Riskcon engineering

Preliminary Hazard Analysis

86 Woodlands Road, Armidale, NSW

ACEnergy Pty Ltd
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Preliminary Hazard Analysis

86 Woodlands Road, Armidale, NSW

ACEnergy Pty Ltd

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Quality Management

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Executive Summary

Background

ACEnergy Pty Ltd propose to develop a new Battery Energy Storage System (BESS) located at 86 Woodlands Road, Armidale, to be known as Gara BESS. The Secretary's Environmental Assessment Requirements (SEARs) require the preparation of a Preliminary Hazard Analysis (PHA) in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 and No. 6 (Ref. and).

The Project will involve the construction and operation of a BESS with a capacity of approximately 400 MW / 1,760 MWh, and associated infrastructure (i.e. Transformers, Control rooms, etc.). The Project will supply electricity to the national electricity grid via a transmission line that will connect to the existing Armidale substation.

This report supports a State Significant Development (SDD) Development Consent approval under Part 4, Division 4.7 of the *Environmental Planning and Assessment Act 1979* (SSD-71680710), as part of the Environmental Impact Statement (EIS) for the Project.

Conclusions

A hazard identification table was developed for the Gara BESS project to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with the potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

A review of the incidents carried forward for further analysis indicates that there were no observed offsite impacts; therefore, based on the analysis conducted, it is concluded that the risks at the site boundary are not considered to exceed the acceptable risk criteria; hence, the project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site. It must be noted that the required bushfire assessment is provided under separate cover.

Recommendations

The following recommendations have been made as a result of the assessment:

- End-to-end spacing (short side) of BESS containerised units shall be a minimum of 3 m between BESS clusters and 0.9 m between BESS units within the cluster.
- Back-to-back spacing (long side) of BESS containerised units shall be no less than 0.9 m for the CATL BESS units selected for this study.
- Front to front spacing is to be no less than 3 m the CATL BESS units selected for this study.
- BESS separation and spacing are to be specific to BESS the selected.
- The BESS containerised units shall be provided with the fire protection system specified by the BESS manufacturer.
- The active ventilation vents shall not be located above battery packs within the BESS container.
- The vent covers of the BESS shall be constructed of non-combustible material.

- Prior to commissioning, the UL test data for the selected battery units shall be made available to the DPHI.

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Abbreviations

Abbreviation	Description
AC	Alternating Current
ADG	Australian Dangerous Goods Code
AS	Australian Standard
BESS	Battery Energy Storage System
DC	Direct Current
DGs	Dangerous Goods
ELF	Extra Low Frequency
EMF	Electric and Magnetic Field
ERPG	Emergency Response Planning Guideline
FCAS	Frequency Control Ancillary Services
FHA	Final Hazard Analysis
HF	Hydrogen Fluoride
HIPAP	Hazardous Industry Planning Advisory Paper
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IDLH	Immediately Dangerous to Life and Health
LFP	LiFePO4 (Lithium Iron Phosphate)
PHA	Preliminary Hazard Analysis
Pmpy	Per million per year
PV	Photovoltaic
SEARs	Secretary's Environmental Assessment Requirements
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SOC	State of Charge
SSDA	State Significant Development Application
STEL	Short-Term Exposure Limit
VBB	Victorian Big Battery

Definitions

Phrase	Definition
Site	The land that is the subject of the application and denoted as the red boundary as per **Figure 3-5.**
Development Footprint	The land to be impacted by the construction of the project and denoted as the yellow boundary as per **Figure 3-5.**

1.0 Introduction

1.1 Background

ACEnergy Pty Ltd propose to develop a new Battery Energy Storage System (BESS) located at 86 Woodlands Road, Armidale, to be known as Gara BESS. The Secretary's Environmental Assessment Requirements (SEARs) require the preparation of a Preliminary Hazard Analysis (PHA) in accordance with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 and No. 6 (Ref. [1] and [2]).

The Project will involve the construction and operation of a BESS with a capacity of approximately 400 MW / 1,760 MWh, and associated infrastructure (i.e. Transformers, Control rooms, etc.). The Project will supply electricity to the national electricity grid via a transmission line that will connect to the existing Armidale substation.

This report supports a State Significant Development (SDD) Development Consent approval under Part 4, Division 4.7 of the *Environmental Planning and Assessment Act 1979* (SSD-71680710), as part of the Environmental Impact Statement (EIS) for the Project.

1.2 Objectives

The key objectives of this PHA are to:

- Complete the PHA according to the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 – Hazard Analysis (Ref. [2]).
- Assess the PHA results using the criteria in HIPAP No. 4 – Risk Criteria for Land Use Planning (Ref. [1]).

This PHA has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SSD-71680710, dated 19 July 2024) as listed below.

Hazards	The EIS must include an assessment of the following:	
	• **Health** – an assessment of potential hazards and risks including but not limited to bushfires, spontaneous ignition, electromagnetic fields or the proposed grid connection infrastructure against the 'International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for limiting exposure to Time-varying Electric, Magnetic and Electromagnetic Fields';	Section 4
	• **Bushfire** – identify potential hazards and risks associated with bushfires / use of bushfire prone land including the risks that a BESS facility would cause bush fire and demonstrate compliance with *Planning for Bush Fire Protection 2019.* It has been	Provided in the Bush Fire Assesment Report.

	noted that this PHA does not contain the bushfire assessment required by the SEARs and will be provided in the Bush Fire Assesment Report.	
	• **Dangerous Goods** – a preliminary risk screening completed in accordance with the State Environmental Planning Policy (Resilience and Hazards);	Section 3.6
	• **Battery Energy Storage System** - a Preliminary Hazard Analysis (PHA) must be prepared in accordance with 'Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis' (DoP, 2011) and Multi-Level Risk Assessment (DoP, 2011). The PHA must consider all recent standards and codes and verify separation distances to on-site and off-site receptors to prevent fire propagation and compliance with Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning (DoP, 2011), include the key design parameters identified in the Project description.	Section 4

1.3 Scope of Services

The scope of work is to complete a PHA study for the proposed Gara BESS project to be located 86 Woodlands Road, Armidale, NSW.

2.0 Methodology

2.1 Multi-Level Risk Assessment

The Multi-Level Risk Assessment approach (Ref. [3]) published by the NSW Department of Planning, Housing and Infrastructure, has been used as the basis for the study to determine the level of risk assessment required. The approach considered the development in context of its location, the quantity and type (i.e. hazardous nature) of Dangerous Goods (DGs) stored and used, and the project's technical and safety management control. The Multi-Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the project being studied.

There are three levels of risk assessment set out in Multi-Level Risk Assessment which may be appropriate for a PHA, as detailed in **Table 2-1**.

Table 2-1: Level of Assessment PHA

Level	Type of Analysis	Appropriate If:
1	Qualitative	No major off-site consequences and societal risk is negligible
2	Partially Quantitative	Off-site consequences but with low frequency of occurrence
3	Quantitative	Where 1 and 2 are exceeded

The Multi-Level Risk Assessment approach is schematically presented in **Figure 2-1**.

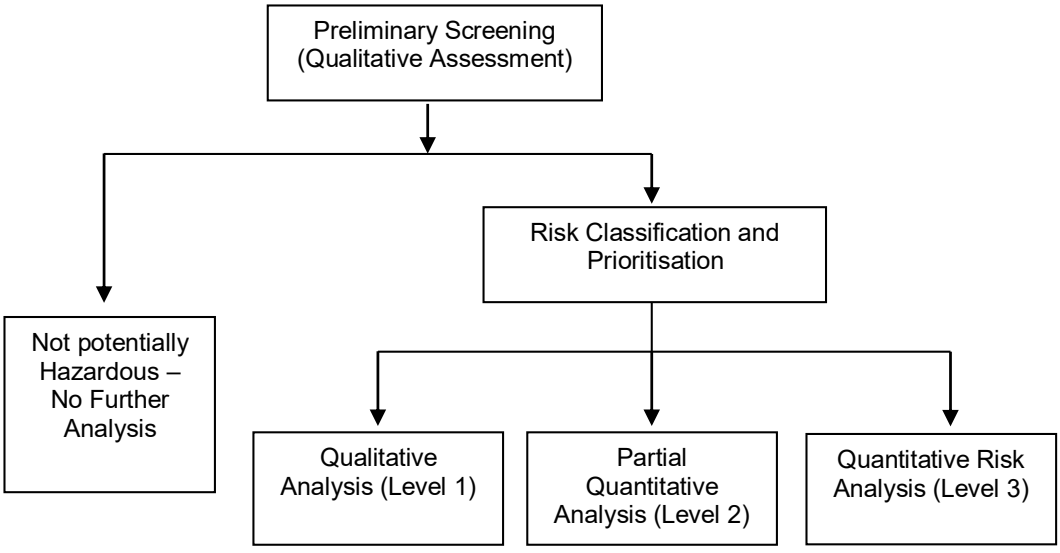


Figure 2-1: The Multi-Level Risk Assessment Approach

Based on the type of DGs to be used and handled at the proposed project, a **Level 1 Assessment** was selected for the Site. This approach provides a qualitative assessment of those DGs of lesser quantities and hazard, and a quantitative approach for the more hazardous materials to be used on-site. This approach is commensurate with the methodologies recommended in "Applying SEPP 33's" Multi Level Risk Assessment approach (DPHI, 2011).

2.2 Risk Assessment Study Approach

The methodology used for the PHA is as follows:

Hazard Analysis – A detailed hazard identification was conducted for the site facilities and operations. Where an incident was identified to have a potential off-site impact, it was included in the recorded hazard identification word diagram (**Appendix A**). The hazard identification word diagram lists incident type, causes, consequences and safeguards. This was performed using the word diagram format recommended in HIPAP No. 6 (Ref. [2]).

Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried into the main report for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would obviously have no offsite impact, no further analysis was performed. **Section 3.1** of this report provides details of values used to assist in selecting incidents required to be carried forward for further analysis.

Consequence Analysis – For those incidents qualitatively identified in the hazard analysis to have a potential offsite impact, a detailed consequence analysis was conducted. The analysis modelled the various postulated hazardous incidents and determined impact distances from the incident source. The results were compared to the consequence criteria listed in HIPAP No. 4 (Ref. [1]). The criteria selected for screening incidents is discussed in **Section 3.1**.

Where an incident was identified to result in an offsite impact, it was carried forward for frequency analysis. Where an incident was identified to not have an offsite impact, and a simple solution was evident (i.e. move the proposed equipment further away from the boundary), the solution was recommended, and no further analysis was performed.

Frequency Analysis – In the event a simple solution for managing consequence impacts was not evident, each incident identified to have potential offsite impact was subjected to a frequency analysis. The analysis considered the initiating event and probability of failure of the safeguards (both hardware and software). The results of the frequency analysis were then carried forward to the risk assessment and reduction stage for combination with the consequence analysis results.

Risk Assessment and Reduction – Where incidents were identified to impact offsite and where a consequence and frequency analysis was conducted, the consequence and frequency analysis for each incident were combined to determine the risk and then compared to the risk criteria published in HIPAP No. 4 (Ref. [1]). Where the criteria were exceeded, a review of the major risk contributors was performed, and the risks reassessed incorporating the recommended risk reduction measures. Recommendations were then made regarding risk reduction measures.

Reporting – On completion of the study, a draft report was developed for review and comment. A final report was then developed, incorporating the comments received for submission to the regulatory authority.

3.0 Site Description

3.1 Site Location

The Project is located at 86 Woodlands Road, Armidale, NSW. The site is located within the Armidale Regional Local Government Area (LGA), approximately 7 km east of the township of Armidale. The Project Area is bounded by primary production land to the North, South, East and West.

Figure 3-1 shows the regional location of the site in relation to Armidale. The conceptual project layout has been provided in **Figure 3-5** and **Figure 3-6**.

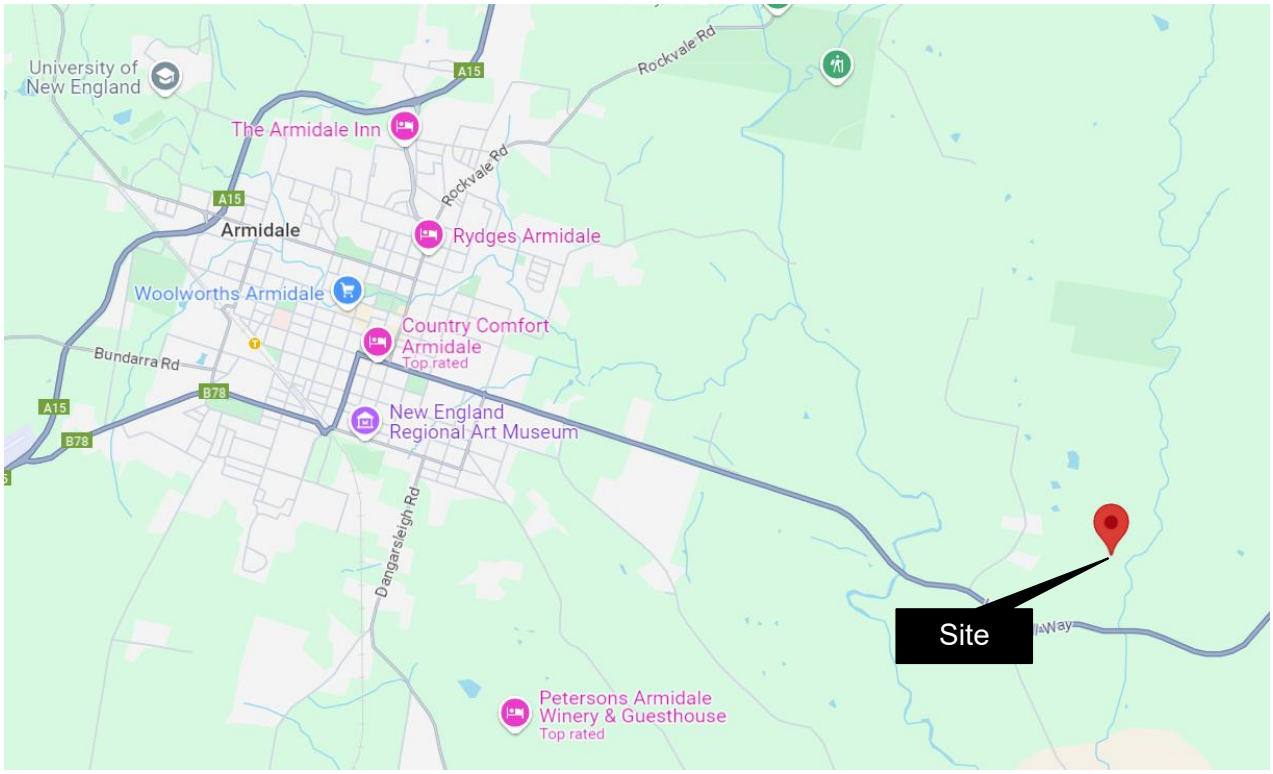


Figure 3-1: Site Location

3.2 Adjacent Land Uses

The land is located in a regional / rural area on land zoned RU1 primary Production surrounded by the following land used which are adjacent to the site:

- North – RU1 Primary Production
- South – RU1 Primary Production
- East – RU1 Primary Production
- West – RU2 Primary Production

3.3 Sensitive Receptors

The nearest residential locations are as follows and shown in **Figure 3-2**.

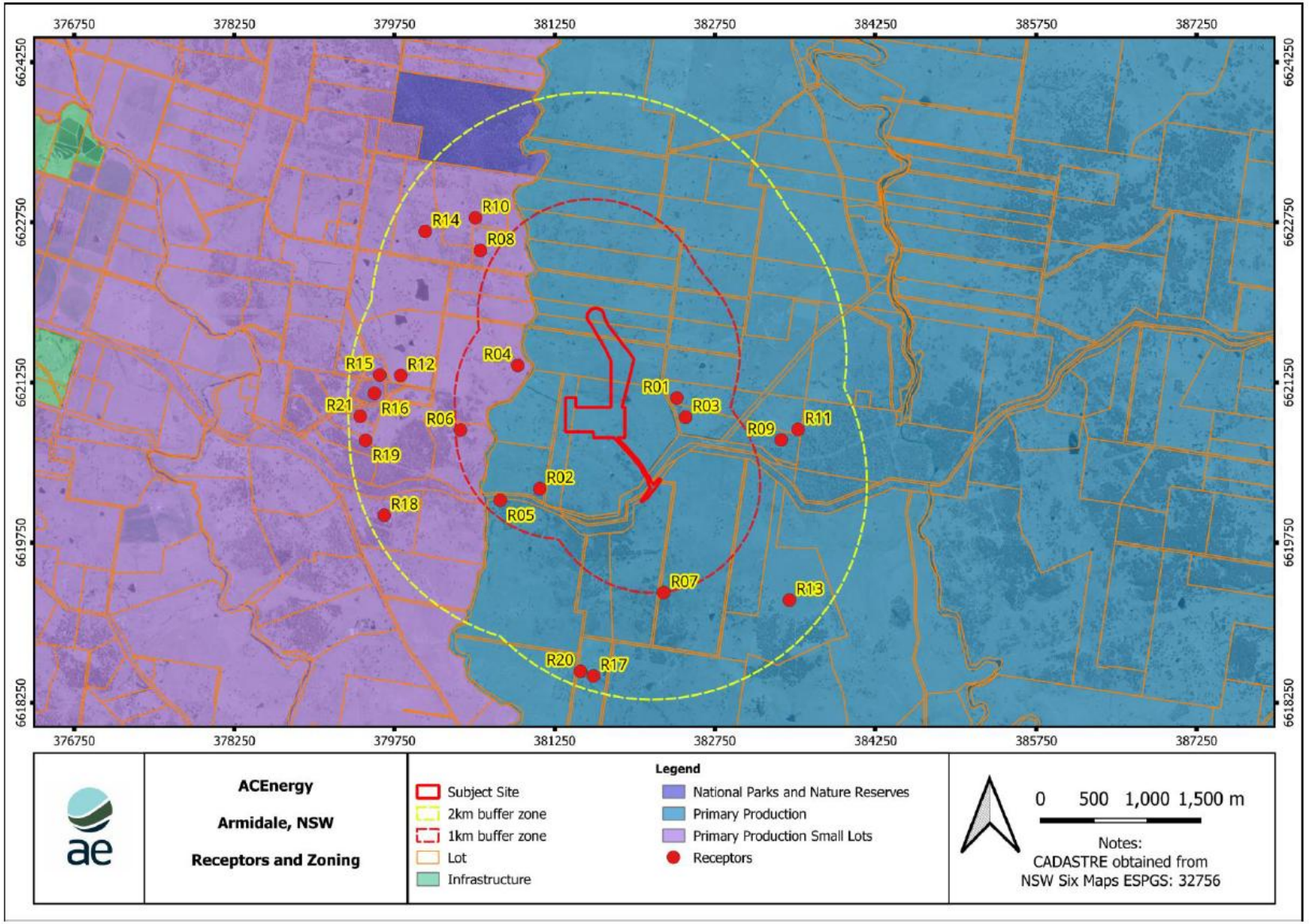


Figure 3-2: Sensitive Receptors

3.4 General Description

The Project will involve the construction, operation and decommissioning of a Battery Energy Storage System (BESS) and associated infrastructure. The conceptual Project includes:

- Operation:
  - BESS with a delivery capacity of up to approximately 400 MW and a storage capacity of approximately 1,760 MWh.
  - Electricity infrastructure:
    - 336 Enclosed lithium-ion batteries (BESS Units).
    - 112 Medium Voltage Power Station (MVPS) and associated transformers.
    - Overhead power and fibre optic cabling interconnecting the equipment.
    - Grid connection equipment including switchgear, protection and control equipment, metering, reactive power equipment, filtering equipment, auxiliary transformers and enclosures / buildings for housing equiptment.
    - Cut-in to existing 330KV line through installation of interface structures to replace the existing tower.
    - Establishment of a new 330 kV switching station within the development footprint.
    - Loop-in, loop-out 330 kV overhead lines connecting the line interface to the new switching station with approximatly 1 km length and supported by dual-circuit tower structures.
    - Earthing and lightning protection systems.
  - On-site permanent supporting infrastructure:
    - Provision of upgrading existing site access road from Waterfall Way to the south.
    - Acoustic barriers.
    - Site office, storage area/enclosure, internal access tracks, on-site parking, security fencing, CCTV, and temporary construction laydown area.
    - Operations and Maintenance (O&M) Facility including control rooms, meeting facilities, storage facilities, benching and earthing, parking, ablutions buildings, septic, static water supply, waste management facilities, lighting and maintenance facility.
    - Vegetation screening.
  - Off-site supporting infrastructure:
    - Existing public road and communications network.
  - The site shall operate 24 hours a day 7 days a week with up to 5 personnel.
  - Operational life of 23 years unless updated to extend operational lifetime.
- Construction:
  - Total duration of 60 weeks with a peak period of 4 months and up to 80 personnel per day.
  - Hours of construction between 7 am to 6 pm weekdays and 8 am to 1 pm Saturdays (no operation on Sundays and NSW public holidays).

