.
Sealing Strip	Every 12 months	Inspect the sealing strip for wear or damage.	Replace damaged sealing strips.

Marks on Products	Every 12 months	Inspect whether the marks are clear, legible, and free of damage.	Clean dirty marks and repair or replace damaged ones.

7.6 UPS Maintenance

7.6.1 Precautions

WARNING

The device contains potentially hazardous voltage. Please do not disassemble the device. This device does not include user repairable components. Repair work must be carried out by trained maintenance personnel.

NOTICE

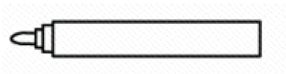
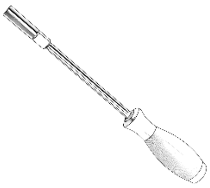
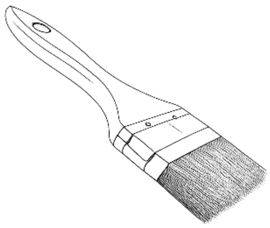
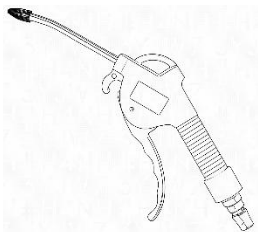
- Before connecting or disconnecting the battery terminals, discharge the charging power source first.
- If a battery leak occurs, do not let the liquid come into contact with the skin or eyes. If contact occurs, rinse the contact area with plenty of water and seek medical attention.

NOTE

- The battery life is usually two to five years. Environmental factors can also affect battery life. Frequent short-term discharges caused by rising environmental temperatures and poor quality of utility power can shorten battery life.

- To extend battery life, the ambient temperature should be maintained between 20 and 25°C.
- Keep the battery and battery pack clean and dry.

7.6.2 Tools and Instruments

Name	Purpose	Image
Marker Pen and Labels	For recording inspection and maintenance dates.	
Screwdriver and Socket Set	For installation and removal of components.	
Brush	For removing dust.	
Air Blower	For blowing away dust.	

7.6.3 Maintenance Requirements

Equipment Care

- **Charge and discharge maintenance**: If the load is below 20% of the UPS rated load or the utility power supply is stable, it is recommended that you perform a complete charge and discharge maintenance once a month. After fully charging the UPS, switch to the battery discharge state (it is recommended to control the load within 20%~60%). When the battery is discharged to near depletion (the product displays only one battery level, or a low battery alarm occurs), switch back to the utility power supply and charge it to full charge. This process helps activate battery activity and maintain its optimal state.
- **Timely charging**: When the utility power is cut off, the UPS built-in battery will discharge to the cut-off voltage and automatically shut down. At this point, it is recommended to charge the battery as soon as possible to avoid prolonged battery depletion, irreversible decline in battery performance, and shortened lifespan.
- **Regularly perform battery maintenance tests**: It is recommended that you regularly perform maintenance tests on the battery, provided that the bypass power supply is within the specification range and the battery level is not less than 25%. During the testing period, the UPS system will switch to battery mode and discharge to the low voltage alarm level of the battery, which helps detect the status of the battery.
- **Regular battery maintenance**: It is recommended that you regularly check the appearance of the battery (such as swelling, deformation, rupture, leakage, etc.) and use professional equipment to detect internal resistance and open circuit voltage, promptly

detect and replace faulty batteries, and ensure the performance and lifespan of the entire battery pack. Do not use batteries that are incompatible with UPS when replacing batteries. Mixing batteries of different brands and models can lead to inconsistent performance of the battery pack, which may cause overheating, expansion, or even damage.

Equipment Storage

- **Storage management**: During the idle period of UPS, it is recommended to ensure that the battery is fully charged before shutting down. If the UPS system is stored for a long time, it is recommended that you disconnect the battery after fully charging it (unplug the connection cable or plug of the built-in battery, if applicable) to reduce the impact of battery self-discharge.
- **Regular maintenance charging**: Regularly perform maintenance charging on the battery based on the storage environment temperature:
  - When the storage temperature is -15~25°C/5~77℉, it is recommended to charge at least once every six months (the charging time should not be less than 8 hours, depending on the charging speed).
  - When the storage temperature is 25~45°C/77~113℉, it is recommended to charge at least once every three months (the charging time should not be less than 8 hours, depending on the charging speed).
  - If batteries stored for a long time are not regularly maintained and charged, their performance may decrease or even fail due to self-discharge. Therefore, regular

maintenance should be carried out according to the above charging cycle to ensure that the battery remains in a healthy state during storage.

Battery Replacement

- Replace the battery at least every 5 years or at the end of its service life (whichever comes first).
- When the UPS indicates that the battery needs to be replaced, replace the battery immediately.
- Replace the battery with the same number and type as originally installed in the device.
- When the UPS displays a high battery temperature or signs of electrolyte leakage, replace the battery immediately. Turn off the UPS, unplug the AC input plug, and then disconnect the battery connection. Do not operate the UPS before replacing the battery.

Power Outage Handling Suggestions

- **Instant response**: In the event of a power outage, first confirm that the UPS has automatically taken over the power supply to ensure the normal operation of critical equipment.
- **Turn off the upstream switch**: If the UPS continues to alarm or the expected power outage time is long, it is recommended to first turn off the power switch upstream of the UPS (i.e. the utility power input switch) to protect the UPS from the impact current that may be generated when the utility power is restored. After the utility power is completely

stable (which can be determined by observing whether other electrical equipment is working properly), restart the UPS power supply system.

8 Troubleshooting

8.1 Precautions

⚠ WARNING
When dealing with a fault, make sure that the device is effectively grounded, otherwise, there may be a risk of electric shock.

⚠ NOTICE
● After a fault occurs, it is recommended to keep the initial fault state and log all relevant information about the fault as comprehensively as possible. ● Do not perform non-standard operations. Refer to this chapter for preliminary diagnosis and handling of the fault. ● If the fault remains unresolved or if you have any questions, please contact technical support and after-sales service, and provide logged fault information.

8.2 Logging Fault Information

Information Type	Description
Basic Information	Model and serial number of the ESS
	The model number of faulty devices
Operating Status	Pre-fault system parameters (e.g., voltage, current, temperature, SOC, etc.)
Fault Details	Fault type (e.g., abnormal system data display, communication failure)
	Fault occurrence time
	Fault duration
	Operational logs at fault occurrence
	Alarm level and fault code (if applicable)
Fault Photos	Faulty device photos
	Internal component photos (if accessible)
	Alarm interface screenshots (if applicable)
Environmental Information	Ambient temperature and humidity at fault occurrence
	Surrounding influencing factors (e.g., other device failure, external grid fluctuations, extreme weather)

8.3 Common Fault Troubleshooting and Solutions

8.3.1 Abnormal System Data Display

Fault Description	Causes	Troubleshooting and Solutions
Displayed cell voltage does not match the actual voltage	● Voltage acquisition harness loose ● Voltage acquisition harness damaged ● BMU defective	1. Use a multimeter to measure the actual voltage of the battery cell. 2. Replug the voltage acquisition harness connector and check wiring integrity. 3. Replace with a new BMU and observe whether the displayed voltage values are accurate. 4. Replace the voltage acquisition harness and observe whether the displayed voltage values are accurate.
Cell voltage fluctuation	● Voltage acquisition harness loose ● Voltage acquisition harness damaged ● Significant on-site interference	1. Replug the voltage acquisition harness connector and check wiring integrity. 2. Replace with a new BMU and observe whether the displayed voltage values are accurate. 3. Replace the voltage acquisition harness and observe whether the displayed voltage

	● BMU defective	values are accurate.
Abnormal cell acquisition quantity	● Project configuration error ● Abnormal acquisition harness ● BMU defective	1. Check the project configuration to confirm whether it is normal. If not, modify the relevant configuration. 2. Replug the acquisition harness connector and check circuit integrity. 3. Replace with a new BMU and observe whether the displayed values are accurate. 4. Replace the acquisition harness and observe whether the displayed values are accurate.
Temperature display shows -40°C/-40℉ or 125°C/257℉	**Note:** -40℃/-40℉ indicates an open circuit, 125℃/257℉ indicates a short circuit. ● Thermistor damaged or temperature acquisition harness damaged ● BMU defective	1. Replug the temperature acquisition harness connector and inspect wiring integrity. 2. Replace with a new BMU and observe whether the displayed values are accurate. 3. Replace the temperature acquisition harness and observe whether the displayed values are accurate.
Abnormal	● Project configuration	1. Check the project configuration to confirm

temperature acquisition quantity	error ● Abnormal acquisition harness ● BMU defective	whether it is normal. If not, modify the relevant configuration. 2. Replug the acquisition harness connector and check circuit integrity. 3. Replace with a new BMU and observe whether the displayed values are accurate. 4. Replace the acquisition harness and observe whether the displayed values are accurate.
Temperature jumps upward	● External interference ● BMU defective	Replace with a new BMU and observe whether the displayed values are accurate.
Temperature jumps downward	● External interference ● High connector impedance ● BMU defective	1. Replug the BMU acquisition harness connector and observe whether the displayed values are accurate. 2. Replace with a new BMU and observe whether the displayed values are accurate.
Abnormal total battery voltage acquisition	● Acquisition circuit open ● Fuse blown ● Incorrect wiring	1. Open the switchgear and perform a fuse continuity test to verify fuse integrity. 2. Inspect acquisition circuit wiring positions

	position ● BCU defective	for correctness. 3. Measure acquisition circuit continuity to confirm circuit integrity. 4. Replace with a new BCU and observe whether the displayed values are accurate.
Abnormal total load voltage acquisition	● Acquisition circuit open ● Relay sticking ● Incorrect wiring position ● BCU defective	1. Measure acquisition circuit continuity to confirm circuit integrity. 2. Test relay status to check for sticking. Replace it if stuck. 3. Inspect acquisition circuit wiring positions for correctness. 4. Replace with a new BCU and observe whether the displayed values are accurate.
Current is 0	● Hall sensor power loss ● CAN Hall baud rate error ● Abnormal communication harness ● Incorrect configuration scheme selection	1. Check Hall sensor power supply status. 2. Verify CAN Hall baud rate. Correct if abnormal. 3. Inspect communication harness integrity. Replace if faulty. 4. Confirm Hall configuration scheme in settings. Adjust if incorrect.

Current sensor direction reversed	Incorrect selection of current sensor direction in the configuration	Check whether the Hall configuration scheme in the settings is correct. Adjust configurations if incorrect.

8.3.2 Communication Fault

Fault Description	Causes	Troubleshooting and Solutions
BCU-BMU communication abnormality	● Abnormal communication harness ● Terminal resistor not added ● Inconsistent baud rates for master-subordinate communication ● BMU address not assigned	1. Inspect the communication harness for integrity. Replace it if abnormal. 2. Confirm the presence of the Terminal resistor. Install it if missing. 3. Verify the baud rate settings in the configuration. Adjust configurations if incorrect. 4. Check the address assignment for the BMU. Adjust configurations if incorrect.
BAU-BCU communication abnormality	● Abnormal communication harness ● Terminal resistor not added ● Inconsistent baud rates	1. Inspect the communication harness for integrity. Replace it if abnormal. 2. Confirm the presence of the terminal resistor. Install it if missing. 3. Verify the baud rate settings in the

	for BAU-BCU communication ● BCU address not assigned or duplicate address ● Excessively long bus	configuration. Adjust configurations if incorrect. 4. Check the address assignment for the BCU. Adjust configurations if incorrect. 5. Adjust the baud rate and check if BAU-BCU communication is normal.
BMS-PCS communication abnormality (if any)	● Communication point list mismatch ● Abnormal communication harness ● BMS hardware failure ● Configuration issues	1. Verify the communication point list used by both BMS and PCS. Correct mapping errors if detected. 2. Inspect BMS-PCS communication harness integrity. Replace if faulty. 3. Replace with new BMS hardware and observe if communication normalizes. 4. Check if point lists and dry contacts exist in the configuration, and verify their settings. Modify relevant configurations if incorrectly set.
BMS-GS/EMS communication abnormality	● Communication point list mismatch ● Abnormal	1. Verify the communication point list used by both BMS and GS/EMS. Correct mapping errors if detected.

	communication harness ● BMS hardware failure ● Configuration issues	2. Inspect BMS-GS/EMS communication harness integrity. Replace if faulty. 3. Replace with new BMS hardware and observe if communication normalizes. 4. Check if point lists and dry contacts exist in the configuration, and verify their settings. Modify relevant configurations if incorrectly set.

8.3.3 Fire Suppression System Fault

Fault Description	Causes	Troubleshooting and Solutions
Fire alarm control panel shows system failure	● Fire alarm control panel displays main power supply fault ● Fire alarm control panel displays ZONE circuit fault	1. Check the power supply of the fire suppression system. Take relevant actions if abnormal. 2. Inspect heat detector and smoke detector circuits per the fire wiring diagram. Verify connection of 470Ω and 6.8kΩ resistors. Reconnect if incorrect.
Disable switch abnormality	Abnormal feedback from the auxiliary contact of the	1. Inspect the disable switch feedback wiring harness integrity. Replace if faulty.

	disable switch	2. Check if the disable switch auxiliary contact is properly plugged in. If not, replug it. 3. Check if the auxiliary contact of the disable switch is normal. Take relevant actions if abnormal.

8.3.4 Liquid Cooling System Fault

8.3.4.1 Fan Fault

Fault Description	Causes	Troubleshooting and Solutions
Condenser fan does not operate	Compressor not started	The condenser fan is not started until the compressor is started, and the refrigerant on the high pressure side needs to reach a certain pressure.
	Fan stuck	Check whether there is foreign matter stuck in the fan.
	Loose terminal	Check whether the wiring terminal of the fan is loose.
	Fan damaged	If there is no abnormality in the wiring of the condenser fan, and there is no foreign matter stuck in the fan, it can be judged that the fan is

		damaged and needs to be replaced.
	Main control board fault	If the above possible causes are ruled out, please check whether the main control board is faulty. If yes, please replace it.
The fan generates abnormal sound	Wear of fan bearings	Replace the fan.
	Fan blades scratch other objects	Check whether cables interfere with fan blades.
	Fan impeller split	Replace the fan.
	The balancing plate of the fan impeller is loose	Re-fix the balancing plate.
	Fan fixing bolts are loose	Retighten the fan fixing bolts.

8.3.4.2 Cooling System Fault

Fault Description	Causes	Troubleshooting and Solutions
Compressor not started	Unpowered (standby)	Check the main power switch, and check whether the chiller has been turned on through the control system operation interface.
	Loose circuit connection	Tighten the circuit connector.
	Open or short circuit	Check the open circuit or short circuit, and

		repair the main power supply.
	Inverter fault	Replace the inverter.
	Control board damaged	Replace the control board.
	Compressor motor fault	Replace the compressor.
Compressor does not operate	No cooling or dehumidification demand	Check the compressor output status on the display. Check whether the chiller is in cooling or dehumidification status on the display.
	Shutdown delay	The compressor has the shortest downtime under normal conditions, and if the temperature rises to the start point during this period, the compressor will still be delayed to open.
High exhaust pressure	Dirty blockage of condenser	Clean up the condenser with air blower or a vacuum with a brush head.
	Condenser fan does not operate	Refer to the Condenser fan does not operate fault in Section 8.3.4.1 Fan Fault for troubleshooting steps.
Electric heater does not operate	No heating demand	Check the outlet coolant temperature, and whether the heating set point is reasonable.

	Loose circuit connection	Tighten the circuit connector.
	Electric heater overheat protection	After waiting for a period of time, restart the electric heater and observe whether the electric heater works normally.
	Electric heater fault	Replace the electric heater.

8.3.4.3 Coolant Circulation System Fault

Fault Description	Causes	Troubleshooting and Solutions
Internal circulating water pump does not start	Unpowered (standby)	Check the main power switch, and check whether the chiller has been turned on through the control system operation interface.
	Loose circuit connection	Tighten the circuit connector.
	Water pump inverter fault	Replace the water pump inverter.
	Self-protection of water pump due to no coolant	Check if there is coolant in the circulation system, if not, replenishment is needed.
	Pump body fault	Replace the water pump.
Electric heater does not operate	Too low heating set point and no heating demand	Check the outlet coolant temperature, and whether the heating set point is reasonable.
	Loose circuit connection	Tighten the circuit connector.
	Electric heater overheat	After waiting for a period of time, restart the

	protection	electric heater and observe whether the electric heater works normally.
	Electric heater fault	Replace the electric heater.
Automatic replenishment pump does not operate	Replenishment pump fault	Replace the automatic replenishment pump.
	Replenishment pump stuck	Check whether there are foreign matters in the replenishment tank. If yes, clear them. Replace the replenishment pump if it is damaged.
	Loose terminal	Check whether the butt terminal of the replenishment pump is loose.
Automatic replenishment pump generates abnormal sound	Replenishment pump shaft worn	Replace the automatic replenishment pump.
	Fixing screws of replenishment pump loose	Tighten loose screws.

8.3.5 UPS Fault

8.3.5.1 Status Indicator

Indicator	UPS Status
Continuously beep once every half second	Battery Low: The battery is nearly fully discharged and the UPS is about to turn itself off.
	Overload: The total power consumed by the devices connected to the UPS exceeds the allowable rated range.
Beep 4 times every 30 seconds (Starts after four seconds from when the UPS entering the battery mode)	Battery Power Status: The UPS is using the battery backup power to power the connected devices.
The beeper rings continuously	Alarm Status: The UPS detected an error. Refer to Section 8.3.5.2 Alarms and Section 8.3.5.3 Notification.
One short beep every 2.5 seconds	The battery is disconnected.
Half-second beep continuous for 1 minute and repeat this every 5 hours	The battery is damaged (and needs to be replaced).
Two short beeps every 5 seconds	Event bypass status: The UPS detected an error. The connected devises is now being powered by the utility power through the

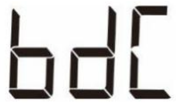
bypass relay.