- Key stages
  - Establishment, drainage, roads and fencing.
  - Footing installation.
  - Delivery and installation.
  - Steel platform installation.
  - MVPS and BESS delivery and installation including electrical.
  - Control room, transformer and switch gear delivery and installation.
  - Commissioning and decommissioning.

- Decommissioning:
  - Components above ground and less than one metre below ground would be removed and land rehabilitated to pre-development conditions.

3.5 Detailed Description

The purpose of the project is to provide dispatchable energy to the NSW grid and contribute towards the goals of the NSW government's NSW Electricity Infrastructure Roadmap.

The electricity will be capable of storage in a 400MW / 1,760 MWh BESS which can be dispatched based on electricity demand fluctuations, providing the opportunity for greater supply dispatch flexibility when electricity demand is highest. This is enabled by the fast response times achievable through lithium-ion battery storage. The Project will have the capacity to discharge up to 400 megawatts (MW) of power for 4 hours resulting in a storage of 1,760 MWh.

3.5.1 Medium Voltage Power Station (MVPS)

The MVPS house transformers and inverters which will be situated adjacent to the BESS units. There will be approximately 112 MVPS installed throughout the project area which typically comprise:

1. 1 x transformers
2. 1 x inverters

The inverters convert the Direct Current (DC) to Alternating Current (AC), while the transformers increase the voltage from Low Voltage to Medium or High Voltage, as required for the electricity grid connection. MPVS are a compact, containerised product, a similar system to the SMA model 4200-S2 shall be utilised, each unit measures approximately 2.5 m wide by 3 m high, with a depth of 6 metres. **Figure 3-3** provides an example of a typical MVPS.

Figure 3-3: Typical MVPS

3.5.2 Battery Storage

Approximately 336 BESS units will be located within the development footprint. The BESS converts electrical energy into chemical energy and stores the energy internally. It may also provide additional network support such as Frequency Control Ancillary Services (FCAS) assisting with transmission network grid stability. A typical BESS is shown in **Figure 3-4**.

Figure 3-4: Typical BESS Arrangement

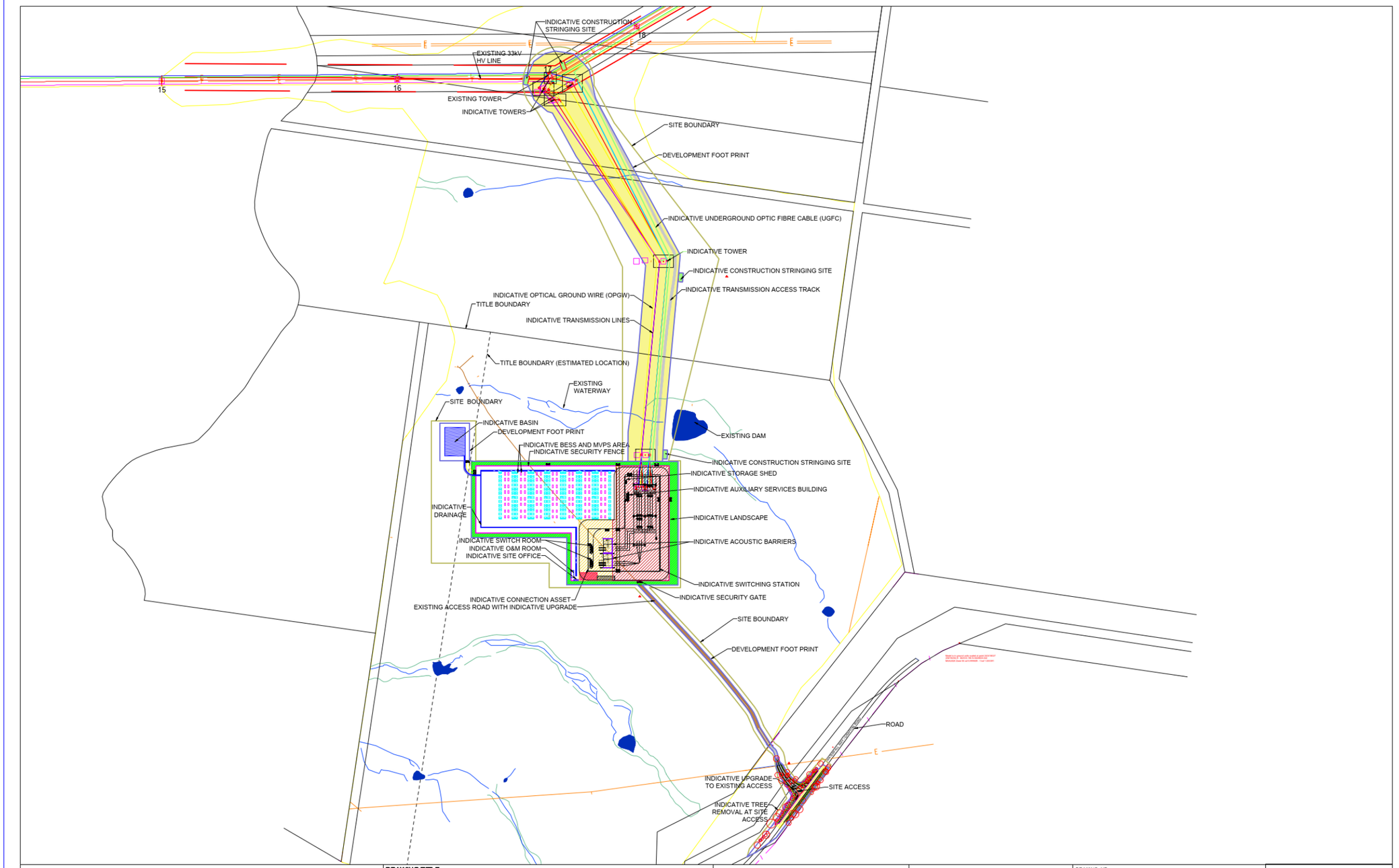
3.6 Quantities of Dangerous Goods Stored and Handled

The classes and quantities of DGs to be approved in the project are summarised **Table 3-1**. The quantities of DG class C1 provided in **Table 3-1** is indicative and will need to be updated once disclosed. The number was adapted from another BESS project with a similar scale and is considered to reasonably represent the Gara BESS project. Additionally, the SEPP threshold of the individual classes has been provided for the purposes of the SEARs.

As the site exceeds the discharge capacity threshold of 30 MW the site is subject to the SEPP-RH and a PHA is required.

Table 3-1: Maximum Classes and Quantities of Dangerous Goods Stored

Area	Class	Description	Quantity	SEPP Threshold
BESS	9	Lithium Batteries	14,256 t	N/A
MVPS Transformer	C2	Transformer oils	4,888 L	N/A
Substation Transformer	C2	Transformer oils	140 t	N/A
Control room generator	C1	Diesel	80,000 L	N/A
Discharge Capacity	-	-	400 MW	30 MW



REVISIONS					
REV	STATUS	DESCRIPTION	DATE	D.B.	C.B.
C3	FA	UPDATED ADDRESS	15/08/24	JC	AA
C4	FA	UPDATED POLE LOCATION	28/08/24	JC	AA
D	FA	UPDATED DRAINAGE AND TRANSMISSION ASSETS	02/10/25	MH	JC
E	FA	SITE ACCESS CIVIL UPGRADES	20/10/25	MH	JC

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-30.543984, 151.752789

DRAWING TITLE: ACENERGY PTY LTD

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SHEET SIZE: A3	PROJECT : 23143	REV. NO: E

Figure 3-5: Site Layout

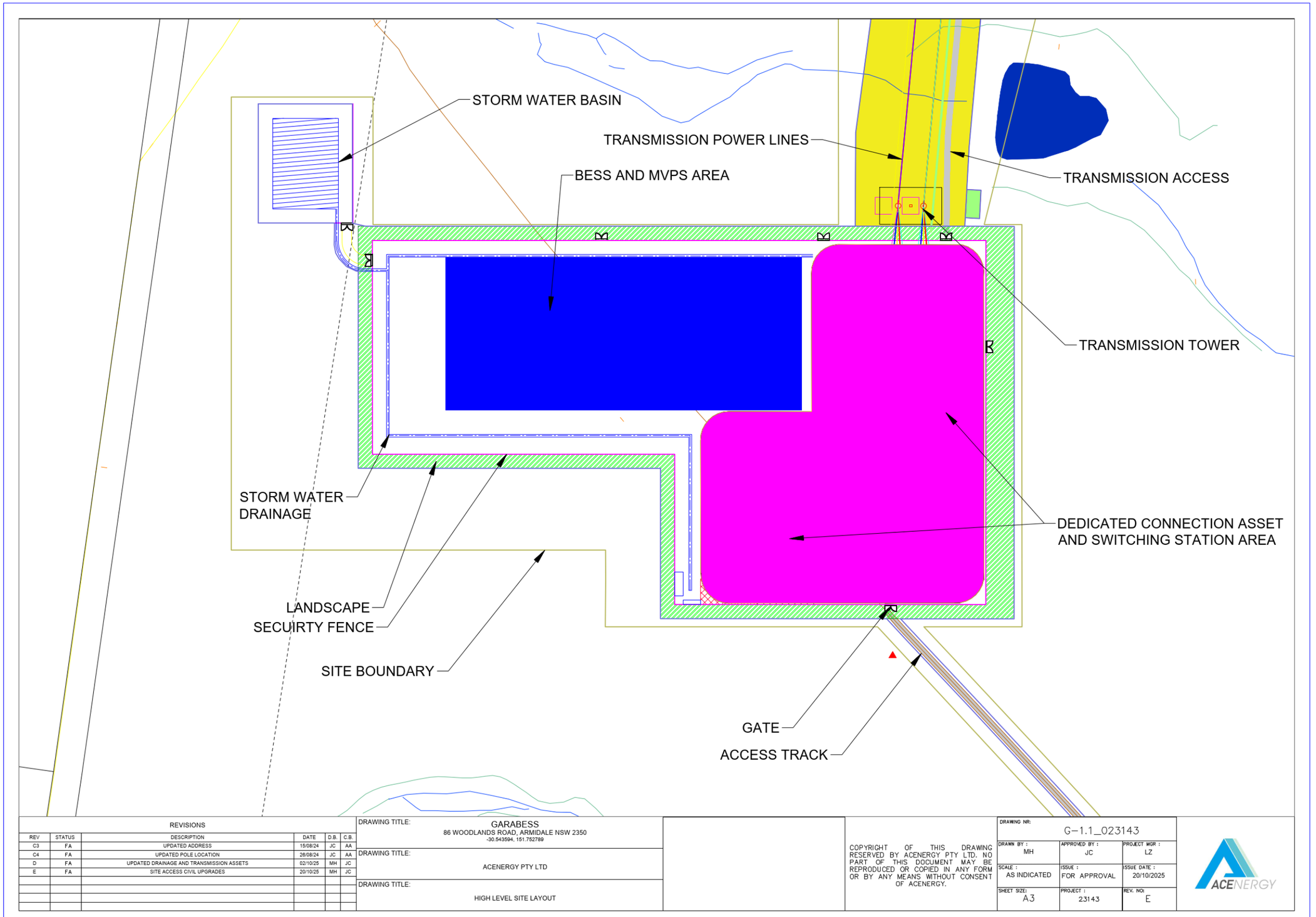


Figure 3-6: Detailed Site Plan

4.0 Hazard Identification

4.1 Introduction

A hazard identification table has been developed and is presented at **Appendix A**. This table has been developed following the recommended approach in Hazardous Industry Planning Advisory Paper No. 6, Hazard Analysis Guidelines (Ref. [2]). The Hazard Identification Table provides a summary of the potential hazards, consequences and safeguards at the site. The table has been used to identify the hazards for further assessment in this section of the study. Each hazard is identified in detail and no hazards have been eliminated from assessment by qualitative risk assessment prior to detailed hazard assessment in this section of the study.

In order to determine acceptable impact criteria for incidents that would not be considered for further analysis, due to limited impact offsite, the following approach has been applied:

- *Fire Impacts* - It is noted in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (Ref. [1]) that a criterion is provided for the maximum permissible heat radiation at the site boundary (4.7 kW/m^2) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in a heat radiation less that at 4.7 kW/m^2, at the site boundary, are screened from further assessment.

  Those incidents exceeding 4.7 kW/m^2 at the site boundary are carried forward for further assessment (i.e. frequency and risk). This is a conservative approach, as HIPAP No. 4 (Ref. [1]) indicates that values of heat radiation of 4.7 kW/m^2 should not exceed 50 chances per million per year at sensitive land uses (e.g. residential). It is noted that the closest residential area is several kilometres from the closest BESS, hence, by selecting 4.7 kW/m^2 as the consequence impact criteria the assessment is considered conservative.

- *Explosion* - It is noted in HIPAP No. 4 (Ref. [1]) that a criterion is provided for the maximum permissible explosion over pressure at the site boundary (7 kPa) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in an explosion overpressure less than 7 kPa, at the site boundary, are screened from further assessment. Those incidents exceeding 7 kPa, at the site boundary, are carried forward for further assessment (i.e. frequency and risk). Similarly, to the heat radiation impact discussed above, this is conservative as the 7 kPa value listed in HIPAP No. 4 relates to residential areas, which are over several kilometres from the closest BESS.

- *Toxicity* – Toxic bi-products of combustion may be generated by a BESS fire; hence, toxicity has been assessed with criteria based upon the Emergency Response Planning Guidelines (ERPG).

- *Property Damage and Accident Propagation* - It is noted in HIPAP No. 4 (Ref. [1]) that a criterion is provided for the maximum permissible heat radiation/explosion overpressure at the site boundary (23 kW/m^2/14 kPa) above which the risk of property damage and accident propagation to neighbouring sites must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk to incident propagation, for this study, incidents that result in a heat radiation heat radiation less than 23 kW/m^2 and explosion over pressure less than 14 kPa, at the site boundary, are screened from further assessment. Those incidents

exceeding 23 kW/m^2 at the site boundary are carried forward for further assessment with respect to incident propagation (i.e. frequency and risk).

- *Societal Risk* – HIPAP No. 4 (Ref. [1]) discusses the application of societal risk to populations surrounding the Project. It is noted that HIPAP No. 4 indicates that where a development proposal involves a significant intensification of population, in the vicinity of such a project, the change in societal risk needs to be taken into account. In the case of the project, there is currently no significant intensification of population around the proposed site; hence, societal risk has not been considered in this assessment.

4.2 Properties of Dangerous Goods

The type of DGs and quantities stored and used at the site has been described in **Section 3**. **Table 4-1** provides a description of the DGs to be stored and handled at the site, including the Class and the hazardous material properties of the DG Class.

Table 4-1: Properties* of the Dangerous Goods and Materials Stored at the Site

Class	Hazardous Properties
9 – Miscellaneous DGs	Class 9 substances and articles (miscellaneous dangerous substances and articles) are substances and articles which, during transport present a danger not covered by other classes. Releases to the environment may cause damage to sensitive receptors within the environment. It is noted that the Class 9s stored within this project are lithium-ion batteries which may undergo thermal runaway (i.e. escalating reaction resulting in heat which ultimately leads to failure of the battery and a fire).
Combustible Liquids	Combustible liquids are typically long chain hydrocarbons with flash points exceeding 60.5^{o}C. Combustible liquids are difficult to ignite as the temperature of the liquid must be heated to above the flash point such that vapours are generated which can then ignite. This process requires either sustained heating or a high-energy ignition source.