8.3.5.2 Alarms

Code	Description	Solution
SC	The UPS detected a short circuit event on the output side. The device will try to recover itself automatically from this state.	Check if the UPS output is short-circuited. After resolving the short circuit, wait for the device to automatically recover itself, or pressing the  button to start the UPS. **Note:** When this alarm happens, the UPS stops powering all connected devices.
OL	The UPS is overloaded.	Disconnect unnecessary devices from the UPS to decrease the load.
dCH	The UPS detected high DC voltage.	Contact the after-sales service. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.
dCF	The UPS detected low DC voltage.	Contact the after-sales service. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.
INF	The inverter soft start failed.	Contact the after-sales service. For contact information, refer to Chapter 9 Technical Support

		and After-Sales Service.
	The UPS detected the output voltage of the inverter is abnormal.	Contact the after-sales service. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.
	The battery voltage is too high.	Contact the after-sales service. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.
	EEPROM data error.	Contact the after-sales service. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.
	The temperature of the unit exceeds the limit.	Disconnect unnecessary devices from the UPS to decrease the load. Make sure that the ambient temperature is within the limit. Make sure enough clearance is around the Unit.
	The UPS detected a charger error.	Contact the after-sales service. For contact information, refer to Chapter 9 Technical Support and After-Sales Service.

8.3.5.3 Notification

Code	Description	Solution
	The battery is not connected.	Connect the battery to the UPS.

8.3.5.4 Fault

Fault Description	Causes	Troubleshooting and Solutions
The utility power input is available, but the UPS does not turn on or there is no power output.	The UPS is not powered on.	Press  button to power on the UPS.
	The UPS is not connected to the utility power.	Check if the security of the both ends of the power cables between the UPS and the utility power.
	The input thermal breaker on the UPS trips.	Press the input thermal breaker reset button which can be found on the rear panel.
When connected to the utility power, the UPS switches into battery mode.	The input voltage or frequency is too high, too low, or unstable.	By connecting the UPS to other outlets of other circuits, test the utility power to ensure that the connected devices receive the input power. If the display is on, navigate and check the input voltage and frequency.
The UPS connected to the battery did	The UPS is not powered on.	If the UPS is off (the display is not on), press the  button once. When the display panel

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not supply power to the connected devices.		lights up, press the button one more time. Then, the connected devices become powered by the UPS battery.
	The UPS is not connected to the battery.	Connect the battery to the UPS.
	Insufficient battery capacity. Maybe because of a power failure, the battery has been discharged or depleted and stopped outputting.	Wait for the utility power to recover and charge the battery. To turn on the power output after the utility power restores, press the button.
UPS keeps beeping for a long time.	The UPS operates normally in battery mode.	The UPS detected an error. Refer to Section 8.3.5.2 Alarms and Section 8.3.5.3 Notification.
Alarm LED lights up. The UPS displays an alarm message and beeps continuously.	The UPS detected an error.	Refer to Section 8.3.5.2 Alarms and Section 8.3.5.3 Notification.
The UPS does not make a sound even if the alarm LED is lit.	The audio alarm feature has been disabled.	Change the UPS configuration to enable the feature.

The UPS cannot provide enough delay time.	The UPS battery has been discharged due to a recent power failure.	The battery needs to be charged after a long power failure. If the battery is used frequently and not charged correctly, or it is often operated at high temperatures, the battery wear will be accelerated.
	The service life of the battery is about to end.	If the battery is near the end of its life, consider replacing the battery even if the replacement battery indicator is not yet lit.
Cannot power off the UPS.	Did not press the shutdown button properly.	To turn off the UPS, hold down the ⏻ button and release it after you hear a beep.
	The utility input power is available.	If the utility input power is available, the UPS logic power cannot be turned off. To turn off the UPS, turn off the utility input first and, then, press down the ⏻ button and release it after you hear a beep.
The UPS is in bypass mode and the LED is not lit red.	The UPS is in Green mode.	You can choose to disable the green mode.
	The UPS is configured to remain in bypass mode.	Change the configuration to exit bypass mode.
	The UPS is still in bypass mode even after the	Reduce the connected load to <90% to allow the UPS to switch to online mode.

	overheat alarm is resolved.	
	The UPS switched to bypass mode because of overload.	The total load of the connected devices exceeds the "Maximum Load". The alarm will persist until the overload is resolved. Disconnect unnecessary devices from the UPS to solve the overload problem. As long as operating in bypass mode and the circuit breaker does not trip, the UPS continues to supply power. If the utility power fails, the UPS will not provide power to the battery.
	The UPS detected an error and switched to bypass mode.	Refer to Section 8.3.5.2 Alarms and Section 8.3.5.3 Notification.

8.3.6 Other Faults

Fault Description	Causes	Troubleshooting and Solutions
Insulation withstand fault	Conduct simultaneous insulation withstand tests on the PCS and BMS	Verify if PCS insulation withstand test is active. Disconnect PCS and check if a fault is triggered. Revise the insulation withstand detection in the configuration.

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Relay Abnormality	● Abnormal relay feedback wiring harness ● Relay sticking	1. Inspect the relay feedback wiring harness integrity. Replace if faulty. 2. Test relay status to check for sticking. Replace it if stuck.
Access control fault	● Display reversed ● No response ● Configuration not written ● Access control damaged	1. Check access control wiring integrity. Take relevant actions if abnormal. 2. Verify configuration settings. Modify incorrect configurations. 3. Replace the access control and observe if it works normally.

9 Technical Support and After-Sales Service

SYL (Ningbo) Battery Co., Ltd. has always adhered to the "Customer First" service philosophy, establishing a full product lifecycle service system. On technical support, the company is supported by a senior engineer team providing end-to-end support from pre-sales consultation to after-sales service. Backed by 23 global service centers, it achieves 24/7 rapid response, delivering comprehensive technical support and efficient after-sales service to customers worldwide.

Contact Information

After-sales Hotline	+86 400-101-8585
After-sales Email	essmkt@risenstorage.com

Warranty

SYL (Ningbo) Battery Co., Ltd. provides warranty services for its products. The duration and specific terms of free warranty coverage shall be exclusively governed by the signed contract clauses.

To protect your rights and clarify service scope, the following scenarios are explicitly excluded from free warranty coverage, and SYL shall not be liable for them:

Improper Operation

- System damage or failure caused by not following the operating instructions and safety precautions in the user manual.
- System damage or failure due to unauthorized disassembly, modification of the product, or alteration of software code by the user.
- Damage or failure to system hardware caused by user negligence, improper operation, or intentional damage.
- System damage caused by third parties or users, including handling and installation not in line with manual requirements, and unauthorized adjustments, modifications, or removal of identification marks.
- After a system failure, the user fails to promptly contact technical support and after-sales service, and performs unauthorized operations, leading to a loss of fault-related information and hindering effective fault identification and resolution.

Improper Use

- Functional abnormalities, component damage, personal injury, or property damage caused by using the system in an environment that does not meet the design requirements.
- System damage or failure due to non-compliance with relevant electrical safety regulations for wiring and power supply.

- Installation and usage environments that do not conform to regulations stipulated in relevant international, national, or regional standards.
- System damage or failure caused by battery usage that does not satisfy the requirements of this manual.
- System damage or failure caused by storage conditions that do not meet the requirements of this manual.
- System damage or failure caused by force majeure natural factors, such as typhoons, earthquakes, floods, fires, mudslides, or adverse environmental conditions like high temperatures, low temperatures, high humidity, and acid rain.

Feedback

If you have any comments or suggestions regarding this manual, please share them with us via email. Your feedback is highly valued as it enables us to constantly enhance the manual's quality, ensuring that we deliver more excellent content and a superior user experience.

Appendix

Abbreviations

Abbreviations	Full Term
AC	Alternating Current
Ah	Ampere-hour
AHJ	Authority Having Jurisdiction
BAU	Battery Array Management Unit
BCP	Battery Connection Panel
BCU	Battery Cluster Management Unit
BESS	Battery Energy Storage System
BMS	Battery Management System
BMU	Battery Module Management Unit
BOS	Balance of System
CAN	Controller Area Network
DC	Direct Current
EMS	Energy Management System

FSS	Fire Suppression System
GS	Golden Shield
HMI	Human Machine Interface
HVAC	Heating, Ventilation, and Air Conditioning
IP	Ingress Protection
kV	Kilovolt
kW	Kilowatt
LFP	Lithium Iron Phosphate
LSI	Large-Scale Integration
MCB	Miniature Circuit Breaker
MCCB	Molded Case Circuit Breaker
MSD	Manual Service Disconnect
MW	Megawatt
MWh	Megawatt-hour
PCB	Printed Circuit Board
PCS	Power Conversion System
PLC	Programmable Logic Controller
SCADA	Supervisory Control and Data Acquisition
SMPS	Switch Mode Power Supply
SOC	State of Charge

SPD	Surge Protective Device
UPS	Uninterruptible Power Supply

Fastening Torque

Bolt	Recommended Torque (N•m)	Torque Range (N•m)
M4	2.59	2.38~2.80
M5	5.18	4.76~5.60
M6	9.07	8.33~9.80
M8	22.67	20.83~24.50
M10	40.80	37.49~44.10
M12	72.62	66.73~78.50
M16	138.75	127.50~150.00

Notes:

- The recommended torque values and torque ranges listed above apply only to fasteners with a property class of 8.8 and not to fasteners of other property classes.
- The torque values listed above are for reference only. Please adjust them according to actual conditions.

SYL (Ningbo) Battery Co., Ltd.

Address Risen Energy Meiqiao Phase I, Ninghai County, Ningbo City, Zhejiang Province

Tel +86 400-101-8585

Website www.risenstorage.com

Appendix D

SAFETY DATA SHEETS

SECTION 1. IDENTIFICATION

Product name	:	Solstice® 513A
Number	:	000000022892
Product Use Description	:	Refrigerant
Manufacturer or supplier's details	:	Honeywell International Inc. 115 Tabor Road Morris Plains, NJ 07950-2546
For more information call	:	800-522-8001 +1-973-455-6300(Monday-Friday, 9:00am-5:00pm)
In case of emergency call	:	**Medical: 1-800-498-5701 or +1-303-389-1414**
	:	**Transportation (CHEMTREC): 1-800-424-9300 or +1-703-527-3887**
	:	
	:	(24 hours/day, 7 days/week)

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Form	:	Liquefied gas
Color	:	clear colourless
Odor	:	slight ether-like

Classification of the substance or mixture

Classification of the substance or mixture	:	Gases under pressure, Liquefied gas Simple Asphyxiant

GHS Label elements, including precautionary statements

Symbol(s) :

Signal word : Warning

Hazard statements : Contains gas under pressure; may explode if heated.
May displace oxygen and cause rapid suffocation.

Precautionary statements : **Storage:**
Protect from sunlight. Store in a well-ventilated place.

Hazards not otherwise classified : May cause cardiac arrhythmia.
May cause frostbite.
May cause eye and skin irritation.

Carcinogenicity

No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP, IARC, or OSHA.

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical nature : Mixture

Chemical name	CAS-No.	Concentration
2,3,3,3-Tetrafluoroprop-1-ene	754-12-1	56.00 %
1,1,1,2-Tetrafluoroethane	811-97-2	44.00 %

SECTION 4. FIRST AID MEASURES

Inhalation : Move to fresh air. If breathing is irregular or stopped, administer artificial respiration. Use oxygen as required, provided a qualified operator is present. Call a physician. Do not give drugs from adrenaline-ephedrine group.

Skin contact	:	After contact with skin, wash immediately with plenty of water. If there is evidence of frostbite, bathe (do not rub) with lukewarm (not hot) water. If water is not available, cover with a clean, soft cloth or similar covering. If symptoms persist, call a physician.
Eye contact	:	Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. In case of frostbite water should be lukewarm, not hot. If symptoms persist, call a physician.
Ingestion	:	Unlikely route of exposure. As this product is a gas, refer to the inhalation section. Do not induce vomiting without medical advice. Call a physician immediately.

Notes to physician

Indication of immediate medical attention and special treatment needed, if necessary	:	Because of the possible disturbances of cardiac rhythm, catecholamine drugs, such as epinephrine, should be used with special caution and only in situations of emergency life support. Treatment of overexposure should be directed at the control of symptoms and the clinical conditions. Treat frost-bitten areas as needed.

SECTION 5. FIREFIGHTING MEASURES

Suitable extinguishing media	:	The product is not flammable. Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide. Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.
Specific hazards during firefighting	:	Contents under pressure. This product is not flammable at ambient temperatures and atmospheric pressure. However, this material can ignite when mixed with air under pressure and exposed to strong ignition sources. Container may rupture on heating. Cool closed containers exposed to fire with water spray. Do not allow run-off from fire fighting to enter drains or water courses. Vapours are heavier than air and can cause suffocation by

		reducing oxygen available for breathing. In case of fire hazardous decomposition products may be produced such as: Hydrogen halides Hydrogen fluoride Carbon monoxide Carbon dioxide (CO_2) Carbonyl halides
Special protective equipment for firefighters	:	In the event of fire and/or explosion do not breathe fumes. Wear self-contained breathing apparatus and protective suit. No unprotected exposed skin areas.
Further information	:	Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures	:	Immediately evacuate personnel to safe areas. Keep people away from and upwind of spill/leak. Wear personal protective equipment. Unprotected persons must be kept away. Remove all sources of ignition. Avoid skin contact with leaking liquid (danger of frostbite). Ventilate the area. After release, disperses into the air. Vapours are heavier than air and can cause suffocation by reducing oxygen available for breathing. Avoid accumulation of vapours in low areas. Unprotected personnel should not return until air has been tested and determined safe. Ensure that the oxygen content is >= 19.5%.
Environmental precautions	:	Prevent further leakage or spillage if safe to do so. The product evaporates readily.
Methods and materials for containment and cleaning up	:	Ventilate the area.

SECTION 7. HANDLING AND STORAGE

Handling

Precautions for safe handling	:	Handle with care. Avoid inhalation of vapour or mist. Do not get in eyes, on skin, or on clothing. Wear personal protective equipment. Use only in well-ventilated areas. Pressurized container. Protect from sunlight and do not expose to temperatures exceeding 50 °C. Follow all standard safety precautions for handling and use of compressed gas cylinders. Use authorized cylinders only. Protect cylinders from physical damage. Do not puncture or drop cylinders, expose them to open flame or excessive heat. Do not pierce or burn, even after use. Do not spray on a naked flame or any incandescent material. Do not remove screw cap until immediately ready for use. Always replace cap after use.
Advice on protection against fire and explosion	:	The product is not flammable. Can form a combustible mixture with air at pressures above atmospheric pressure.

Storage

Conditions for safe storage, including any incompatibilities	:	Pressurized container: protect from sunlight and do not expose to temperatures exceeding 50 °C. Do not pierce or burn, even after use. Keep containers tightly closed in a dry, cool and well-ventilated place. Storage rooms must be properly ventilated. Ensure adequate ventilation, especially in confined areas. Protect cylinders from physical damage.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Protective measures	:	Do not breathe vapour. Avoid contact with skin, eyes and clothing.

Ensure that eyewash stations and safety showers are close to the workstation location.

Engineering measures : General room ventilation is adequate for storage and handling.
Perform filling operations only at stations with exhaust ventilation facilities.

Eye protection : Wear as appropriate:
Safety glasses with side-shields
If splashes are likely to occur, wear:
Goggles or face shield, giving complete protection to eyes

Hand protection : Leather gloves
In case of contact through splashing:
Protective gloves
Neoprene gloves
Polyvinyl alcohol or nitrile- butyl-rubber gloves

Skin and body protection : Avoid skin contact with leaking liquid (danger of frostbite).
Wear cold insulating gloves/ face shield/ eye protection.

Respiratory protection : In case of insufficient ventilation, wear suitable respiratory equipment.
Wear a positive-pressure supplied-air respirator.
Vapours are heavier than air and can cause suffocation by reducing oxygen available for breathing.
For rescue and maintenance work in storage tanks use self-contained breathing apparatus.

Hygiene measures : Handle in accordance with good industrial hygiene and safety practice.
Ensure adequate ventilation, especially in confined areas.
Avoid contact with skin, eyes and clothing.
Remove and wash contaminated clothing before re-use.
Keep working clothes separately.

Exposure Guidelines

Components	CAS-No.	Value	Control parameters	Update	Basis
2,3,3,3-Tetrafluoroprop-1-ene	754-12-1	TWA : Time weighted average	(500 ppm)	2009	WEEL:US. OARS. WEELs Workplace Environmental Exposure Level Guide, as amended

2,3,3,3-Tetrafluoroprop-1-ene	754-12-1	TWA : Time weighted average	(500 ppm)	03 15 2010	Honeywell:Limit established by Honeywell International Inc.
2,3,3,3-Tetrafluoroprop-1-ene	754-12-1	STEL : Short term exposure limit	(1,500 ppm)	03 15 2010	Honeywell:Limit established by Honeywell International Inc.
1,1,1,2-Tetrafluoroethane	811-97-2	TWA : Time weighted average	(1,000 ppm)		Honeywell:Limit established by Honeywell International Inc.
1,1,1,2-Tetrafluoroethane	811-97-2	TWA : Time weighted average	4,240 mg/m3 (1,000 ppm)	2007	WEEL:US. OARS. WEELs Workplace Environmental Exposure Level Guide, as amended

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state	:	Liquefied gas
Color	:	clear colourless
Odor	:	slight ether-like
Odor threshold	:	Note: No data available
pH	:	Note: Not applicable
Melting point/range	:	Note: No data available
Boiling point/boiling range	:	-29.2 °C

Flash point	:	Note: Not applicable
Flammability	:	The product is not flammable.
Lower explosion limit	:	Note: None
Upper explosion limit	:	Note: None
Vapor pressure	:	0.637 MPa at 21.1 °C(70.0 °F)
Vapor density	:	3.83 Note: (Air = 1.0)
Density	:	1.15 g/cm3 at 21.1 °C
Water solubility	:	Note: No data available
Partition coefficient: n-octanol/water	:	Note: No data available
Ignition temperature	:	Note: No data available
Auto-ignition temperature	:	> 750 °C
Decomposition temperature	:	> 250 °C Note: To avoid thermal decomposition, do not overheat.
Viscosity, dynamic	:	Note: No data available
Viscosity, kinematic	:	Note: No data available

SECTION 10. STABILITY AND REACTIVITY

Chemical stability	:	Stable under normal conditions.
Possibility of hazardous reactions	:	Hazardous polymerisation does not occur.
Conditions to avoid	:	Pressurized container. Protect from sunlight and do not expose to temperatures exceeding 50 °C. Decomposes under high temperature. Some risk may be expected of corrosive and toxic decomposition products. Can form a combustible mixture with air at pressures above atmospheric pressure. Do not mix with oxygen or air above atmospheric pressure.
Incompatible materials	:	Potassium Calcium Powdered metals Finely divided aluminium Finely divided magnesium Zinc
Hazardous decomposition products	:	Halogenated compounds Hydrogen fluoride Carbonyl halides Carbon oxides