* The Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [4]

4.3 Hazard Identification

Based on the hazard identification table presented in **Appendix A**, the following hazardous scenarios have been developed:

- Transportation and storage of toxics.
- Li-ion battery fault, thermal runaway and fire.
- Victorian Big Battery fire review.
- Li-ion battery fire and toxic gas dispersion.
- Electrical equipment failure and fire.
- Transformer internal arcing, oil spill, ignition and bund fire.
- Transformer electrical surge protection failure and explosion
- Electromagnetic field Impacts.

Each identified scenario is discussed in further detail in the following sections.

4.4 Transportation and Storage of Toxics

The Gara BESS facility does not store or transport toxic DGs during the construction phase, operational phase and decommissioning stage. Hence, risks associated with toxic goods do not apply to this project. Due to this incident has not been carried forward for further analysis.

4.5 Li-Ion Battery Fault, Thermal Runaway and Fire

Lithium ion (Li-ion) batteries are composed of a metallic anode and cathode which allows for electrons released from the anode to travel to the cathode where positively charged ions in the solute migrate to the cathode and are reduced. The flow of electrons provides the source of energy which is discharged from a battery and used for work. In a Li-ion battery, the lithium metal composites (a composite of lithium with other metals such as cobalt, manganese, nickel, or any combination of these metals) oxidises (loses an electron) becoming a positively charged ion in solution which migrates through the battery separator to the cathode. At the same time, the lost electron travels through the circuit to the cathode. The lithium ions in solution then recombine with the electron at the cathode forming lithium metal within the cathodic metal composite. This process is shown in **Figure 4-1**.

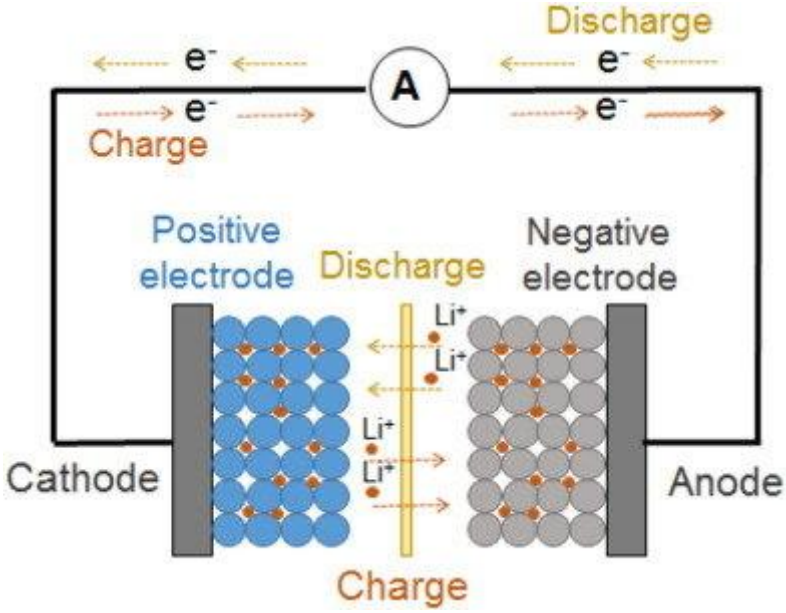


Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

Initial lithium batteries were designed around lithium metal (i.e. no composite structure) due to the high energy density yielded by the metal. However, when overcharging a battery, lithium ions can begin to plate on the anode in the form of lithium dendrites. Eventually, the dendrites pierce the separator within the battery resulting in a short of the battery which could result in heat, fire, or explosion of the battery. The technology evolved to move away from lithium metal to lithium ions (held within composite materials) which reduced the incidence of lithium dendrites forming resulting in an overall safer battery.

Despite the improvement in battery technology, there are several degradation mechanisms that are still present within the battery which can result in thermal runaway. These include:

- Chemical reduction of the electrolyte at the anode
- Thermal decomposition of the electrolyte

- Chemical reduction of the electrolyte at the cathode
- Thermal decomposition by the cathode and the anode
- Internal short circuit by charge effects

These effects arise primarily as a result of high discharge, overcharging, or water ingress into the battery which results in a host of bi-products being formed within the battery during charge and discharge cycles.

As a result, Li-ion batteries are equipped with several safety features to prevent the batteries from charging or discharging at voltages which result in battery degradation, leading to shorting of the battery and thermal runaway. Safety features generally include:

- Shut-down separator (for overheating)
- Tear-away tab (for internal pressure relief)
- Vent (pressure relief in case of severe outgassing)
- Thermal interrupt (overcurrent/overcharging/environmental exposure)

These features are designed to prevent overcharging or excessive discharge, pressurisation arising from heat generated at the anode or from battery contamination. Protection techniques for Li-ion batteries are standard; hence, the potential for thermal runaway to occur in normal operation is very low with the only exceptions being due to manufacturing faults or battery damage (i.e. battery cell is ruptured as this can short circuit the battery resulting in thermal runaway).

In terms of physical damage, the batteries are contained within in modules which are located within a fenced area; therefore, there is a low potential for damage to occur to the batteries which may initiate an incident.

A review of the batteries proposed to be used as part of this project indicates the battery chemistry is lithium-Ion phosphate (LiFePO4, or simply LFP) which are considered to be one of the safest battery chemistries within the industry. When exposed to external heat the thermal rise of typical lithium-ion battery chemistries is 200-400 ºC / min resulting thermal run away and fire which can then propagate to adjacent batteries escalating the incident to a full container fire. For LFP batteries, the thermal rise of the batteries at peak is 1.5ºC/min which results in a gradual temperature rise and does not result in fire and thus incident propagation to other batteries. The thermal rise of various battery chemistries is provided in **Figure 4-2** with a zoomed in temperature rise for LFP provided in the top right of **Figure 4-2**. The stability of the batteries is due to the cathode which does not release oxygen therefore preventing violent redox reactions resulting in rapid temperature rise as the oxygen oxides the electrolyte.

Additional testing for shock and damage to batteries (i.e. nail puncture test) has been shown that LFP batteries when punctured through membranes which typically results in a shorting of the battery and fire does not result in ignition of the battery demonstrating that the battery chemistry is protected against shock damage.

In the event that LFP chemistries do ignite by artificial means, the combustion by products release carbon dioxide which reduces the oxygen concentration within a confined space reducing the combustion rate. Finally, the containers are fitted with a fire suppression system which will activate to suppress and control a fire preventing escalation to other battery units.

In addition to this, manufacturers and integrators can implement different means of preventing battery ignition or controlling if it occurs (such as physical construction arrangements, battery monitoring, heat detection, etc). These are implemented on a system-by-system basis and are specific to the system needs.

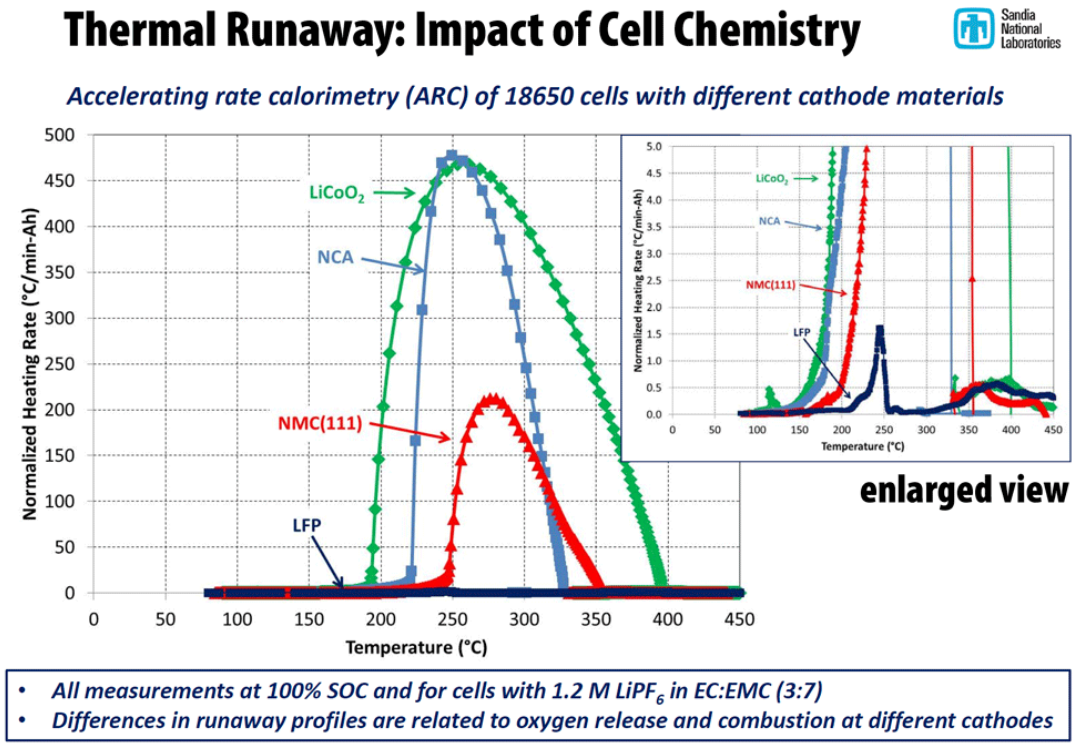


Figure 4-2: Temperature Rise of Lithium-Ion Battery Chemistries (Ref. [5]).

The preliminary battery product proposed for the Gara project is CATL EnerX 0.25P. Both the module and unit level UL9540A report (Appendix B) for this product demonstrates that when thermal runaway is triggered in one cell in a BESS container, the heat generated only propagates to thermal runaway to one adjacent cell. All other cells within the battery module, nor from the test module to adjacent ones, enter thermal runaway. This is attributed to the nature of LFP technology as well as the sheer mass of the battery module (heavier objects have higher thermal capacity).

The UL9540A report also supports the findings that the temperature rise caused on a nearby object by thermal runaway within one module is negligible. To be specific, **Figure 4-3** shows the test setup where the rear wall is distanced 150 mm from the test battery racks.

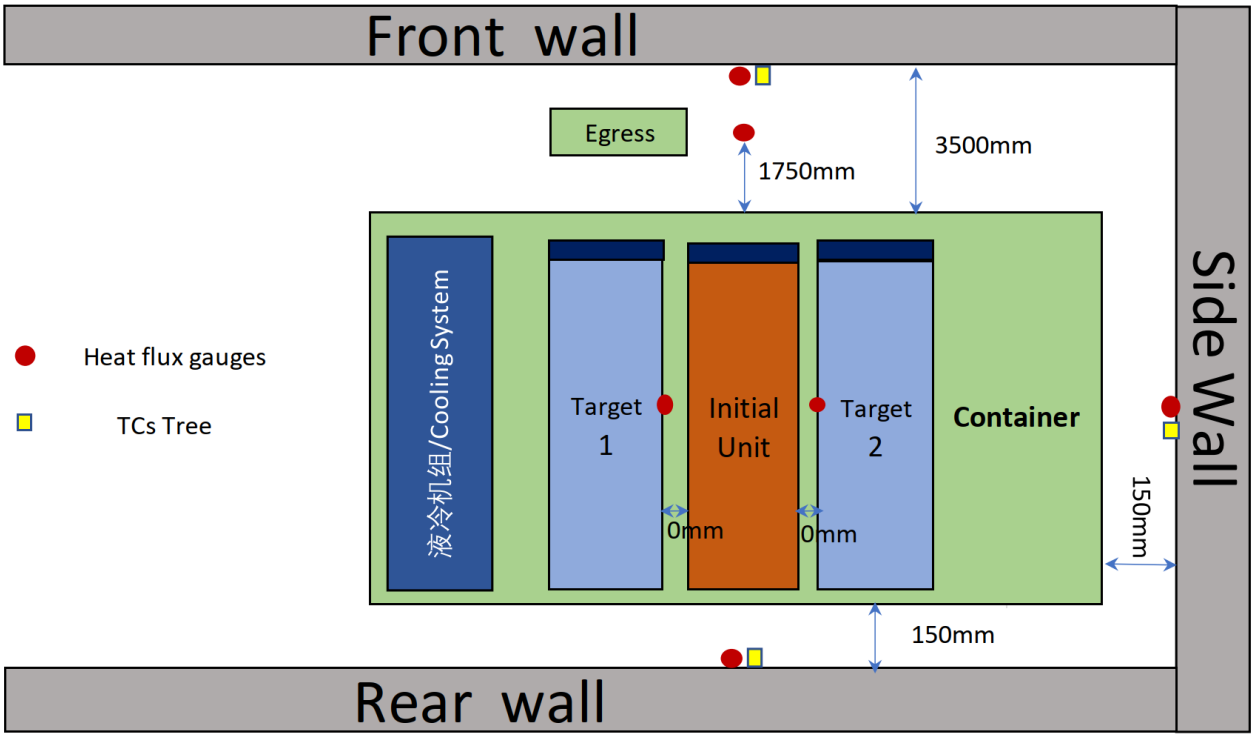


Figure 4-3: Test Site Diagram with Separation Distance (Top View)

The temperatures on the rear wall during the thermal runaway test are recorded by thermal couples across the wall surface facing the test battery racks. The recorded temperature rises are no more than 25 ºC as shown in **Figure 4-4**.

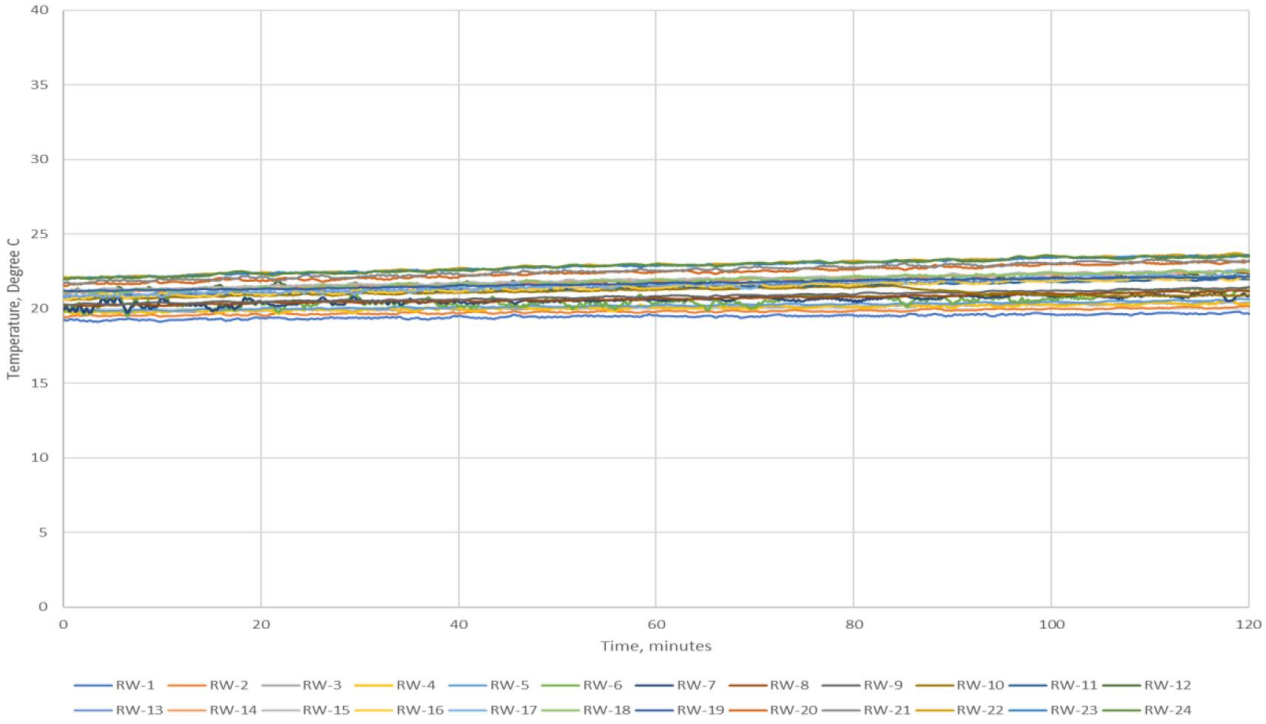


Figure 4-4: Temperature Measured on Rear Wall During the Test

There were also no external flames observed during the UL9540A test. All findings and observations combined mean the proposed LFP batteries would not cause fire due to thermal runaway.

Although the LFP technology does not cause fire, there can be a few circumstances where battery modules catch fire due to leaking coolant or electric faults. In those cases, fire will be constrained by the metal enclosure. The BESS container wall has been tested to this scenario. The report (**Appendix C**) shows that the container wall remains intact after sustaining heating in a furnace to the temperatures intended for use.

Furthermore, each container also has multiple built-in fire protection devices that work collaboratively, including smoke and thermal sensors, combustible gas detector, pressure relief system, and aerosol fire extinguishing system outlined in **Figure 4-5**, **Figure 4-6 and** (**Appendix D**). Therefore, a container will automatically suppress an internal fire in the first instance. The diagram below provided by CATL shows a typical arrangement for fire safety devices within a BESS container.

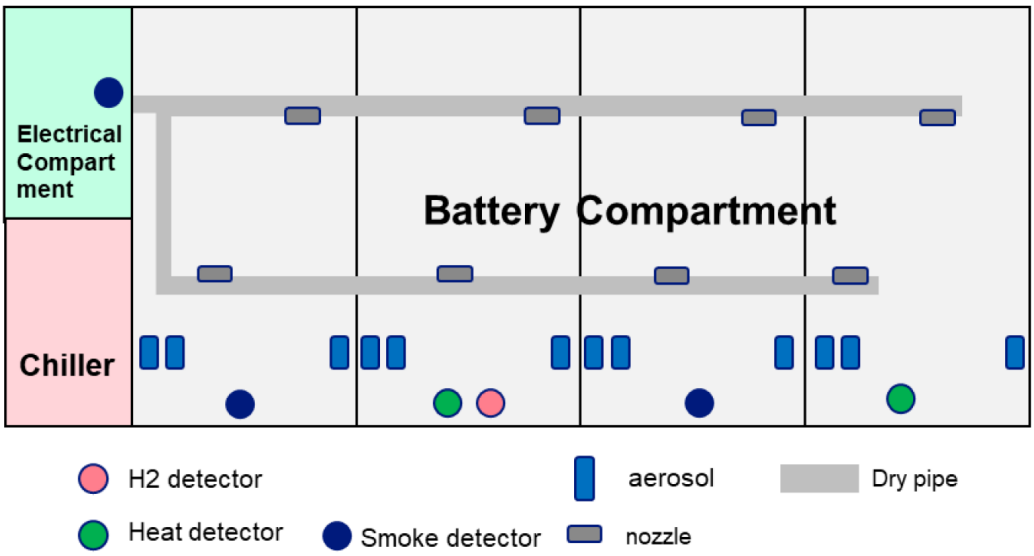


Figure 4-5: Detection Systems

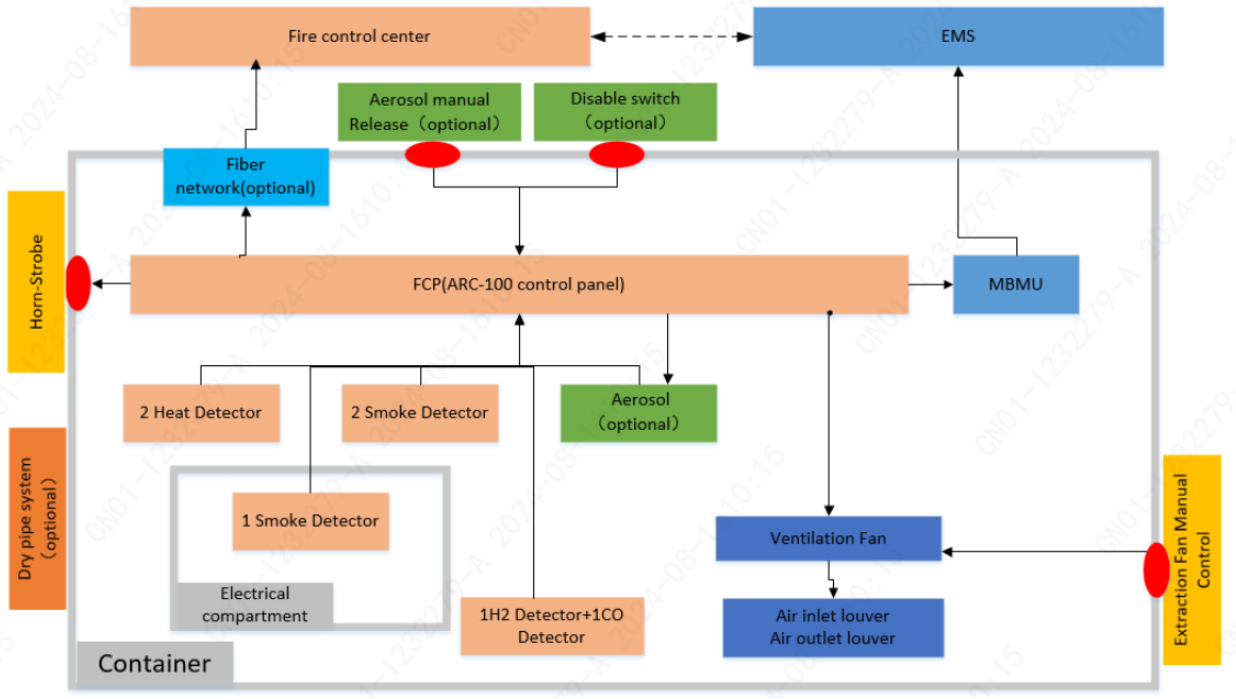


Figure 4-6: Fire Suppression System Layout

Apart from UL9540A, CATL EnerX 0.25P battery holds UL9540 and UL1973 certificates (see **Appendix F, G**). In addition, the product's NFPA-855 Compliance Guide (**Appendix H**) demonstrates fire-related compliance with NFPA-855 standards. These certificates collectively demonstrate that thermal runaway on the chosen LFP BESS product does not propagate from one module to another.

In conclusion, the LFP technology does not cause fire during thermal runaway. Should fire develop within one CATL EnerX 0.25P BESS container it would not transfer to nearby containers due to the fire safety design features and recommended separation; hence, this incident has not been carried forward for further analysis.

4.6 Victorian Big Battery Fire Review

Notwithstanding the findings of **Section 4.5**, it is necessary to review recent large-scale BESS fires to determine whether similar incidents could occur with the Gara BESS.

The Gara BESS has thoroughly considered the separation distance, considering fire safety, and operation and maintenance. The fire safety assessment is essentially around heat transfer which has been discussed in detail in **Section 4.5**.

The Gara BESS preliminary design is based on the installation requirements of CATL EnerX 0.25P BESS. **Figure 4-7** shows the CATLs approved BESS installation, which has considered fire propagation, the thermal test result of the module thermal runaway and heat flux assessment from the UL9540A report (**Appendix C**). **Table 4-2** outlines the dimensions of the BESS layout in **Figure 4-7** (**Appendix E**) . The BESS configuration for the site is summarised in **Figure 4-9** which shows the conformity of the layout outlined by CATL requirements.

Table 4-2 BESS Layout Dimensions

BESS Layout Dimensions	L1 (m)	L2 (m)	L3 (m)	L4 (m)
Recommended by Manufacturer	3	3	3.5	0.9

Figure 4-7: CATL EnerX 0.25P BESS Layout Guide

The Victorian Big Battery (VBB) also has a back-to-back layout. According to the independent investigation report on its fire incidence (**Appendix L**), the back-to-back layout was not the cause. The main reason for fire propagation was strong wind blowing flames from one Megapack into the unprotected vent atop of an adjacent Megapack which resulted in the ignition of the plastic fan which was able to impact the battery modules directly beneath the fan.

Lessons learnt from the VBB incident results in fire safety precautions on the design of the Gara BESS. The vent of the containers is to be constructed of metal instead of plastic and covered by a metallic mesh shield. Furthermore, the placement of the fans shall be such that batteries or flammable materials shall not be located directly beneath ventilation openings.

To ensure the above are captured the following recommendations have been made:

- The vent covers of the BESS shall be constructed of non-combustible material.
- Active ventilation vents shall not be located above battery packs within the BESS container.

4.6.1 Available Space Review

An additional review has been conducted to demonstrate that there is sufficient space within the development footprint for the arrangement outlined in **Figure 4-7** to maintain the required separation distances to prevent incident propagation between BESS subunits. Provided in **Figure 4-8** is the proposed BESS layout and in **Figure 4-9** is a summary of the dimensions required to inhibit fire propagation between MVPS and BESS units.

BESS units will be installed in clusters of 4 with back-to-back faces having a separation of 1 m, end-to-end faces and the front opening face will be separated by 3 m of each BESS unit cluster. A BESS cluster contains 4 BESS units and requires a footprint of 176.7 m^2 (9.3 m x 19 m) to comply with the separation distances mentioned. There are 336 BESS units, totalling 84 clusters, which results in a total BESS footprint of 14,842.8 m^2.

Additionally, MVPS are clusters of 4, which are separated by 6m from long sides and 6.5 m from short ends, with 9.5 m between each cluster, requiring a footprint of 472.6 m^2 (27.8 m x 17 m). There are 112 MVPS units, totalling 28 clusters, which results in a total MVPS footprint of 13,232.8 m^2.

The total footprint required for the MPVS and BESS units totals 28,075.6 m^2. The total project area prescribed for the BESS and MVP footprint is 37,375 m^2 (299 m x 125 m).

The proposed BESS and MVP footprint exceeds the area required by 9,300 m^2; hence, the appropriate segregation measures are in place to prevent propagation.

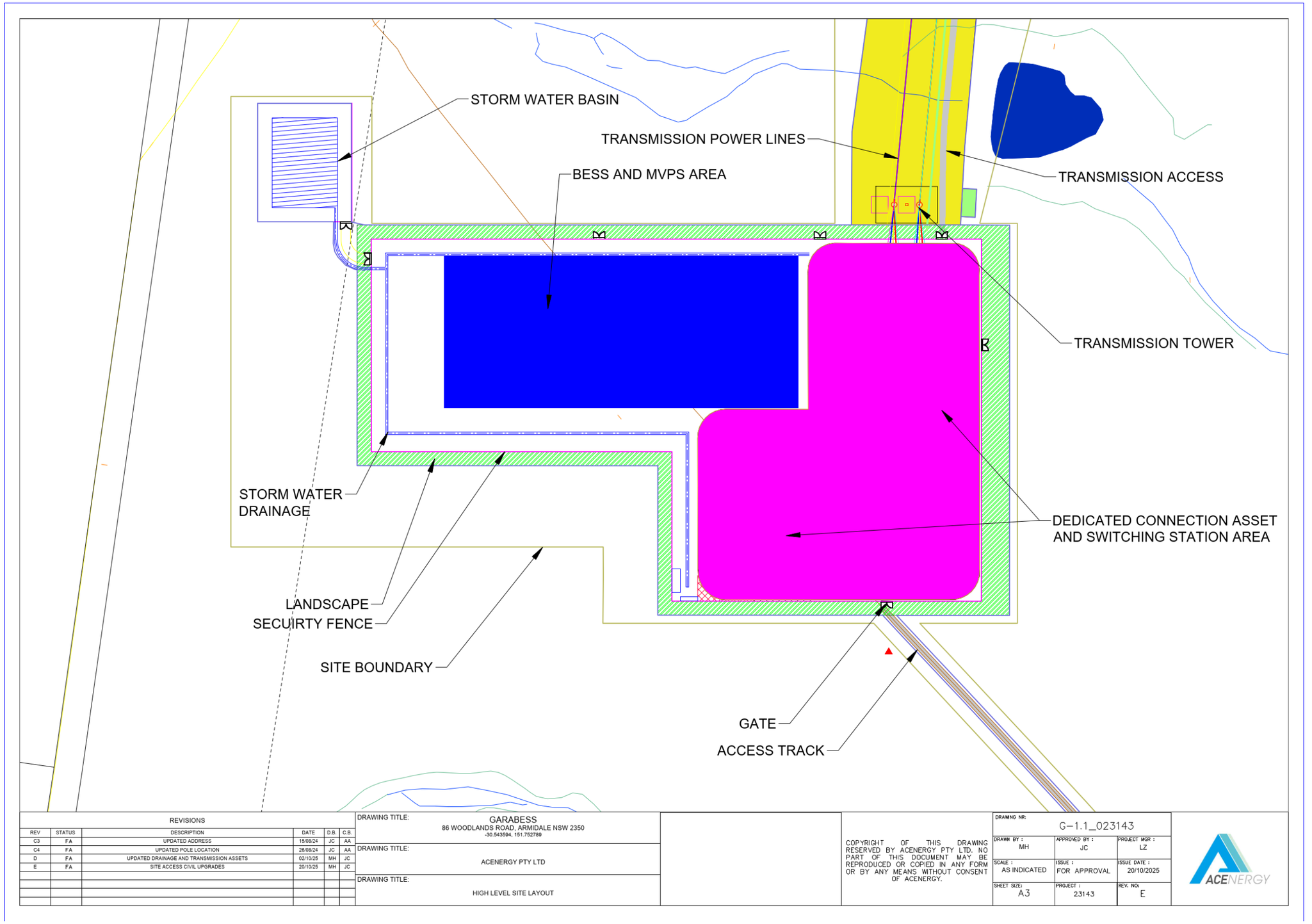
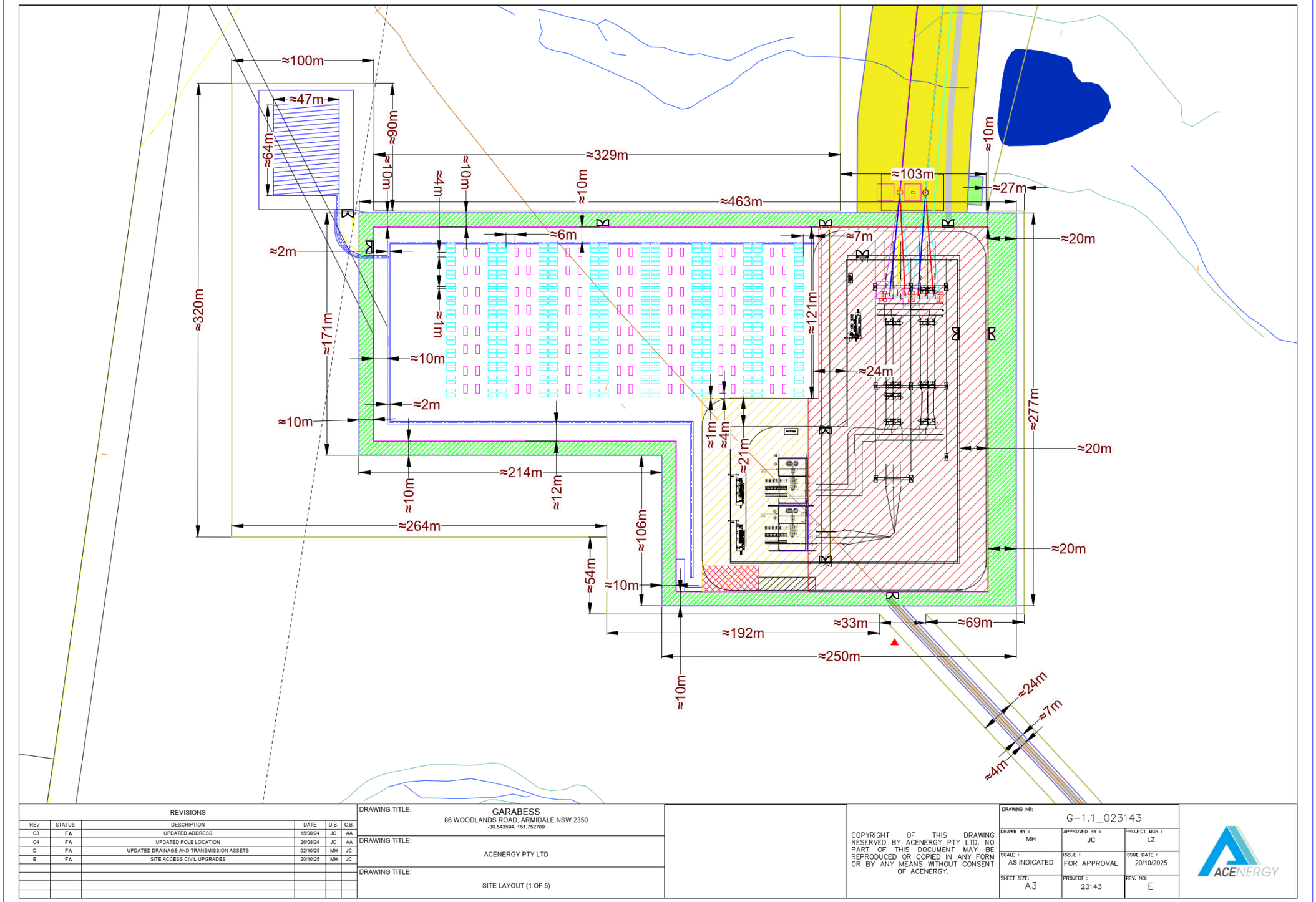


Figure 4-8: BESS Layout



REVISIONS					
REV	STATUS	DESCRIPTION	DATE	D.B.	C.B.
C3	FA	UPDATED ADDRESS	15/08/24	JC	AA
C4	FA	UPDATED POLE LOCATION	26/08/24	JC	AA
D	FA	UPDATED DRAINAGE AND TRANSMISSION ASSETS	02/10/25	MH	JC
E	FA	SITE ACCESS CIVIL UPGRADES	20/10/25	MH	JC

DRAWING TITLE: GARABESS
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-30.543594, 151.752789

DRAWING TITLE: ACENERGY PTY LTD

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DRAWING NR: G-1.1_023143		
DRAWN BY : MH	APPROVED BY : JC	PROJECT MGR : LZ
SCALE : AS INDICATED	ISSUE : FOR APPROVAL	ISSUE DATE : 20/10/2025
SHEET SIZE: A3	PROJECT : 23143	REV. NO: E

ACENERGY

Figure 4-9: BESS Dimensioned Layout

4.6.2 Separation Review

Multiple LFP battery products are assessed among limited options currently available in the Australian market, which meet the requirements of a utility application, containerized solution, and LFP chemistry at the same time. Their UL9540A unit-level test reports are assessed. A key takeaway message from the UL9540A test is the minimum required spacing between two battery units (racks) without propagating thermal runaway from one unit to another summarised in **Table 4-3**. This is then used to guide the separation distance requirement between BESS containers summarised in **Figure 4-9**.

Table 4-3: Minimum separation required between BESS Units

No.	Battery Manufacturer	Minimum Required Spacing Between Battery Units
1	Sungrow (Appendix M)	160mm
2	CATL (Appendix N)	10 mm
3	EVE POWER (Appendix O)	160 mm
4	Ruipu Energy (Appendix P)	160 mm

The CATL EnerX 0.25P requires a minimum separation of 0.9 m as outlined in **(Appendix E)**. As can be seen in **Figure 4-9**, the spacing utilised between two CATL EnerX 0.25P BESS units is 0.9 m end to end, 0.9 m back to back between clusters and 3 m between adjacent clusters and MVPS units which is far greater than the required spacing between LFP battery units. Therefore, the minimum proposed battery container separation distance for Gara BESS of clusters of 4 with back-to-back faces having a separation of 1 m, end-to-end faces and the front opening face will be separated by 3 m of each BESS unit cluster and MVPS clusters of 4, separated by 6m from long sides and 6.5 m from short ends and 9.5 m between each cluster is considered appropriate based on a generic analysis.

Based upon the designs incorporated with the container based upon the VBB fire, the available area assessment and the separation distance assessment, it is considered that the propagation between two units is unlikely; hence, this incident has not been carried forward for further analysis.

4.7 Li-ion Battery Fire and Toxic Gas Dispersion

If a BESS failure occurs resulting in a fire, toxic by-products of combustion may form. A literature review was conducted on lithium-ion battery fires to identify the toxic gases that may be generated in the event of a fire. The review identified the following gases or classes of gases that can form:

- Carbon dioxide;
- Carbon monoxide; and
- Fluorine gases.

Each of these has been discussed in further detail in the following subsections.

4.7.1 Carbon Dioxide

Carbon dioxide is a colourless, odourless, dense gas that is naturally forming and is present in the atmosphere at concentrations around 415 ppm (0.0415%). At low concentrations, carbon dioxide is physiologically impotent and at low concentrations does not appear to have any toxicological

effects. However, as the concentration grows it increases the respiration rate with short-term Exposure Limit (STEL) occurring at 30,000 ppm (3%), above 50,000 ppm (5%) a strong respiration effect is observed along with dizziness, confusion, headaches, and shortness of breath. Concentrations in excess of 100,000 ppm (10%) may result in coma or death.