SECTION 11. TOXICOLOGICAL INFORMATION

Acute inhalation toxicity

2,3,3,3-Tetrafluoroprop-1-ene	:	LC50: > 400000 ppm Exposure time: 4 h Species: Rat Method: OECD Test Guideline 403
1,1,1,2-Tetrafluoroethane	:	LC50: > 500000 ppm Exposure time: 4 h Species: Rat

Skin irritation	:	Note: Not applicable study technically not feasible
Eye irritation	:	Note: Not applicable study technically not feasible
Sensitisation		
2,3,3,3-Tetrafluoroprop-1-ene	:	Dermal Note: Not applicable, as this product is a gas. study technically not feasible
1,1,1,2-Tetrafluoroethane	:	Cardiac sensitization Species: dogs Note: No-observed-effect level 50 000 ppm Lowest observed effect level 75 000 ppm
Repeated dose toxicity		
2,3,3,3-Tetrafluoroprop-1-ene	:	Species: Rat Application Route: Inhalation Exposure time: (2 Weeks) No-observed-effect level: 50000 ppm Method: OECD Test Guideline 412 Species: Rat Application Route: Inhalation Exposure time: (4 Weeks) NOAEL (No observed adverse effect level): 50000 ppm Method: OECD Test Guideline 412 Species: Rat Application Route: Inhalation Exposure time: (13 Weeks) NOAEL (No observed adverse effect level): 50000 ppm Method: OECD Test Guideline 413 Species: Rabbit, male Application Route: Inhalation Exposure time: (28 d) No-observed-effect level: 500 ppm Method: OECD Test Guideline 412 There are no observed toxicological effects, which result in

classification as a specific target organ toxicant.

Species: Rabbit, female
Application Route: Inhalation
Exposure time: (28 d)
No-observed-effect level: 1000 ppm
Method: OECD Test Guideline 412
There are no observed toxicological effects, which result in classification as a specific target organ toxicant.

Species: Mini-pig
Application Route: Inhalation
Exposure time: (28 d)
NOAEL (No observed adverse effect level): 10000 ppm
highest exposure tested

1,1,1,2-Tetrafluoroethane : Species: Rat
NOEL: 40000 ppm

Genotoxicity in vitro
2,3,3,3-Tetrafluoroprop-1-ene : Test Method: Ames test
Result: 20% and higher, positive in TA 100 and e. coli WP2 uvrA, negative in TA98, TA100, and TA1535.
Method: OECD Test Guideline 471

1,1,1,2-Tetrafluoroethane : Note: In vitro tests did not show mutagenic effects

: Test Method: Chromosome aberration test in vitro
Cell type: Human lymphocytes
Result: negative
Method: OECD Test Guideline 473
Note: Dose 760,000 ppm

Genotoxicity in vivo
2,3,3,3-Tetrafluoroprop-1-ene : Species: Mouse
Cell type: Micronucleus
Dose: up to 200,000 ppm (4 hour)
Method: OECD Test Guideline 474
Result: negative

: Test Method: Unscheduled DNA synthesis
Dose: up to 50,000 ppm (4 weeks)

		Method: OECD Test Guideline 486 Result: negative
	:	Species: Rat Cell type: Micronucleus Dose: up to 50,000 ppm (4 weeks) Method: OECD Test Guideline 474 Result: negative

Carcinogenicity

2,3,3,3-Tetrafluoroprop-1-ene	:	Species: Rat Note: Not classified as a human carcinogen. Substance not expected to be a carcinogen based on available data.
Further information	:	Note: Rapid evaporation of the liquid may cause frostbite. Vapours are heavier than air and can cause suffocation by reducing oxygen available for breathing. Handle in accordance with good industrial hygiene and safety practice.

SECTION 12. ECOLOGICAL INFORMATION

Toxicity to fish

2,3,3,3-Tetrafluoroprop-1-ene	:	LC50: > 197 mg/l Exposure time: 96 h Species: Cyprinus carpio (Carp) Method: OECD Test Guideline 203 Note: No demonstrable toxic effect in saturated solution.

Toxicity to daphnia and other aquatic invertebrates

2,3,3,3-Tetrafluoroprop-1-ene	:	EC50: > 83 mg/l Exposure time: 48 h Species: Daphnia magna (Water flea) Method: OECD Test Guideline 202

Toxicity to algae

2,3,3,3-Tetrafluoroprop-1-ene	:	EC50: > 100 mg/l Species: Scenedesmus capricornutum (fresh water algae) Method: OECD Test Guideline 201

Bioaccumulation

2,3,3,3-Tetrafluoroprop-1-ene	:	Note: Due to the distribution coefficient n-octanol/water, accumulation in organisms is not expected.

Biodegradability

2,3,3,3-Tetrafluoroprop-1-ene	:	Result: Not readily biodegradable. Method: OECD Test Guideline 301F

Further information on ecology

Ecotoxicology Assessment

Results of PBT assessment
This substance is not considered to be persistent, bioaccumulating and toxic (PBT)., This substance is not considered to be very persistent and very bioaccumulating (vPvB).

Additional ecological information	:	Accumulation in aquatic organisms is unlikely. This product is subject to U.S. Environmental Protection Agency Clean Air Act Regulations at 40 CFR Part 82. This product contains greenhouse gases which may contribute to global warming. Do NOT vent to the atmosphere. To comply with provisions of the U.S. Clean Air Act, any residual must be recovered.

SECTION 13. DISPOSAL CONSIDERATIONS

Disposal methods	:	Observe all Federal, State, and Local Environmental regulations.
Note	:	This product is subject to U.S. Environmental Protection Agency Clean Air Act Regulations Section 608 in 40 CFR Part 82 regarding refrigerant recycling.

SECTION 14. TRANSPORT INFORMATION

DOT	UN/ID No.	:	UN 3163
	Proper shipping name	:	LIQUEFIED GAS, N.O.S.

			(R-1234yf, 1,1,1,2-Tetrafluoroethane)
	Class		2.2
	Packing group		
	Hazard Labels		2.2
IATA	UN/ID No.	:	UN 3163
	Description of the goods	:	LIQUEFIED GAS, N.O.S. (R-1234yf, 1,1,1,2-Tetrafluoroethane)
	Class	:	2.2
	Hazard Labels	:	2.2
	Packing instruction (cargo aircraft)	:	200
	Packing instruction (passenger aircraft)	:	200
IMDG	UN/ID No.	:	UN 3163
	Description of the goods	:	LIQUEFIED GAS, N.O.S. (R-1234yf, 1,1,1,2-TETRAFLUOROETHANE)
	Class	:	2.2
	Hazard Labels	:	2.2
	EmS Number	:	F-C, S-V
	Marine pollutant	:	no

SECTION 15. REGULATORY INFORMATION

Inventories

US. Toxic Substances Control Act	:	On TSCA Inventory
Australia. Inventory of Industrial Chemicals (AIIC), as amended	:	On the inventory, or in compliance with the inventory
Canada. Canadian Environmental Protection Act (CEPA). Domestic Substances List (DSL)	:	All components of this product are on the Canadian DSL
Japan. Kashin-Hou Law List	:	On the inventory, or in compliance with the inventory

Korea. Existing Chemicals Inventory (KECI)	:	On the inventory, or in compliance with the inventory
Philippines. Inventory of Chemicals and Chemical Substances (PICCS)	:	Not in compliance with the inventory
China. Inventory of Existing Chemical Substances (IECSC)	:	On the inventory, or in compliance with the inventory, or has been registered as new substance
New Zealand. Inventory of Chemicals (NZIoC), as published by ERMA New Zealand	:	Not in compliance with the inventory
Taiwan Chemical Substance Inventory (TCSI)	:	On the inventory, or in compliance with the inventory
TSCA 12B	:	US. Toxic Substances Control Act (TSCA) Section 12(b) Export Notification (40 CFR 707, Subpt D) 2,3,3,3-Tetrafluoroprop-1-ene 754-12-1

National regulatory information

US. Toxic Substances Control Act (TSCA) Section 5(a)(2) Final Significant New Use Rules (SNURs) (40 CFR 721, Subpt E)	:	: Issued.
	:	2,3,3,3-Tetrafluoroprop-1-ene 754-12-1
SARA 302 Components	:	No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.
SARA 313 Components	:	This material does not contain any chemical components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.
SARA 311/312 Hazards	:	Sudden Release of Pressure Hazard Acute Health Hazard

California Prop. 65 : This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

SECTION 16. OTHER INFORMATION

		HMIS III	NFPA
Health hazard	:	1	2
Flammability	:	1	1
Physical Hazard	:	0	
Instability	:		0

Hazard rating and rating systems (e.g. HMIS® III, NFPA): This information is intended solely for the use of individuals trained in the particular system.

Further information

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text. Final determination of suitability of any material is the sole responsibility of the user. This information should not constitute a guarantee for any specific product properties.

Changes since the last version are highlighted in the margin. This version replaces all previous versions.
Previous Issue Date: 05/08/2018
Prepared by Honeywell Performance Materials and Technologies Product Stewardship Group

Appendix C

SYL USER MANUAL

Appendix D

SAFETY DATA SHEETS

Appendix E

NFPA 69 TEST REPORT

MRP-NA-U-24-02 (401.2768 MWh)

NFPA 69 Analysis Report

Note: This report provides evaluation and CFD analysis of the ventilation system in energy storage system referring to Chapter 8 in NFPA69:2024.