Carbon dioxide is a by-product of combustion where hydrocarbon or carbon-based materials are involved. A typical combustion reaction producing carbon from a hydrocarbon has been provided in **Equation 4-1**. This reaction proceeds when there is an excess of oxygen in the fuel being consumed and is known as complete combustion as it is the most efficient reaction pathway.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3Co_2(g) + 4H_2O(g) \qquad \textbf{Equation 4-1}$$

The lithium-ion batteries are predominantly composed of metal structures. However, during a fire event ancillary equipment and materials within the batteries will be involved in the fire including wiring, plastics, anodes, etc. which will liberate carbon dioxide. However, a review of the toxicological impacts indicates high concentrations would be required to result in injury or fatality. Based upon a review of the sensitive areas, and the similar BESS fires (i.e. Victoria BESS fire), it is not considered that the formation of carbon dioxide in a fire would be sufficient to result in downwind impacts sufficient to cause injury or fatality. In other words, there would be insufficient production of carbon dioxide to generate a plume of sufficient concentration to displace the required oxygen for a significant downwind consequence to occur. Therefore, this incident has not been carried forward for further analysis.

4.7.2 Carbon Monoxide

Carbon monoxide is an odourless, colourless gas that is slightly denser than air and occurs naturally in the atmosphere at concentrations around 80 ppb. Carbon monoxide is a toxic gas as it irreversibly binds with haemoglobin which prevents these molecules from carrying out the function of oxygen / carbon dioxide exchange. The loss of 50% of the haemoglobin may result in seizures, coma or death which can occur at concentration exposures of approximately 600 ppm (0.06%).

Carbon monoxide is by-product of combustion if there is insufficient oxygen to enable complete combustion. The reaction pathway for the formation of carbon monoxide is provided in **Equation 4-2**.

$$2C_3H_8(g) + 7O_2(g) \rightarrow 6CO(g) + 8H_2O(g) \qquad \textbf{Equation 4-2}$$

As noted, in **Section 4.7.1** there is the potential for a fire to occur with the BESS units which could form carbon monoxide if there is insufficient oxygen to sustain complete combustion. However, it is noted that the combustible load within the BESS which could result in the formation of carbon monoxide is relatively low compared to the available oxygen in the surrounding atmosphere. Therefore, it is considered that the formation of carbon monoxide at levels that would result in a substantial downwind impact is not considered credible and subsequent analysis of, this incident is not required.

4.7.3 Fluoride Gases

The electrolyte used in Li-ion batteries typically is lithium hexafluorophosphate ($LiPF_6$) or other li-salts containing fluorine. In the event of a thermal runaway, the electrolyte will expand and be vented from the battery. In the event of a fire, the vented gas and other components such as the polyvinylidene fluoride binders may form gases such as hydrogen fluoride (HF), phosphorous pentafluoride (PF_5) and phosphoryl fluoride (POF_3) (Ref. [6]).

The decomposition of $LiPF_6$ can be promoted by the presence of water / humidity according to reactions **Equation 4-3** to **Equation 4-5**.

$$LiPF_6 \rightarrow LiF + PF_5 \qquad \textbf{Equation 4-3}$$

$$PF_5 + H_2O \rightarrow POF_3 + 2HF \qquad \textbf{Equation 4-4}$$

$$LiPF_6 + H_2O \rightarrow LiF + POF_3 + 2HF \qquad \textbf{Equation 4-5}$$

Of the fluorine gases formed, PF_5 is a short-lived gas while POF_3 is a reactive intermediate. Thermal destruction of several battery chemistry, configurations and State of Charge (SOC) indicated the vast majority of these did not produce observable POF_3 with the only observance occurring in a specific battery chemistry at 0% SOC (Ref. [6]). Therefore, the main fluorine gas of concern in a Li-ion battery fire is HF.

HF gas is hydroscopic readily dissolving into water vapour / humidity or moisture in airways forming hydrofluoric acid. Hydrofluoric acid is a weak acid although is highly corrosive and may result in chemical burns. In addition, it is calcium scavenging. Hence, it will readily bind with calcium in cells and tissues disrupting the nerve signalling. The immediate danger to life or Health (IDLH) for HF is 30 ppm and the 10-minute lethal concentration is 170 ppm.

For a toxic gas dispersion, a battery container fire is necessary as the initiating event. As discussed in **Section 4.4** the potential for a fire to occur is considered negligible due to the highly stable and safe battery chemistries used. As the potential for the initiating event is considered unlikely, this incident has not been carried forward for further analysis.

4.8 Electrical Equipment Failure and Fire

Electrical equipment is located within the switch room which may fail resulting in overheating, arcing, etc. which could initiate a fire. In the event of a fire, it may begin to propagate to adjacent combustible materials (i.e. wiring). It is noted that electrical equipment fires typically start by smouldering before flame ignition occurs resulting in a slow fire development.

The type of equipment used within the Project is ubiquitous throughout the world and across industry segments and is therefore not a unique fire scenario. Based upon fire development within switch rooms the fire would be considered to be relatively slow in growth and would be unlikely to result in substantial impacts in terms of offsite impact or incident propagation. Therefore, this incident has not been carried forward for further analysis.

4.9 Transformer Internal Arcing, Oil Spill, Ignition and Bund Fire

Transformers contain oil which is used to insulate the transformers during operation. If arcing occurs within the transformer (e.g. due to a low oil level), the high energy passing through the coolant vaporises the oil into light hydrocarbons (methane, ethane, acetylene, etc.) resulting in rapid pressurisation within the reservoir.

Notwithstanding the protection systems, if the pressure rise exceeds the structural integrity of the reservoir, and the installed pressure relief devices, the reservoir can rupture allowing the release of oil into the bund. The rupture also allows oxygen to enter the reservoir. The temperature of the gases is above the auto ignition point, but this does not occur until oxygen is present. When oxygen enters the reservoir, the gases auto-ignite which generates sufficient heat to ignite the oil in the bund.

Notwithstanding this, transformers are ubiquitous units with a low potential for failure and the separation distance to the site boundary and other adjacent units would be unlikely to result in incident propagation and offsite impacts. Therefore, this incident has not been carried forward for further analysis.

4.10 Transformer Electrical Surge Protection Failure and Explosion

Transformers generate large amounts of heat as a result of the high electrical currents that pass through them; hence, oil is used as an insulating material within the transformers to protect the mechanical components. However, if the transformer gets an extreme surge of energy, such as that which could occur due to a lightning strike, and the electrical surge protection measures fail, the mineral oil may start to decompose and vapourise, resulting in gas bubbles of hydrogen and methane (Ref. [7]) as temperatures above the autoignition of the gases.

The formation of gases will increase the pressure within the transformer which can result in the transformer structure rupturing which allows the ingress of oxygen. As the oxygen enters, the concentration of flammable gases falls within the explosive limits which are above their autoignition temperatures which ignite resulting in increased formation of hot gaseous products resulting in an explosion. The explosion may generate significant overpressure, sparks and fire and would result in a whole transformer fire, as discussed in **Section 4.9**.

In order to protect against overheating and explosions, transformers generally have surge protection devices which shunt electrical surges safely to ground. However, this surge detection and protection devices are not universally installed, nor do they protect against all events such as in the case of a major lightning strike or significant oil deterioration, leakage of water into the transformer, and physical damage such as a fallen tree (Ref. [8]). Therefore, there is the potential for an explosion to occur which may result in offsite impacts; however, as previously noted, these units are ubiquitous and have a low potential for failure. Therefore, this incident has not been carried forward for further analysis.

4.11 Electromagnetic Field Impacts

4.11.1 Introduction

Electric and Magnetic Fields (EMFs) are associated with a wide range of sources and occur both naturally as well as man-made. Naturally occurring EMFs, occurring during lightning storms, are generated from Earth's magnetic field. Man-made EMFs are present wherever there is electricity; hence, EMFs are present in almost all built environments where electricity is used.

Extremely low frequency (ELF) electric and magnetic fields (EMF) occupy the lower part of the electromagnetic spectrum in the frequency range 0-3,000 Hz which is the current will change direction 0-3,000 times a second. ELF EMF result from electrically charged particles. Artificial sources are the dominant sources of ELF EMF and are usually associated with the generation, distribution and use of electricity at the frequency of 50 Hz in Australia. The electric field is produced by the voltage whereas the magnetic field is produced by the current.

BESS create EMFs from operational electrical equipment, such as transmission lines, transformers and the electrical components found within BESS units, inverters, etc. This equipment has the potential to produce ELF EMF's in the range of 30 to 300 Hz.

4.11.2 Existing Standards

There are currently no existing standards in Australia for governing the exposure limits to ELF EMFs; however, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has provided some guidelines around exposure limits for prolonged exposure which limits the exposure to 2,000 milligauss (mG) for members of the public in a 24 hour period (Ref. [9]).

Table 4-4 provides typical magnetic field measurements and ranges associated with EMF sources. It is noted that electric fields around devices are generally close to 0 due to the shielding provided around the equipment. In addition, EMF levels drop away quickly with distance; hence, while a value may be measurable at the source, within a short distance the EMF is undetectable.

Table 4-4: EMF Sources and Magnetic Field Strength

Source	Typical Measurement (mG)	Measurement Range (mG)
Television	1	0.2 – 2
Refrigerator	2	2 – 5
Kettle	3	2 – 10
Personal computer	5	2 – 20
Electric blanket	20	5 – 30
Hair dryer	25	10 – 70
Distribution powerline (under the line)	10	2 – 20
Transmission power line (under the line)	20	10 – 200
Edge of easement	10	2 – 50

4.11.3 Exposure Discussion

A review of the site indicates there are no immediate residences adjacent to the area where the BESS will be developed providing substantial distance for attenuation of EMFs. Based upon the typical levels which may be generated by transmission equipment the cumulative effect would not exceed the 2,000 mG limit for prolonged exposure. In addition, the closest residence is approximately over 400 m away from the EMF generating sources at the BESS; hence, the potential for the EMF to exceed the accepted levels is considered negligible.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) advises that the strength of radiation decreases exponentially with distance from the source, and it will become indistinguishable from background radiation within 50 m of a high voltage power line and within 5 to 10 m of a substation. (Ref. [10]).

A field study was undertaken to characterise the EMF between the frequencies of 0 – 3 GHz at two large scale solar facilities operated by the Southern California Edison Company in Porterville and San Bernardino, (Ref. [11]).

The field study findings were adopted to estimate the EMF measurements for the project. The findings are as follows:

- The highest DC magnetic fields were measured adjacent to the inverter (277 µT) and transformer (258 µT). These fields were lower than the ICNIRP's occupational exposure limit.
- The highest AC magnetic fields were measured adjacent to the inverter (110 µT) and transformer (177 µT). These fields were lower than the ICNIRP's occupational exposure limit.

- The strength of the magnetic field attenuated rapidly with distance (i.e. within 2-3 metres away, the fields drop to background levels).
- Electric fields were negligible to non-detectable. This is mostly likely attributed to the enclosures provided for the electricity-generating equipment.

As the strengths of EMF attenuate rapidly with distance, the ICNIRP reference level for exposure to the general public will not be exceeded and the impact to the general public in surrounding land uses is negligible.

As the potential for exposure to EMF exceeding the international guidelines is negligible, this incident has not been carried forward for further analysis.

5.0 Conclusion and Recommendations

5.1 Conclusions

A hazard identification table was developed for the Gara BESS project to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with the potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

A review of the incidents carried forward for further analysis indicates that there were no observed offsite impacts; therefore, based on the analysis conducted, it is concluded that the risks at the site boundary are not considered to exceed the acceptable risk criteria; hence, the project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site. It must be noted that the required bushfire assessment is provided under separate cover.

5.2 Recommendations

The following recommendations have been made as a result of the assessment:

- End-to-end spacing (short side) of BESS containerised units shall be a minimum of 3 m between BESS clusters and 0.9 m between BESS units within the cluster.
- Back-to-back spacing (long side) of BESS containerised units shall be no less than 0.9 m for the CATL BESS units selected for this study.
- Front to front spacing is to be no less than 3 m the CATL BESS units selected for this study.
- BESS separation and spacing are to be specific to BESS the selected.
- The BESS containerised units shall be provided with the fire protection system specified by the BESS manufacturer.
- The active ventilation vents shall not be located above battery packs within the BESS container.
- The vent covers of the BESS shall be constructed of non-combustible material.
- Prior to commissioning, the UL test data for the selected battery units shall be made available to the DPHI.

6.0 References

[1] Department of Planning, Industry and Environment, “Hazardous Industry Planning Advisory Paper No. 4 - Risk Criteria for Land Use Safety Planning,” Department of Planning, Industry and Environment, Sydney, 2011.

[2] Department of Planning, Industry and Environment, “Hazardous Industry Planning Advisory Paper No. 6 - Guidelines for Hazard Analysis,” Department of Planning, Industry and Environment, Sydney, 2011.

[3] Department of Planning, Industry and Environment, Multi-Level Risk Assessment, Sydney: Department of Planning, Industry and Environment, 2011.

[4] National Transport Commission (NTC), “Australian Code for the Transport of Dangerous Goods by Road & Rail, 7th Edition,” 2011.

[5] Power Tech Systems, “Safety of Lithium-Ion batteries,” Power Tech Systems, 2022. [Online]. Available: https://www.powertechsystems.eu/home/tech-corner/safety-of-lithium-ion-batteries/. [Accessed 13 April 2022].

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[7] J. Demos, “What Causes Transformer Explosions and Burns?,” Durabarrier USA Fire Barrier Experts, 26 July 2021. [Online]. [Accessed 2 February 2022].

[8] P. Hoole, S. Rufus, N. Hashim, M. Saad, S. Abdullah, A. Othman, K. Piralaharan, A. CV and S. Hoole, “Power Transformer Fire and Explosion: Causes and Control,” *International Journal of Control Theory and Applications,* vol. 10, no. 16, pp. 211-219, 2017.

[9] International Commission on Non-Ionizing Radiation Protection, “ICNIRP Guideline for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1-100 Hz),” International Commission on Non-Ionizing Radiation Protection, 2010.

[10] EMM Consulting, “Planning Permit Application - Mornington Battery Energy Storage System,” Maoneng Australia Pty Ltd, Sydney, 2021.

[11] R. A. Tell, H. C. Hooper, G. G. Sias, G. Mezei, P. Hung and R. Kavet, “Electromagentic Fields Associated with Commercial Solar Photovoltaic Electric Power Generating Facilities,” *Journal of occupational and environmental hygiene,* vol. 12, no. 11, pp. 796-803, 2015.

[12] Standards Australia, “AS/NZS 3000:2007 - Wiring Rules,” Standards Australia, Sydney, 2007.

Appendix A

Hazard Identification Table

A1. Hazard Identification Table

Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
Battery Storage	• Failure of Li-ion battery protection systems	• Thermal runaway resulting in fire or explosion • Incident propagation through battery cells • Toxic smoke dispersion	• Batteries are tested by the manufacturer prior to sale / installation • Overcharging and electrical circuit protection • Battery monitoring systems • Batteries composed of subcomponents (i.e. BBU, cells) reducing risk of substantial component failure • Batteries are not located in areas where damage could easily occur (i.e. within the fenced property) • Electrical systems designed per AS/NZS 3000:2007 (Ref. [12]) • Acoustic barriers
Switch rooms, communications, etc.	• Arcing, overheating, sparking, etc. of electrical systems	• Ignition of processors and other combustible material within servers and subsequent fire	• Fires tend to smoulder rather than burn • Isolated location • Switch room separation from other sources of fire
Substation	• Arcing within transformer, vaporisation of oil and rupture of oil reservoir	• Transformer oil spill into bund and bund fire	• Bunded • Isolated location
	• Power surge to transformers (e.g. from lightning)	• Major failure of surge protection in transformer, vapourisation of mineral oil, ignition and explosion	• Transformers have surge protection system to shut down upon detection of extreme energy input • Lightning protection to prevent lightning strikes impacting transformers • Control of ignition sources – no smoking / open flames around the transformers
EMF	• Electric and magnetic equipment	• Generation of ELF EMF and injury / nuisance to surrounding area	• Large separation distances allow for attenuation of EMFs • Cumulative impacts from equipment below acceptable thresholds. • Low occupancy density within vicinity of the development

Appendix B

UL9540 Test Report

TEST REPORT
ANSI/CAN/UL 9540
TÜV SÜD Test Program for
Energy Storage Systems and Equipment

Report No.:	64.290.24.30249.01
Date of issue:	2024-09-10
Project handler:	Vincent Liang
Name of Testing Laboratory preparing the Report: Address:	TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch 5F&8F East, Communication Building, No.163 Pingyun Road, Huangpu Ave. West, Guangzhou 510656, China
Client: Client number: Address: Contact person:	Contemporary Amperex Technology Co., Limited 004951 No.2 Xingang Road, Zhangwan Town, Jiaocheng District, 352100 Ningde, Fujian, PEOPLE'S REPUBLIC OF CHINA Shirley Chen
Standard:	This TÜV SÜD test report form is based on the following requirements: ANSI/CAN/UL 9540:2023(ed.3), Rev.00
TRF number and revision:	TRF ANSI/CAN/UL 9540:2023 (ed.3), Rev.00
eDoc_ID:	-
TRF originated by:	TÜV SÜD Certification and Testing (China) Co., Ltd., Guangzhou Branch, Mr. Billy Qiu
Copyright blank test report:	This test report is based on the content of the standard (see above). The test report considered selected clauses of the a.m. standard(s) and experience gained with product testing. It was prepared by TÜV SÜD Product Service. TÜV SÜD Group takes no responsibility for and will not assume liability for damages resulting from the reader's interpretation of the reproduced material due to its placement and context.
General disclaimer:	This test report may only be quoted in full. Any use for advertising purposes must be granted in writing. This report is the result of a single examination of the object in question and is not generally applicable evaluation of the quality of other products in regular production.
Scheme:	☒ TUV Mark ☐ without certification ☐ GS Mark ☐ NRTL Mark ☐ SCC Mark ☐ EU-Directive
Non-standard test method: National deviations:	☒ No ☐ Yes, see details under *Summary of testing* N/A
Number of pages *(Report)*: Number of pages *(Attachments)*:	108 N/A

Tested by (name, function, signature):	Vincent Liang Vincent Liang (Project Handler)	Approved by (name, function, signature):	Lincoln Zhang Lincoln Zhang (Designated Reviewer)