Risen Energy Co., Ltd.
HQ TEL: 0086-574-59953588
HQ ADD: Tashan Industry Zone, Meilin Street, Ninghai, Ningbo, China

1.General Production Information:

1.1 Cell

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

Manufacturer:	Xiamen Hithium Energy Storage Technology Co., Ltd.
Model number:	LFP71173207 / 314Ah
Chemistry:	Iron Phosphate-Lithium Cell
Physical configuration:	Prismatic
Electrical rating:	Rated capacity: 314Ah
	Nominal voltage: 3.2V
UL 9540A cell test report number:	CN23F118 001
Average cell surface temperature at gas venting:	203.7℃
Average cell surface temperature at thermal runaway:	295.7℃
Gas volume:	130 L
Lower flammability limit(LFL), % volume in air at the ambient temperature:	8.1
Lower flammability limit(LFL), % volume in air at the venting temperature:	6.5
Burning velocity(S_u) cm/s:	77.9
Maximum pressure(P_{max}) :	0.78 Mpa

1.2 Module

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

Manufacturer:	SYL(Ningbo) Battery Co., Ltd..
Type/model:	SM104KFE5
Cell Capacity:	314 Ah
Cell Quantity:	104
Battery structure:	1P104S
Nominal voltage:	332.8 V
Standard charge current:	314 A
Standard discharge current:	314 A
Maximum charge voltage：	374.4 V
External dimensions：	2168 mm(L)×790 mm(W)×243 mm(H)

Weight:	650±10 kg

1.3 Battery System

The product information and parameters are provided as below.

Table 1.1 Specification of Batterry Container

ITEM	UNIT	SPECIFICATION
Make	-	SYL
Container Size	-	20ft
Configuration	-	1P416S12P
Number of Racks	-	12
Cooling System	-	Liquid cooled
Weight	T	40.3±0.5
Nominal Capacity	Ah	314
Nominal Energy	kWh	5015.96
Nominal Voltage	V	1331.2
Operating Voltage	V	1164.8~1497.6V
Operating Temperature Range	℃	-30~50
Recommended Operating Temp	℃	25±3
Storage Temperature	℃	-30~50
Storage Humidity	%	≤95
Degree of Protection	-	IP55
DC Combiner	-	Busbar combiner
AC Aux. Power Supply	-	480VAC 3P4L should be provided by the Client
FSS System	-	Fire suppression and detection system
Cooling System	-	1 set of liquid cooling system with 60kW cooling capacity

Figure 1.1 Battery Container Overview

2. Product Description

2.1 General Description

1.The EUT covered by this report is a Rechargeable Li-ion Battery System which includes one liquid cooling system, one fire protection system, six master control boxes, achieving 12 clusters in parallel connection. Each cluster consists of 4 battery modules connected in series, and each battery module contains 104 secondary Li-ion cells connected in series.

2.2 Venting System Layout

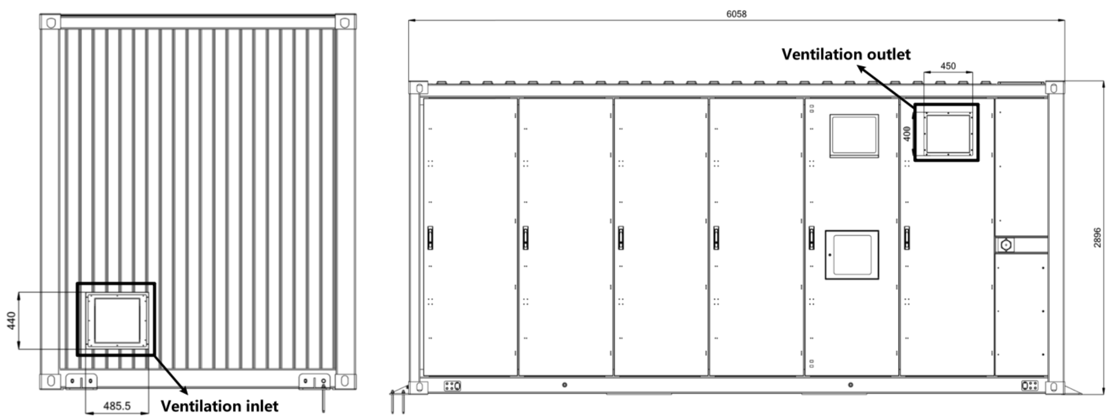

Figure 2.1 Ventilation Layout

3. CFD analysis of the ventilation system

3.1 Basic Information of the system

Figure3.1 shows an external view of the container, the dimensions from a front view, and top view. The cube measures 6058×2438×2896 mm including one battery cabinet, and one electrical cabinet. The battery cabinet contains 12 clusters, each containing 4 modules, and each module contains 104 cells. The overall internal volume is approximately 31.993 m^3. Subtracting the space filled by racks, modules and the support structure, the actual open internal volume(efficient volume) is 11.077 m^3.

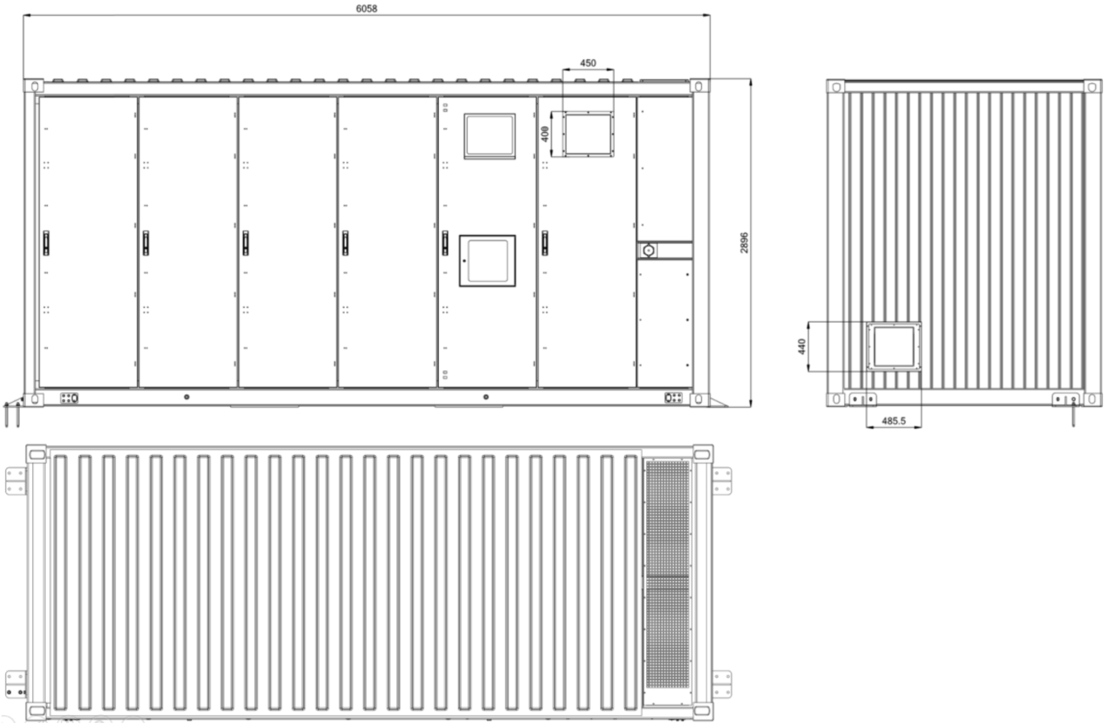

Figure 3.1 Geometry of energy storage system

3.2 Principles and Assumptions

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

3.2.1 Thermal runaway and propagation

(1) Propagation between cells:
The UL 9540A test report of module level indicate that cell to cell propagation could happen within a submodule which contains 13 cells. According to the test report total 4 cells were failed.

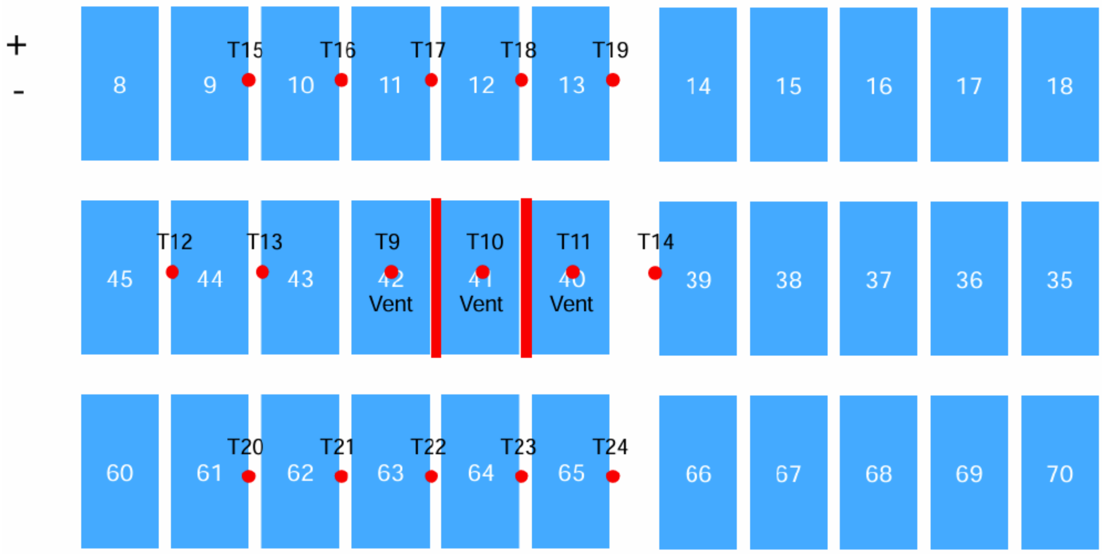

Figure 3.2 Initiating cell set up in module level UL9540Atest report

3.2.2 Leakage profile and gas composition

(1) Leakage profile:
To support the design of an explosion prevention system by means of reduction in flammable concentration, the amount (rate of release into the enclosure over time) of flammable species (battery vent gas) must be estimated. Using UL 9540A test data as the design basis, a gas release rate model was developed.
From cell level UL 9540A report, it was determined that a cell may release 130 L of battery gas at normal temperature and pressure. From module level UL 9540A report, the venting duration for a single cell is approximately 16 minutes. Assuming four cells undergo thermal runaway venting simultaneously within this 16-minute period, the total gas release volume for a module would be 520 liters. Additionally, based on the gas release rate curve from the module level UL 9540A report, it is estimated that the venting rate of a single cell reaches its maximum approximately 1.5 minutes after the onset of venting.
Based on all the information above, the gas release rate curve shown in Figure 3.3 was established to evaluate the feasibility of the explosion prevention system.