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Test sample:	Energy storage system (Battery energy storage system)
Type of test object:	Energy storage system (Battery energy storage system)
Trademark:	CATL
Model and/ or type reference:	C06530P25L01
Rating(s):	Refer to rating table at page 6
Manufacturer:	Contemporary Amperex Technology Co., Limited
Manufacturer number:	004951
Address:	No.2 Xingang Road, Zhangwan Town, Jiaocheng District, 352100 Ningde, Fujian, PEOPLE'S REPUBLIC OF CHINA
Name and address of factory(ies) Factory name: Contemporary Amperex Technology Co., Limited Factory number: 004951 Address: No.2 Xingang Road, Zhangwan Town, Jiaocheng District, 352100 Ningde, Fujian, PEOPLE'S REPUBLIC OF CHINA	
Sub-contractors / tests (clause):	N/A
Name:	N/A
Order description:	☒ Complete test according to TRF
	☐ Partial test according to manufacturer's specifications
	☐ Preliminary test
	☐ Spot check
	☐ Others:
Date of order:	2024-02-19
Date of receipt of test item:	2024-02-19
Date(s) of performance of test:	2024-02-19 to 2024-09-02

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Test item particulars:	
Energy storage system (ESS) technologies.....:	☒ Electrochemical ☐ Chemical ☐ Mechanical ☐ Thermal
Installation.....:	☒ Non-residential ☐ Residential ☐ Indoor ☒ Outdoor ☐ Floor mounted ☐ Wall mounted ☐ Ground mounted ☐ Rooftop ☐ Open garage
Connection to the mains.....:	☐ Pluggable equipment ☐ Direct plug-in ☒ Permanent connection ☐ For building-in
Special enviromental rating.....:	☒ Moisture exposure ☐ Marine environments ☐ Seismic environments
Overvoltage category of Mains ..:	☐ OVC I ☐ OVC II ☒ OVC III (Considered in the final system) ☐ OVC IV
Overvoltage category of Energy Storage Mechanism.....:	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
Overvoltage category of Output Energy Conversion Mechanism.:	☐ OVC I ☐ OVC II ☒ OVC III (Considered in the final system) ☐ OVC IV
Overvoltage category of Auxiliary subsystem.....:	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
Mains supply tolerance (%).....:	±10%
Type of power systems.....:	IT system (Battery power circuit) TT or TN system (Auxiliary power circuit)
Class of equipment ..... :	☒ Class I ☐ Class II ☐ Class III ☐ Not classified
Mass of equipment (kg)..... :	Approx. 45000 kg
Pollution degree ..... :	PD3 (External), PD2 (Internal)
IP protection class..... :	IP55 (Battery Room) IP55 (Electrical Room) IP67 (Electrical Control Box of Chiller)

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Purpose of the product (description of intended use):

1. The Rechargeable Lithium-ion Battery System is the Battery Energy Storage System (BESS) which mainly consists of Electrochemical accumulation subsystem, Management subsystem, Auxiliary subsystem.
   - Electrochemical accumulation subsystem: The BESS include 4 Rechargeable Lithium-ion Battery Strings (certificated by UL 1973:2022) connected in parallel, each Rechargeable Lithium-ion Battery String is consisted of 1 high voltage controlling box and 8 Rechargeable Lithium-ion Battery modules connected in series.
   - Management subsystem: the MBMU is considered as the Energy management system.
   - Auxiliary subsystem includes heat/smoke/combustible gas detection system, fire suppression system, fire extinguisher, ventilation system, liquid cooled system, auxiliary power system and uninterruptible power supply.
2. The conditions for operation of Battery Energy Storage System is specified as below:
   - Outdoor.
   - Ambient temperature range: -35 °C to 55 °C.
   - Relative humidity range: 5 % - 95%.
   - Altitude ≤ 4000m (Only Clearance for insulation requirement for using at altitude up to 4000m is considered in this report.)
   - Overvoltage category: II (Battery side), III (PCS grid side considered in the final installation, max 800 V a.c., IT system), II (Auxiliary power supply side).
   - Environment pollution degree: less than or equal to 3.
3. Low voltage electrical installations shall comply with national and local regulation. The compatibility between PCS intended to be connected shall be verified for final use.
4. Only electrically skilled persons and electrically instructed persons with the proper authorization are permitted to install, operate, and maintain according to the user manual.
5. There are 2 optional constructions of the power supply in case of power outage occurred for Auxiliary subsystem (except for the liquid cooled system and fire system), management subsystem and low voltage circuit of Electrochemical accumulation subsystem is provided:
   1) Construction 1: UPS, supply to above systems from batteries of UPS
   2) Construction 2: Switching Power Supply 24V, supply to above systems from battery modules of Electrochemical accumulation subsystem.

   Above 2 optional constructions of the BESS are defined as the same model, refer to CDF and photo documentation for details. Different internal part numbers represented the products in the manufacture will be used to distinguish between the two BESS.

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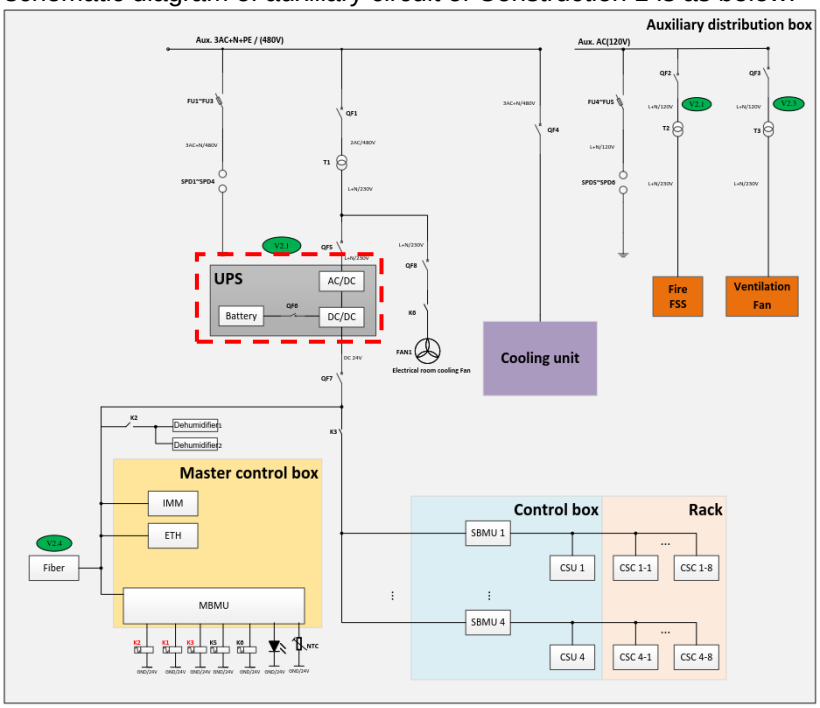
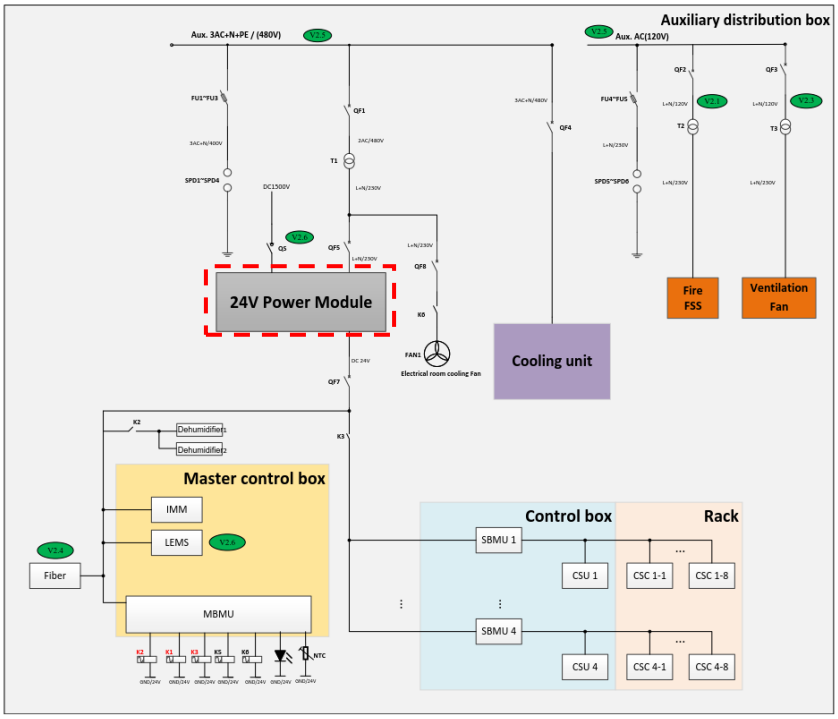
6. The electrical schematic diagram of auxiliary circuit of Construction 1 is as below:



The electrical schematic diagram of auxiliary circuit of Construction 2 is as below:



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Characteristic data (not shown on the marking plate*)*:

Model:	C06530P25L01
Rated energy [kWh]:	5644.29
Rated capacity [Ah]:	4240
Rated voltage [V d.c.]:	1331.2
Voltage range [V d.c.]:	1040 ~ 1500
Maximum continuous charging power [kW]:	1411.07
Maximum continuous charging current [A d.c.]:	1060
Maximum continuous discharging power [kW]:	1411.07
Maximum continuous discharging current [A d.c.]:	1060
Battery String parameters:	
Battery String model:	C06530P25L01-R
Battery type:	LFP
Battery module model:	M02530P25L01
Rated Energy [kWh]:	1411.07
Rated capacity [Ah]:	1060
Rated voltage [V d.c.]:	1331.2
Voltage range [V d.c.]:	1040 ~ 1500
Maximum continuous charging power [kW]:	352.77
Maximum continuous charging current [A d.c.]:	265
Maximum continuous discharging power [kW]:	352.77
Maximum continuous discharging current [A d.c.]:	265
Auxiliary power supply parameters:	
Maximum input power for AUX1 terminal [kW]:	34.5
Rated input voltage for AUX1 terminal [V a.c.]:	480, 3P/N/PE (for other systems)
Maximum input power for AUX2 terminal [kW]:	0.5
Rated input voltage for AUX2 terminal [V a.c.]:	120, L/N/PE (for fire system and ventilation system)
Rated input frequency [Hz]:	60
General	
Protective class:	I
Ingress protection rating:	IP55(Battery Cabinet) IP55(Electrical Cabinet) IP67(Electrical Control Box of Chiller)
Ambient temperature range [°C]:	-35 ~ 55

Attachments:

N/A

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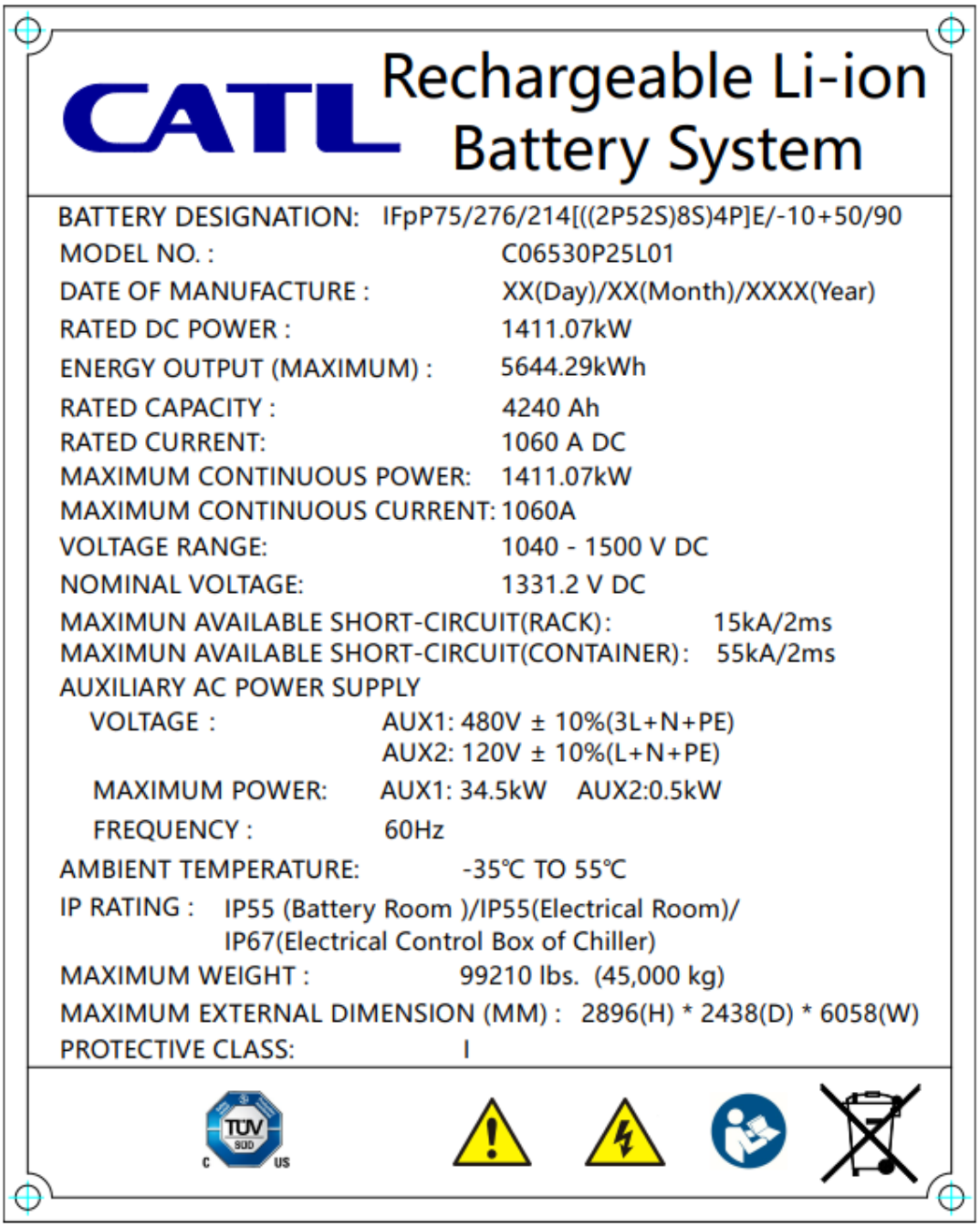
If additional information is necessary, please provide

N/A

Copy of marking plate:

The artwork below may be only a draft. The use of certification marks on a product must be authorized by the respective NCBs that own these marks.



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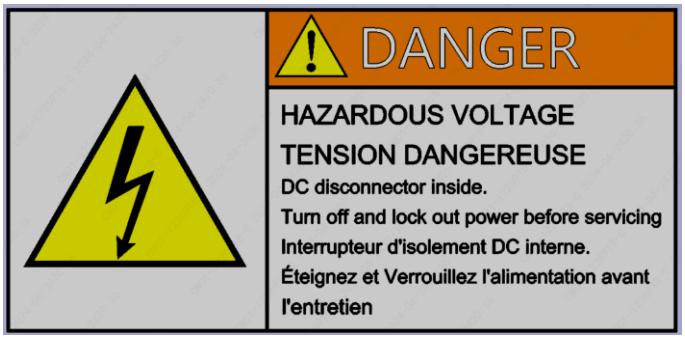
The Warning labels:

Warning for fuse replacement

Warning for multiple sources



Warning for hazard voltage

Warning for Isolating devices and disconnects

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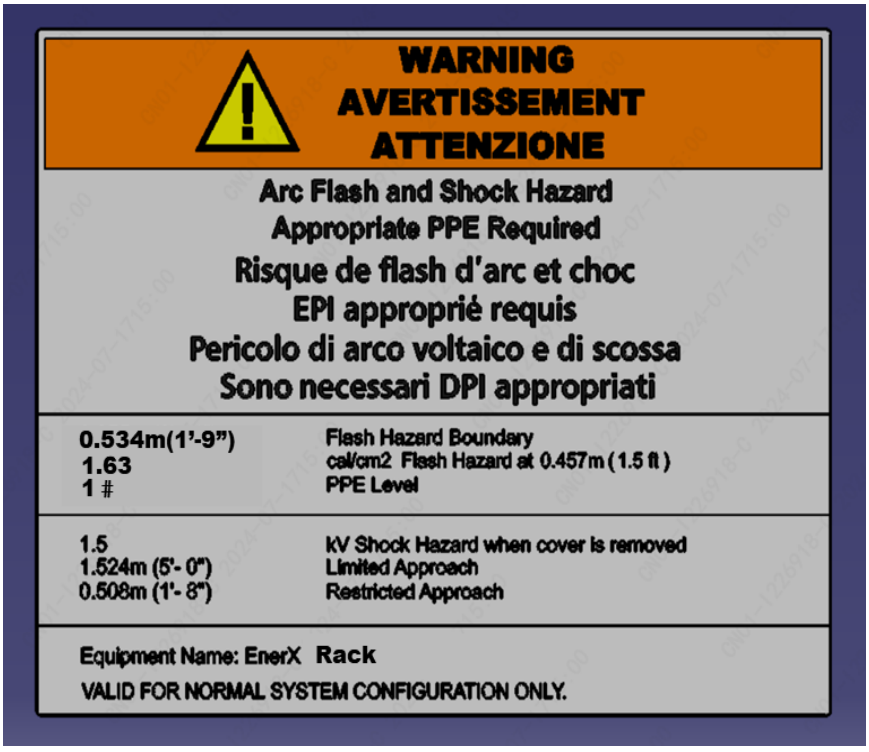
Warning labels:

Arc-flash warning label for BESS



Arc-flash warning label for battery string

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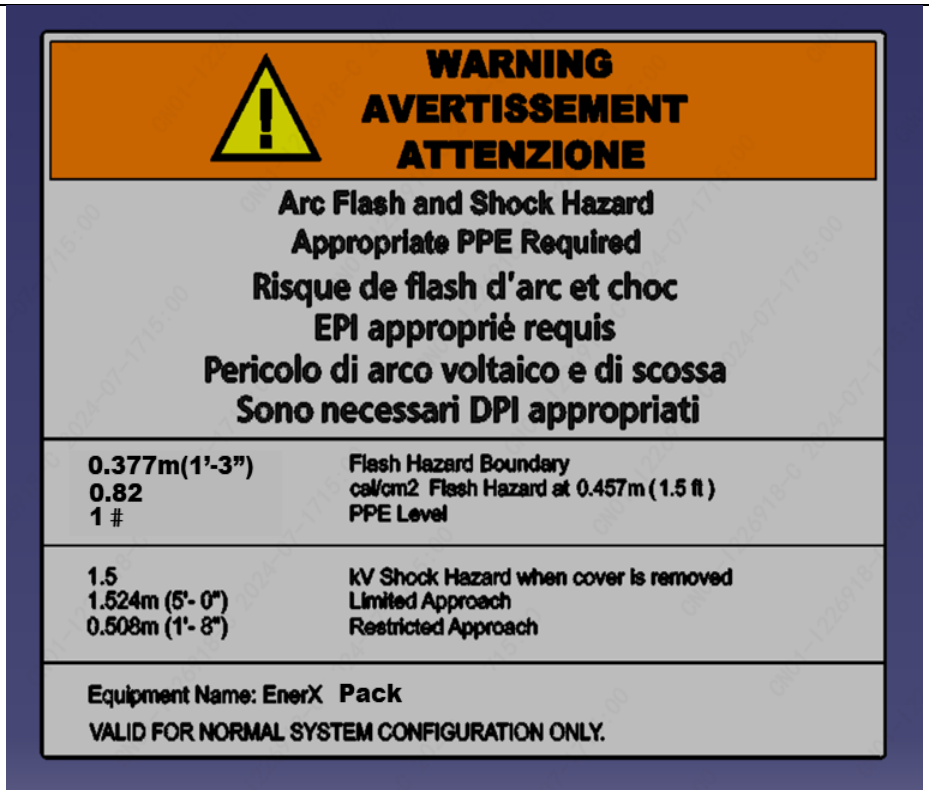

Arc-flash warning label for battery module

Pictures of the product:

See photo documentation.

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Summary of testing:

All tests were carried out according to ANSI/CAN/UL 9540:2023.

Tests performed (name of test and test clause):

ELECTRICAL TESTS	
30	Normal Operations Test
31	Abnormal Operation Tests for Thermal Energy Storage Systems
32	Dielectric Voltage Withstand Test
33	Impulse Test
34	Equipment Grounding and Bonding Test
35	Insulation Resistance Test
36	Electromagnetic Immunity Tests
MECHANICAL TESTS	
39.2	Pneumatic strength test
Environmental test	
41.2	Outdoors installations subject to moisture exposure
41.3	Outdoor installation in marine environments

Testing location:

TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch

B1F&2F of A4, D1 Buildings, No. 63 Chuangqi Road, Shilou Town, Panyu District, Guangzhou 511447, China

☐ deviation(s) found

☒ no deviations found

The product fulfils the requirements of: ☒ ANSI/CAN/UL 9540:2023

☐ **Additional information on non-standard test method(s)**

Sub clause: N/A

Page: N/A

Rational: N/A

Possible test case verdicts:

test case does not apply to the test object: N/A (not applicable / not included in the order)

test object does meet the requirement: P (Pass)

test object does not meet the requirement: F (Fail)

General remarks:

"(see remark #)" refers to a remark 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.

The test results presented in this report relate only to the object tested.

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ANSI/CAN UL 9540			
Clause	Requirement + Test	Result – Remark	Verdict

INTRODUCTION

1	**Scope**		/
2	**Components**		P
2.1	A component or equipment of an energy storage system covered by this standard shall comply with the safety requirements for that component or equipment. See Appendix A for a list of standards covering components generally used in the energy storage systems covered by this standard. Components and equipment shall comply with the CSA and/or UL standards as appropriate for the country or countries where the energy storage system is to be installed.	See CDF	P
3	**Units of Measurement**		/
4	**Undated References**		/
5	**Normative References**		/
6	**Glossary**		/

CONSTRUCTION

7	**Non-Metallic Materials**		P
7.1	Polymeric materials employed for enclosures, or parts of enclosures for ESS shall comply with (a) and (b) below:	Metal enclosure	N/A
	a) The enclosure requirements outlined in UL 746C, Path III of the Enclosure Requirements, or CSA C22.2 No. 0.17; and		N/A
	b) For BESS, the enclosure shall be evaluated to UL 9540A Unit Level testing and meet the unit level performance criteria.		N/A
	Exception: Equipment of a multi-part ESS that complies with the enclosure requirements in the appropriate standard for that equipment is not required to comply if the equipment enclosure is determined suitable for the intended environmental conditions that the ESS will be exposed to.		N/A
7.2	The following factors in (a) – (e) shall be taken into consideration when an enclosure employing nonmetallic materials is being judged. For a nonmetallic enclosure, all of		N/A

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ANSI/CAN UL 9540			
Clause	Requirement + Test	Result – Remark	Verdict
	these factors are to be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief test. Suitability to factors (a) – (e) below shall be determined by the tests of this standard or UL 746C, or the enclosure tests of critical component standards such as UL 1973 or UL 1971, if the enclosure for the critical component is covered under that standard.		
	a) Resistance to impact; b) Crush resistance; c) Abnormal operations; d) Severe conditions; and e) Mold-stress relief distortion.		N/A
7.3	In addition to the items in 7.2, polymeric enclosures shall have the following properties:		N/A
	a) Minimum 5 VA flame rating, or the enclosure complies with the 127 mm (5 inch) Flame test of UL 746C, and for large surface areas having for any single unbroken section, a projected surface area greater than 0.93 m^2 (10 ft^2) or a single linear dimension greater than 1.83 m (6 ft) require flame spread testing per the Enclosure Flammability – Large Surface Area Considerations test of UL 746C;		N/A
	b) Insulation material properties per the Material Property Considerations table of UL 746C;		N/A
	c) Compliance with the Strain-Relief Test after Mold Stress-Relief Distortion of UL 746C if serving as a securement means for a strain relief;		N/A
	d) Compliance with the Ultraviolet Light Exposure test of UL 746C if exposed to UV rays in the end use;		N/A
	e) Compliance with the Water Exposure and Immersion test of UL 746C if exposed to rain in the end use; and		N/A
	f) Compliance with the Conduit Connections in the Enclosure Requirements table of UL 746C if mounting conduit connections.		N/A
7.4	The requirements in 7.3 do not apply to a nonmetallic part that forms part of the enclosure under any one of the following		P

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ANSI/CAN UL 9540			
Clause	Requirement + Test	Result – Remark	Verdict
	conditions in accordance with UL 94 or CSA C22.2 No. 0.17:		
	a) The part covers an opening that has no dimension greater than 25.4 mm (1 in) and the part is made of a material Classed as V-0, V-1, V-2, or HB;		N/A
	b) The part is made of a material Classed V-0, V-1, V-2, or HB and covers an opening which does not give access to the user, when the part is removed, to live parts involving a risk of fire, electric shock, or electric energy-high current levels or moving parts;		N/A
	c) The part covers an opening that has no dimension greater than 101.6 mm (4 in) and the part is made of a material Classed as V-0, V-1, V-2, or HB, and there is no source of a risk of fire closer than 101.6 mm (4 in) from the surface of the enclosure; or		N/A
	d) The part is made of a material Classed V-0, V-1, V-2, or HB and there is a barrier or a device that forms a barrier made of a material Classed V-0 between the part and a source of a risk of fire.		P
	Exception: A part of a component is not required to be Classed V-0, V-1, V-2, or HB when it complies with the flammability requirements applicable to the component.		N/A
7.5	Materials employed as electrical insulation in the ESS shall be resistant to deterioration that would result in an electrical shock, fire or other safety hazard. Insulation materials that are in direct contact with or close proximity to hazardous live parts in accordance with Figure 6.1 of the Material Property Considerations table in UL 746C or CAN/CSA-C22.2 No. 0.17, shall additionally meet the insulation criteria outlined in either standard unless employed as part of a component that has been evaluated to a component standard that has comparable safety criteria. Insulated wiring is subjected to the requirements outlined in Section 11.		P
	Exception: As an alternative, polymeric materials used to support live parts shall comply with the Control of Fire Spread in PS2 Circuits requirements or the Control of Fire Spread in a PS3 Circuit requirements in UL		N/A

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	62368-1/CSA C22.2 No. 62368-1, Clauses 6.4.5 or Clause 6.4.6 as applicable.		
7.6	Gaskets and Seals relied upon for safety, shall be determined suitable for the environmental conditions and chemical substances they are anticipated to be exposed to in their end use.		P
7.7	Compliance with 7.6 for gaskets and seals relied upon to prevent ingress of moisture into the enclosure, can either comply with the Gaskets Tests Clause of UL 50E/CSA C22.2 No. 94.2 or comply with UL 157 or ASTM D412 for the anticipated exposures.		P
8	**Metallic Enclosures and Parts Resistance to Corrosion**		P
8.1	Metallic enclosure parts for BESS shall be of non-combustible materials as defined in this Standard		P
	Exception: Metallic enclosures of BESS that do not meet the definition of non-combustible, shall be evaluated to UL 9540A Unit Level testing and meet the performance level criteria for the unit level test.		N/A
8.2	Metallic enclosure parts that provide physical protection to ESS components, or prevent access to hazardous ESS components shall have sufficient strength to provide physical protection and shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion resistance can be found in UL 50E or CSA C22.2 No. 94.2. Metallic enclosures of parts of a multi-part ESS that meet the enclosure requirements of their component standard such as UL 1741 and UL 1973 are considered to comply with these requirements without further evaluation.		P
8.3	Conductive parts with dissimilar metals in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Figure F.1 of Appendix F shall be avoided. Use of coatings to prevent corrosion such as silver are methods to meet this requirement.	The final installation for the external on-site wiring shall in accordance with requirements.	P
9	**Enclosures and Guarding of Hazardous Parts**		P
9.1	The enclosure(s) of an ESS shall have the strength and rigidity required to resist the possible physical abuses that it will be	Comply with IEC 62477-1	P

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	exposed to during its transportation, installation and intended use. The enclosure strength shall be determined and specified to demonstrate compliance. The enclosure strength requirements outlined in UL 50, UL 1741, IEC 62477-1, UL 2755, ISO 1496-1 or equivalent standard shall be applied to demonstrate compliance.		
	Exception: For smaller systems that are less than or equal to 50 kWh, the enclosure strength may be evaluated to the enclosure requirements of this Standard and tested in accordance with the applicable tests of Section 40.	Greater than 50 kWh	N/A
9.2	Rack assemblies complying with UL 2416 are a means to meet this criteria for internal support structures of the ESS if the assembly is used within its load ratings. See also 10.2 regarding walk-in units and modifications to load bearing walls.	Not walk-in units	N/A
9.3	Openings in the enclosure of an ESS shall be designed to prevent inadvertent access to hazardous parts. Compliance shall be determined in accordance with the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, Clause 12 of IEC 60529 or CAN/CSA-C22.2 No. 60529, for a minimum IP rating of IP2X and CSA C22.1, the Enclosure Selection Table for Nonhazardous Locations, with consideration of the end use installation.	IP55 (Battery Cabinet) IP55 (Electrical Cabinet) IP67 (Electrical Control Box of Chiller)	P
	Exception: An ESS intended for restricted access locations need not meet the accessibility criterion if permanent warning markings for service and other personnel having access to the system are provided directly on the system. Protection from access to hazardous live parts in restricted locations shall be in accordance with Article 110 of NFPA 70, or Sections 2 and 36 of the CSA C22.1, or Section 124 of IEEE C2, as applicable. Suitable cautionary warnings and signage for identifying exposed hazardous voltage circuits shall be provided for protection of service personnel.		N/A
9.4	In service access areas, bare parts of hazardous voltage circuits, shall be located or guarded so that accidental shorting across circuits at opposite polarity, to ground, to		P

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	SELV circuits or communications circuits, that could be caused by items such as, but not limited to, tools or test probes used by service personnel, is unlikely.		
9.5	Enclosures of systems and components of systems located where they will be subject to exposure to water and other elements shall be rated for the level of intended exposure as outlined in Table 110.28 of Article 110 of NFPA 70, or Section 2 of CSA C22.1 or for the ingress protection rating of IPX3 or higher as outlined in IEC 60529 or CSA C22.2 No. 60529 if using as IP rating. Installation instructions shall indicate restrictions with regard to limiting ingress from the environment based upon the enclosure rating.	IP55 (Battery Cabinet) IP55 (Electrical Cabinet) IP67 (Electrical Control Box of Chiller)	P
10	**General Electrical Safety of Systems and Additional Requirements for Walk-in Units**		N/A
10.1	The instructions shall include measures and procedures for worker safety in, on and adjacent to the ESS according to NFPA 70E and CSA Z462, and Section 2 of CSA C22.1, and in accordance with this standard.		N/A
10.2	Walk-in unit enclosures shall have suitable mechanical load ratings for equipment installed within the enclosure, including maximum number of persons who may enter the enclosure when all of the equipment is installed.		N/A
10.3	Shipping container type enclosures with cutouts or other modifications to support walls that may affect their load bearing performance shall be re-evaluated to ASTM D4169 for ability to handle the intended loads post modification.		N/A
10.4	The enclosures for outdoor walk-in units shall not exceed 16.2 × 2.6 × 2.9-m (53 × 8.5 × 9.5-ft) high, not including HVAC and related equipment that may be secured to the exterior of the enclosure. A walk-in enclosure exceeding these dimensions are subjected to indoor installation criteria in accordance with the applicable codes.		N/A
10.5	If the walk-in unit is provided with an explosion venting system, it shall comply with the applicable requirements in 24.5.		N/A
10.6	Where persons can access the hazardous areas within a walk-in unit, procedures for		N/A

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	safe entry into and exiting the system shall be provided in the instructions provided with the ESS. Means, such as, but not limited to a placard(s) and lock(s), shall be provided to prevent unauthorized persons from entering these hazardous areas. See 46.17.		
10.7	Personnel doors of walk-in units shall be designed to prevent persons from becoming trapped within the unit and shall be able to be opened from the inside without use of a tool or key. Door(s) intended for entrance to, and egress from a walk-in unit, shall open in the direction of egress and provide a clear width of at least 80 cm (32 in) and clear height of at least 183 cm (72 in) based on the dimensions specified in the ICC IBC. Each egress door shall be marked in accordance with 45.19 and the line-of-sight to an exit sign shall not be interrupted. Any doorway or passage that might be mistaken for an exit shall be marked in accordance with 45.19 or with an indication of its actual use. See also 45.18.		N/A
10.8	Work space dimensions and requirements within an ESS, provided with walk-in enclosures, shall be in accordance with NFPA 70, or CSA C22.1, or in accordance with IEEE C2 as applicable to where the system is installed. The space requirement shall also provide for appropriate arc flash safety under specified personal protective equipment (PPE). See 45.13.		N/A
10.9	Areas of access to walk-in units shall be designed to prevent tripping, slipping or falling when persons enter, exit or while within the unit. Surfaces and parts within a walk-in unit shall be designed to prevent inadvertent hazards to personnel within the enclosure through appropriate guarding, electrical and thermal insulation methods and cautionary warnings and signage in accordance with this standard. See 10.7 and 45.16		N/A
10.10	Protection against contact with hazardous voltage parts in the ESS, including walk-in enclosures, shall be in accordance with 9.3 or through the use of guarding to prevent access with cautionary warnings and signage where only qualified personnel are allowed access. Entrances to walk-in enclosures that contain exposed live parts shall be marked with conspicuous warning signs forbidding		N/A

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	unqualified persons to enter. See also 12.2 with regard to disconnect criteria for servicing, etc. and 45.13 and 45.16. The enclosures of walk-in units shall be provided with grounding in accordance with 14.4.		
10.11	The type of protection equipment to be provided for arc flash hazards shall be determined by an arc flash risk assessment conducted according to NFPA 70E and CSA Z462. The arc flash assessment results shall be labeled on the ESS. The assessment shall determine: a) The arc flash incidental energy level; b) The arc flash boundary, restricted approach boundary; and c) The required arc flash personal protective equipment.		N/A
10.12	The boundary for an unprotected arc flash shall be considered one that has an arc rating above 5 J/cm^2 (1.2 cal/cm^2) incident energy level (e.g. can cause a second degree burn to unprotected skin) per NFPA 70E and CSA Z462.		N/A
10.13	Energy storage system enclosures that can be fully entered by persons such as walk in units, shall be designed to automatically provide mechanical ventilation using 100% outdoor air when anyone is working within the enclosure. The minimum amount of ventilation air shall be 5.1 L/s/m^2 (1 cf/min/ft^2).		N/A
10.14	Electrical circuits that are an integral part of the ESS including those that are part of a walk-in enclosure including lighting, controls, power, HVAC, emergency lighting, alarm circuits, and the like shall comply with the appropriate requirements for the type of equipment and the specific application within the ESS.		N/A
10.15	Electrical equipment including electrical equipment that is located in the walk-in enclosure in areas that will be subject to condensation, or the effects of condensation from equipment or systems that are provided with and installed in, on or around the ESS enclosure, shall be suitable for outdoor use or suitably protected against contact with water and protected against unsafe conduction of hazardous voltages to personnel via water as a conduction path.		N/A

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10.16	Lighting shall be provided in enclosed working spaces associated with the ESS. The lighting source shall provide at least 100 lux and controlled only by manual means. Lighting within an ESS including lighting within a walk-in enclosures shall be installed in accordance with Article 410 of NFPA 70 or Section 30 of CSA C22.1 as applicable to the system where the system is installed.		N/A
10.17	Where there is more than one source of energy input to the ESS, the ESS shall be provided with information and markings to indicate which disconnect device or devices are required to be operated to completely isolate the equipment.		N/A
10.18	Protection against lightning surges shall be provided in accordance with the requirements of NFPA 70 or CSA C22.1, or IEEE C2 as applicable to where the system is intended to be installed.		N/A
11	**Wiring and Electrical Supply Connections**		P
11.1	Wiring installed on the equipment, including internal wiring or supplied with the equipment for installation on-site, shall be insulated and acceptable for the intended purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected where the wiring is located.		P
11.2	Wiring methods and electrical supply connections of energy storage systems shall be in accordance with NFPA 70 or CSA C22.1, or IEEE C2 as applicable to where the system is installed. Energy storage systems which are considered evaluated pieces of equipment shall ensure the electrical supply connections comply with NFPA 70, CSA C22.1 or IEEE C2 as applicable to where the system is installed. Wiring methods for such evaluated pieces of equipment are encouraged to follow the aforementioned codes, but at a minimum shall comply with this Wiring and Electrical Supply Connections Section.		P
11.3	An ESS shall have provision for connection of the system to an external wiring system consisting of: a) Wiring terminals or wiring leads; or		P