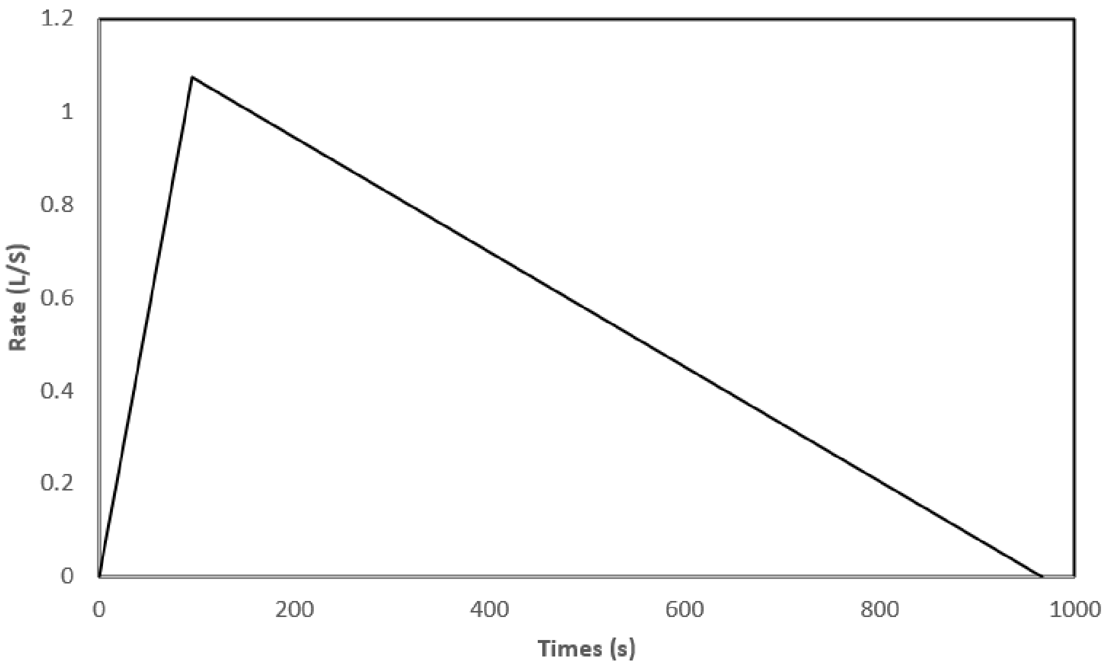

Figure 3.3 Gas release rate profile

(2) Position of the leak:

The gas release from the bottom module of the rack takes more time to reach the detector located at the top of the container. For conservative consideration, the bottom module located farthest from the vent in the battery cabinet was designated as the initiation module and named 001.

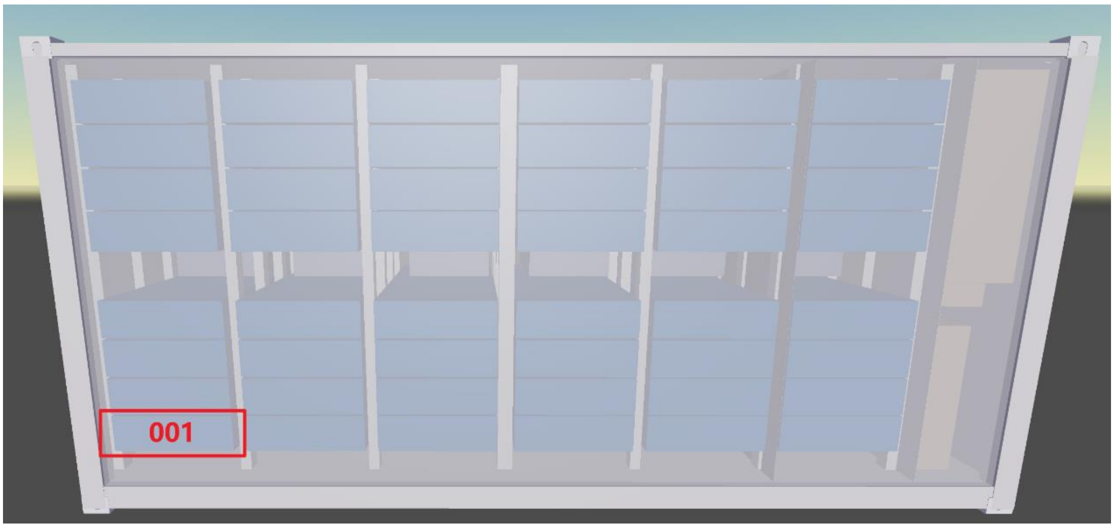

Figure 3.4. Location of gas leakage position (back view)

Assumption: One offgas release position on the rack is considered in this study. (See Figure 3.4)

(3) Gas detector:

Regarding the construction of the container, there is one gas detector equipped on the edge of the roof in battery compartment. Gas detector 1 detects H_2, its location is shown in Figure 3.5

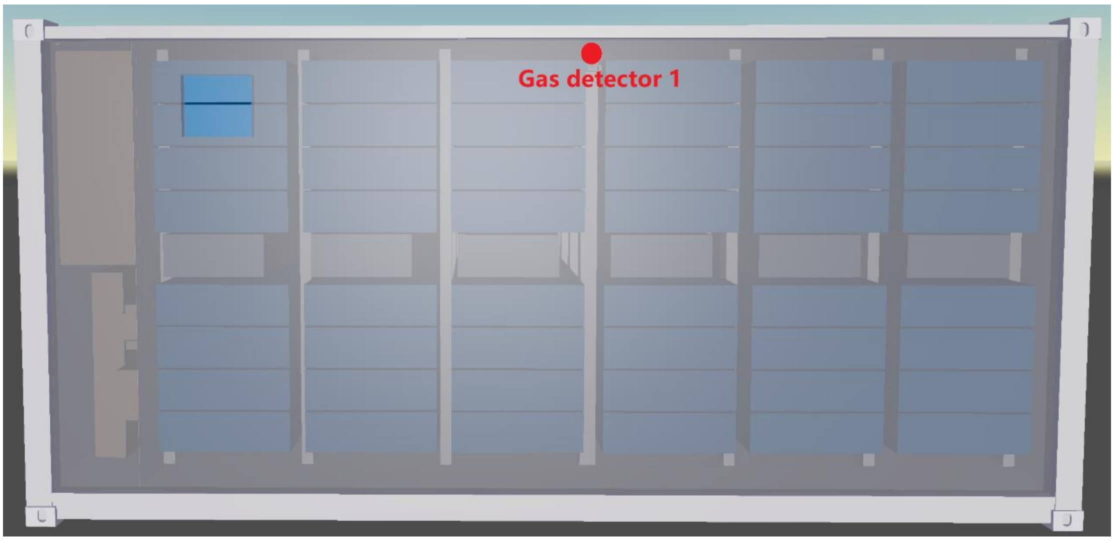

Figure 3.5 Location of gas detector position (front view)

Note: The flammable gas detector, calibrated using hydrogen, is connected to the explosion-proof fan and the fire control panel via dry contacts. Upon detecting a hydrogen concentration at 10% LFL, the detector immediately triggers the fan to start. This activation is accompanied by the opening of the hinge valve.

(4) Gas composition and LFL:

Gas composition was provided in the test data of cell level UL 9540A report. Table 3.1 lists the release gas composition by volume.

Table 3.1 Gas composition by volume

Index	Gas Components	Volume Fraction %
1	CO	16.202
2	CO_2	26.861
3	H_2	49.875
4	CH_4	3.671
5	C_2H_4	1.389
6	C_2H_6	0.548
7	C_3H_6	0.745
8	C_3H_8	0.18
19	n-C_4H_{10}	0.068
10	n-C_4H_8	0.22
11	n-C_5H_{12}	0.076
12	iso-C_5H_{12}	0.112
13	n-C_5H_{10}	0.053
	LFL (Lower Flammable Limit)	6.5

3.2.3 System safety

Ventilation system:
The container is equipped with one exhaust fan, which activates when 4000ppm H_2 (10%LFL) is detected. Based on the fan performance curve (P-Q curve) provided by the exhaust fan supplier, computational fluid dynamics (CFD) simulations were conducted to analyze the flow resistance characteristics of the energy storage container, determining the operating point of the exhaust fan within the system to be 851 CFM.

Figure 3.6 Exhaust fans in the container (side view)

Assumption: The dispersion simulations are run with the exhaust fans working. The exhaust fan operates at a flow rate of 851 CFM. The activation time will be calculated from the CFD simulations.

3.3 Simulation Results

This dispersion scenario processed represents progressively worse-case scenarios based on the assumptions made in the previous sections. The model covers 1 leakage position. According to the strategy of the ventilation system, the fan will be activated when the detection reaches 4000 ppm of hydrogen. Considering the time delay of the exhaust fan's hinge from initiation to full opening, we set the hinge's opening angle to gradually increase over 7 seconds, simulating the real-world process where the fan's airflow volume progressively reaches its maximum (851CFM). Table 3.2 shows the activating time for the scenario. Figure 3.7 shows the H_2 concentration at the location of the gas detector in the scenario.

Table 3.2 Fan activating time

Scenario	Leakage Point	Detector activation time (s)	Peak airflow time (s)
001	1	69.5	76.5

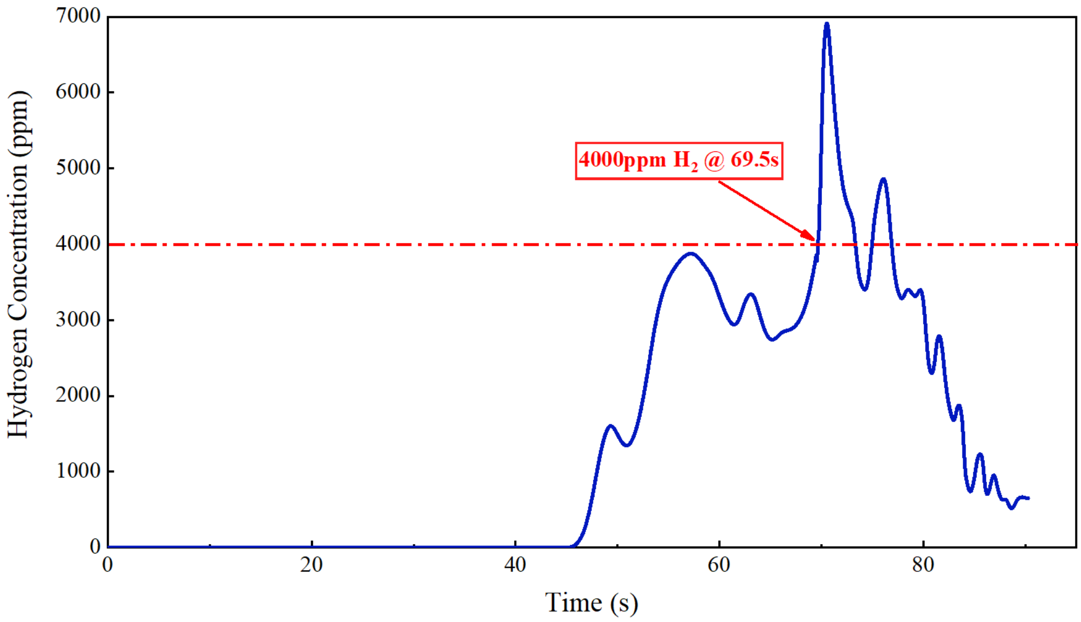

Figure 3.7 Hydrogen concentration at detector

Table 3.3 presents a summary of the scenario and corresponding result from the simulations. The maximum average concentration inside enclosure is presented as the combustible concentration limit according to NFPA 69 Chapter 8.

Table 3.3 Average gas concentration

Scenario	Maximum average gas concentration	
	Vol%	%LFL
001	0.58%	8.92%

Figure 3.8 shows the average gas concentration for the scenario and with the extraction fans activated.

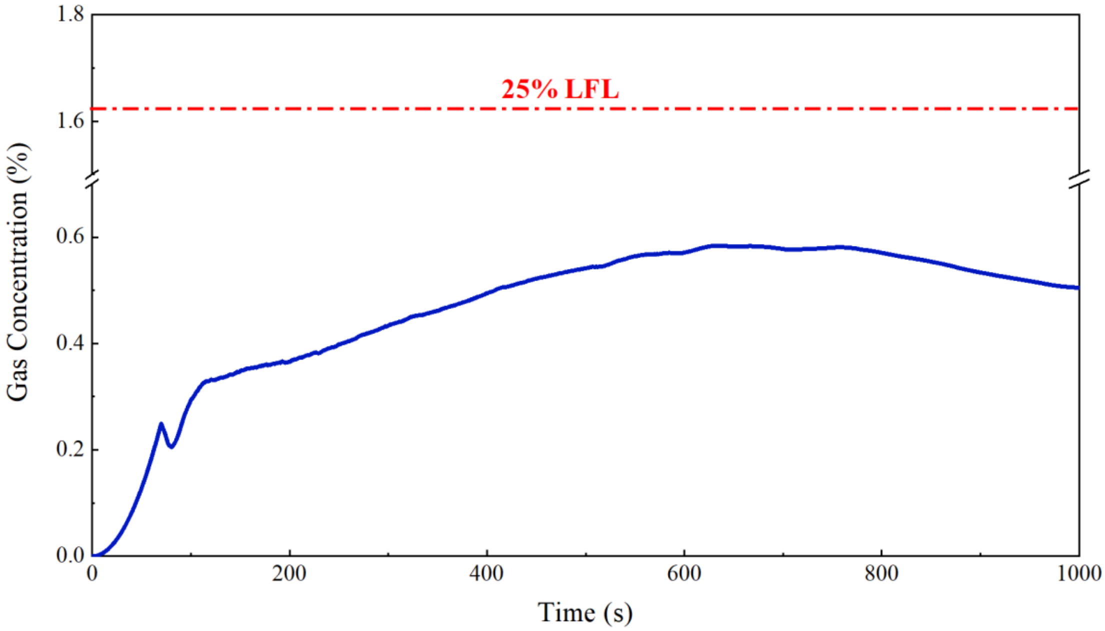

Figure 3.8 Average gas concentration plot

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;

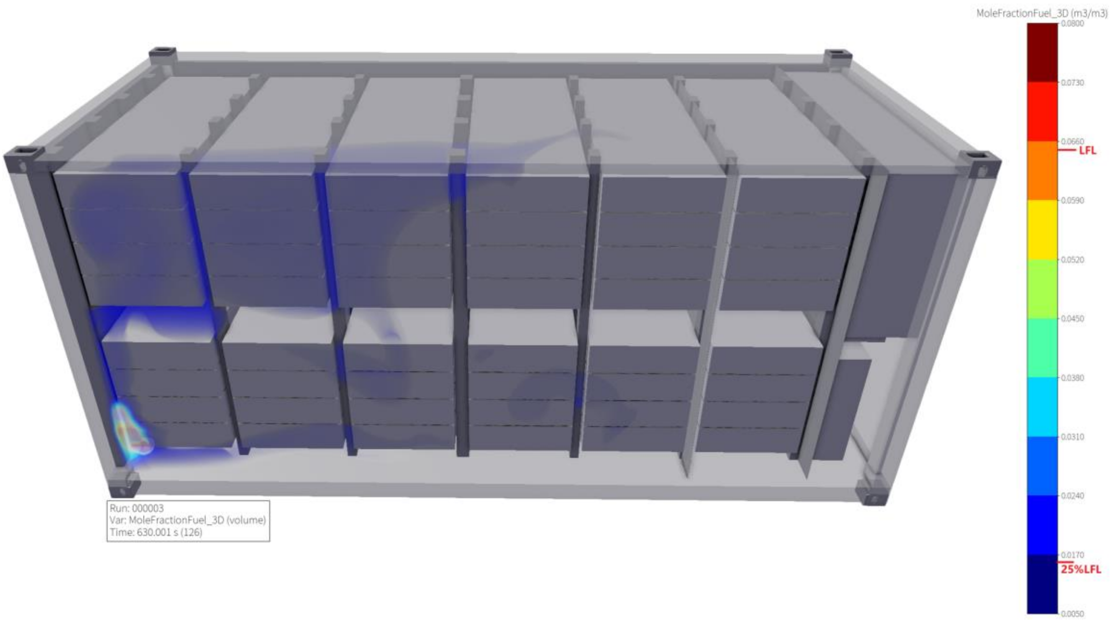

Figure 3.9 The gas cloud inside container at the time step that the gas average concentration is the maximum

4. Conclusions

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 are within the limit of NFPA 69.

The scenarios in this report follow the situation of cell failure and gas release from test observations outlined in the UL 9540A test report and are considered conservative by adopting the severe case of simultaneous thermal runaway in three cells as the basis for calculating the gas release rate. The exhaust fan activates when the hydrogen concentration at the detector reaches 4000 ppm. To accurately simulate the actual physical opening process of the explosion-proof hinges on the exhaust duct in the CFD simulation, we set them to gradually open to their maximum angle over a period of 7 seconds. The dynamic airflow changes during this process are calculated in real-time by the solver.

5. References

(1) NFPA 69:2024 Standard on Explosion Prevention Systems
(2) Cell Level UL9540A Report: CN23F118 001
(3) Module Level UL9540A Report: CN253I80 001