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	b) A means for connection of cable or conduit in accordance with the codes in 11.2.		
11.4	A wiring terminal or lead that is supplied as a component of the ESS shall be rated and sized for connection to a field wiring conductor having an ampacity of no less than 125% of the ac or dc current that the circuit carries during rated conditions and in accordance with the codes in 11.2.		P
11.5	A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is to be connected, and shall not be smaller than 2.08 mm^2 (14 AWG). A field-wiring lead shall not be less than 152.4-mm (6-in) long.		P
	Exception No. 1: Communications cable may be less than 2.08 mm^2 (14 AWG).		P
	Exception No. 2: Field wiring harness accessories supplied by the manufacturer and evaluated for use with the system.		P
11.6	Field-wiring compartments, in which branch circuit connections are to be made, shall: a) Permit the connection of the supply wires after the ESS is installed; b) Permit the connection to be introduced and connected easily and safely; and c) Be located so that the connections can be readily inspected after the ESS is installed.		N/A
11.7	Internal wiring shall be routed, supported, clamped or secured in a manner that reduces the likelihood of excessive strain on wire and on terminal connections; loosening of terminal connections; and damage of conductor insulation. In safety critical circuits, for soldered terminations, the conductor shall be positioned or fixed so that reliance is not placed upon the soldering alone to maintain the conductor in position.		P
11.8	A hole by which insulated wires pass through the system enclosure or elements providing separation within the enclosure shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, to prevent abrasion of the insulation.		P
11.9	Where multiple conductors are installed in parallel, they shall be installed in groups consisting of not more than one conductor per		P

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	phase, neutral or ground so that the current in each group sums to zero. Where conductors pass through a metal opening, all conductors in a group shall pass through the same opening.		
12	**General Electrical Equipment**		P
12.1	Replaceable fuses shall have a fuse replacement marking with the fuse ratings located adjacent to each fuse or fuse holder, or on the fuse holder, or in another location provided that it is obvious to which fuse the marking applies. Where replaceable fuses with special characteristics such as time delay or breaking capacity are necessary, the type shall also be indicated. Information on proper fuse replacement of replaceable fuses shall also be included in the service manual instructions.	Fuse model is specified in the Operating Instruction and Maintenance Manual for replacement. It shall be replaced by qualified person.	P
12.2	Exposed hazardous voltage in an ESS shall be provided with a lockable manual disconnect to enable Lock-Out-Tag-Out (as required in NFPA 70E and CSA Z462) during servicing or for emergency procedures. The lockable manual disconnect shall have sufficient interrupt ratings, shall be accessible to the technician servicing the system and to first responders and shall be located as close to the exposed hazardous voltage conductors as possible. When the lockable manual disconnect is not provided directly on the system by the system manufacturer, the installation instructions shall indicate the type and ratings of the disconnect to be provided in the installation and how it is to be installed in accordance with NFPA 70E and CSA Z462.	The lockable manual disconnect requirement specified in the Operating Instruction and Maintenance Manual .	P
	Exception: A lockable disconnect is not required where it is infeasible based upon the design of the system (e.g. interspersed in the middle of a high voltage battery string, within a battery system, to segment the string into segments less than the minimum hazardous voltage).		N/A
12.3	Fuses, circuit breakers and disconnect devices shall be rated for the application including fault current ratings, suitability for disconnect under load, etc., as applicable to the device and application in the system. The ESS shall be provided with short circuit protection within the system to mitigate hazards associated with a short circuit		P

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	condition of the integral energy storage technology, including addressing the potential for additive fault currents when multiple battery systems are connected in parallel. This protection shall be provided as part of the energy storage technology or installed as a separate component within the ESS. Protection against overload and short circuits of external circuits shall use branch circuit rated protectors or electronic circuits evaluated for the purpose.		
12.4	Transformers installed as part of the ESS shall be of the dry type or type filled with a non-combustible dielectric medium. Such transformers shall be installed in accordance with the requirements of NFPA 70 or CSA C22.1, or in accordance with Section 15 of IEEE C2 as applicable to where the system is installed.	Dry type	P
12.5	With reference to 12.4, oil filled transformers shall be permitted for use in outdoor locations in accordance with the applicable local codes or utility requirements.		N/A
12.6	Convenience receptacles provided for maintenance and servicing of the ESS shall be rated for outdoor use if the system is intended to be installed where the receptacle is exposed to the outdoor environment or outdoor environmental conditions.		N/A
12.7	The inverter and other equipment connected to the output terminals of the battery or other storage device of the ESS shall be able to safely withstand the potential short circuit current from the storage device. The rated input short circuit current of the inverter and other equipment shall be equal to or greater than the rated output short circuit current of the battery or other energy storage mechanism. Compliance can be determined through evaluation of the output short circuit ratings of the energy storage mechanism (e.g. for the battery) as determined by testing in UL 1973. For equipment capable of providing an output short circuit current, the rating shall reflect the protection provided by any internal branch circuit protectors, including electronic circuit regulation, such as limitation of peak currents, inrush currents and time. An energy storage mechanism relying on a branch circuit protector installed on the output of the energy	External PCS shall comply with the requirement	N/A

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	storage mechanism shall provide the maximum short circuit current from that device.		
13	**Electrical Spacings and Separation of Circuits**		P
13.1	Electrical circuits within the ESS at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits or potential for arc flash (i. e. electrical spacings on printed wiring boards, physical securing of uninsulated leads and parts, etc.). Insulation suitable for the anticipated operating temperatures and voltages shall be used where spacings cannot be controlled by reliable physical separation.		P
13.2	Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in Table 13.1 or as outlined in UL 62368-1/CSA C22.2 No. 62368-1, Clearances, Clause 5.4.2, and Creepage Distances, Clause 5.4.3.		N/A
	Exception No. 1: The spacing requirements in UL 840, CAN/CSA-C22.2 No. 62109-1, UL 62109-1, IEC 60664-1, or CSA C22.2 No. 0.2, shall be acceptable alternatives. The anticipated pollution degree and overvoltage category is determined by the design and application of the ESS assembly or subassembly under evaluation.	The electrical spacing is inspected according to IEC 60664-1 See appended table Clause 13	P
	Exception No. 2: Electrical spacings within components and parts of an ESS previously determined to comply with an appropriate safety standard for the equipment need not be evaluated.		P
13.3	There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a compound or subassembly if the distance through the insulation, at voltages above 60 Vdc or above 30 Vrms, is a minimum of 0.4-mm (0.02-in) thick for supplementary or reinforced insulation, and passes the Dielectric Voltage Withstand Test. There is no minimum insulation thickness requirement for insulation of circuits at or below 60 Vdc or for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation. Materials employed as electrical insulation shall meet the requirements of 7.5.	Dielectric Voltage Withstand test are performed, see appended table Clause 32	P

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13.4	Conductors of circuits operating at different voltages shall be reliably separated from each other through the use of mechanical securements such as barriers or wire ties to maintain spacing requirements unless they are each provided with insulation acceptable for the highest voltage involved. An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different voltage.		P
14	**Insulation Levels and Protective Grounding**		P
14.1	Hazardous voltage circuits shall be insulated from accessible conductive parts and safety extra low voltage (SELV) circuits as outlined in 14.2 through the following: a) Basic insulation and provided with a protective grounding system for protection in the event of a fault of the basic insulation that complies with 14.3; b) A system of double or reinforced insulation; or c) A combination of (a) and (b).	Inspected, see appended table Clause 13	P
14.2	Safety extra low voltage (SELV) circuits, as defined in 6.40, that are insulated from accessible conductive parts through functional insulation only are considered accessible.	Inspected	P
14.3	Accessible non-current carrying metal parts of an ESS containing hazardous voltage circuits that could become live in the event of an insulation fault shall be bonded to the equipment ground terminal. The main grounding terminal shall be identified through use of grounding symbol, green coloring or word “GR” etc. to signify it as the equipment ground terminal and shall not be utilized for any other purpose than for the connection of the grounding and bonding conductors.	Inspected	P
14.4	The methods of protective bonding and grounding of an ESS shall be in accordance with Article 250 of NFPA 70 or Section 9 of IEEE C2 as applicable to where the system is located. When sizing the protective bonding and grounding wire, the rating and fault current path of all sources of supply onnected to the equipment or system shall be considered. If used, grounding (bonding) braids used in the ESS or from the ESS to the	Inspected	P

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	grounding electrode shall comply with UL 467/CSA C22.2 No. 41, and sized according to the Grounding – Size of Terminal or Bonding Conductor requirements of UL 508A or CSA C22.1..		
	In Canada, the methods of bonding and grounding an ESS shall be in accordance with Section 10 and 36 of CSA C22.1.	Inspected	P
14.5	Parts of the protective grounding system shall be securely fastened and provided with metal-to-metal contact that will ensure the continuity of the grounding system. All connections shall be secured against accidental loosening and shall ensure a thoroughly good connection. See 14.6, 14.7, and Section 33.	Inspected	P
14.6	With reference to 14.5, when connecting conductive parts to be bonded, paint or coatings in areas of contact shall be removed or paint piercing lock washers shall be used with securement bolts or screws to provide good metal to metal contact. Thread-locking sealants, epoxies, glues, or other similar compounds, and solder alone shall not be used as a securement means as these are not considered reliable. In addition, rivets, hinges (unless metal-to-metal piano type hinges), and parts that may be removed as a result of servicing shall not be relied upon as connections for ensuring continuity of the protective grounding and bonding system. Bonding shall be achieved through the use of dedicated connections that are not utilized for other purposes.	Inspected	P
14.7	With reference to 14.5, methods of securement considered reliable and ensuring good metal-to-metal contact can consist of the following methods: a) Terminal blocks; b) Pressure connectors, grounding lugs and similar grounding and bonding equipment connectors; c) Fusion welding processes; d) Machine screw-type fasteners that engage not less than two threads or are secured with a nut; and	Inspected	P

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	e) Thread-forming machine screws that engage not less than two threads in the enclosure.		
14.8	For ESS greater than 100 V between conductors or to ground, the battery circuits can be ungrounded if the system is provided with a ground fault detector and indicator to monitor ground faults.	Ground fault detection function provided	P
15	**Safety Analysis and Control Systems**		P
15.1	A safety analysis consisting of a hazard identification, risk analysis and risk evaluation including a safety analysis such as a failure modes and effects analysis (FMEA) that identifies critical safety components and circuits of the system, shall be conducted on the equipment forming the ESS and components of the ESS considering any interactions that provide a safety function. The analysis shall consider the compatibility of the parts of the ESS (e.g. battery system, charger, inverter, etc.) with regard to safety of the overall system. The analysis shall be performed by the manufacturer of the ESS or the entity that integrates the components that comprise the ESS, referred to as the energy storage system integrator. Guidance for analysis can be found in the following standards: a) IEC 60812; b) IEC 61025; and c) MIL-STD-882E.	Safety analysis through method FMEA by manufacturer is reviewed	P
15.2	Even when the major parts of the ESS are in compliance with their individual safety standards and they are being used within their ratings, it cannot be assumed that when the parts are connected together to form an ESS that the system is safe, without further analysis. The analysis of the ESS must evaluate whether or not the various parts of the ESS, even though determined to be safe individually, work compatibly with each other to prevent hazardous conditions from occurring. When conducting this analysis, it is important that the interaction of the various parts of the ESS be evaluated as noted in 15.1 to determine that there are no hazards introduced in the system as a result of their interaction. For example, communications delays between parts that could affect safety,	Inspected	P

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	surges or noise introduced from power conditioning devices or noise introduced from electrical connections, shall not affect the functionality or result in damage to these safety controls such as the battery management system (BMS), contactors or the energy storage management system.		
15.3	The safety analysis shall consider mechanical and other potential hazards associated with the ESS in addition to potential electrical hazards. This is especially critical when evaluating systems with hazardous kinetic energy and systems with parts under hazardous pressure levels. Analysis of flywheel systems shall be conducted on the bearing failure detection system, which shall detect signs of bearing failure before catastrophic failure occurs, and shall be designed to initiate safety mechanisms within the flywheel control system to bring the system to a safe state upon catastrophic failure of the bearings. Analysis of flywheel systems shall also include the feedback and control for any active bearing unloading systems.	Inspected	P
15.4	Analysis of thermal ESS shall ensure that there is sufficient monitoring and control of pressure, thermal and fluid flow to ensure that the various parts of the system are maintained within their specifications for pressure temperature and fluid levels.	Electrochemical ESS	N/A
15.5	Electrical and electronic controls of the ESS that are determined to be critical for safety shall comply with an appropriate safety standard for the control and used within their ratings. Electronics and software controls determined to be critical for safety are to be tested to verify electromagnetic immunity in accordance with Section 36 if this testing is not part of the functional safety standard requirements, and shall be evaluated for functional safety to one of the following sets of standards and safety ratings as applicable to the system: a) UL 991 and UL 1998; b) CSA C22.2 No. 0.8 (Function Class B requirements); c) The Annex for Requirements for Electronic Controls, Annex H of UL 60730-1 or CSA E60730-1 (Function Class B requirements);	Functional safety evaluated to Annex H of UL 60730-1, class B Report: 64.280.23.60639.01	P

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	d) IEC 61508 (all parts) (minimum of Safety Integrity Level (SIL) "2" requirements for active protective devices with software controls); e) ISO 13849-1 and ISO 13849-2 (minimum of Performance Level (PL) "c" requirements for active protective devices with software controls); or f) ISO 26262 (all parts) (minimum Automotive Safety Integrity Level (ASIL) "C" requirements for active protective devices with software controls).		
15.6	The required SIL, PL, or ASIL for a safety function shall be permitted to be reduced if the manufacturer provides additional safety analysis (e. g. Layer of Protection Analysis) showing that the required risk reduction level has been reduced by other measures within the ESS.	Not applied with this rule	N/A
15.7	When conducting the functional safety evaluation of electronic controls, the interaction of the various parts of the system need to be considered for their impact on each other. In particular, a number of disruptive interactions shall be considered in all cases. These interactions include: a) Noise, or other disturbances introduced into the system as a result of the interaction of the various ESS components such as between the PCS and the BMS of the battery or other electronic controls, shall be considered when evaluating the reliability of electronic and programmable electronic controls; b) The surge protection evaluation of the BMS and other electronic controls shall be sufficient to address potential surges that may be transmitted from the PCS or other equipment; c) Surge suppression protection shall be provided to protect the BMS or other electronic safety controls devices, if the control functionality of a BMS or other controls can be impacted as a result of this interaction; d) Parts such as power conditioning system (PCS) connected to the storage devices of the system (e.g. batteries), shall be able to safely withstand a fault current from the storage devices including current that is	Inspected	P

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	transmitted prior to operation of the short circuit protection; and e) Delays or other faults in communication signals between the various parts of the ESS that can impact safety.		
15.8	Software and its associated hardware determined critical to safety that can be updated remotely shall meet the requirements outlined in Section 16, Remote Software Update Enabled ESS. Section 16.1 applies to software evaluated in accordance with UL 1998 and Section 16.2 applies to software evaluated in accordance with UL 60730-1 or CSA E60730-1.	Not designed for remote update	N/A
16	**Remote Software Update Enabled ESS**		N/A
16.1	Critical and/or critical supervisory software (UL 1998)		N/A
16.1.1	The requirements in 16.1.2 – 16.1.7 apply when the manufacturer declares the ESS has critical and supervisory and related critical supervisory sections of software per UL 1998, and has the functionality to remotely update this software.		N/A
16.1.2	The critical/supervisory sections of UL 1998 software, intended to be updated, shall comply with UL 1998.		N/A
16.1.3	User authorization is required prior to any remote update of critical/supervisory sections of UL 1998 software.		N/A
16.1.4	The remote update of software shall occur when the ESS is in a risk addressed state.		N/A
16.1.5	The remote software update shall comply with UL 5500, with the following modifications:		N/A
	a) The device specific requirements for a remote update of software, per the requirements for Application of Received Software Download Package in UL 5500, shall occur when the ESS is in a risk-addressed state; and		N/A
	b) The bulleted items in the compliance criterion of the requirements for Documentation & Tracking in UL 5500 are replaced with the following:		N/A
	1) Communication protocol (Compliance with the requirements for Establish Remote Connection, and the requirements for Download/Transmission in UL 5500);		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	2) Software update process (Compliance with the requirements for Hardware / Architecture / Software Download Package Compatibility Check, Application of Received Software Download Package, and Conclusion of Remote Software Update Process in UL 5500);		N/A
	3) Identity and access management (Compliance with the requirements for Authentication, and Authorization in UL 5500); and		N/A
	4) Validation measures (Compliance with the requirements for Remote Software Update Validation: General, Failure/Status Identification Detection, Response to Error Detection, and Software Download Package Version in UL 5500).		N/A
16.1.6	The correct operation of the ESS safety functions shall be maintained after the critical/supervisory sections of software in accordance with UL 1998 software is updated.		N/A
16.1.7	Compliance is checked by a functional test of a remote software update using the procedure outlined in Operational Verification of Remote Software Update Capability in 36.9 after implementing a remote software update. Consideration shall be made for a functional test (based on an impact analysis of the changes made to the software) to verify the proper operation of the ESS system protective control functions.		N/A
16.2	Class B software (UL 60730-1 or CSA E60730-1)		N/A
16.2.1	The requirements in 16.2.2 – 16.2.8 apply when the manufacturer declares the ESS has Class B software in accordance with UL 60730-1 or CSA E60730-1, and has the functionality to remotely update this software.		N/A
	NOTE 1: An update occurs when software replaces or modifies the previous version of the Class B software, UL 60730-1 or CSA E60730-1 software. Additionally, an update occurs when the same version of Class B software, is replaced during the remote update process.		N/A
	NOTE 2: These requirements are not intended to address cybersecurity.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
16.2.2	The Class B software of UL 60730-1 or CSA E60730-1 intended to be remotely updated, shall comply with the requirements for Controls Using Software in UL 60730-1 or CSA E60730-1.		N/A
16.2.3	The remotely actuated control function, including the software update function, shall comply with the requirements for Remotely Actuated Control Functions in UL 60730-1 or CSA E60730-1. With respect to transmission faults, Note 1 of Clause H.11.12.4.1.3.1, Transmission, is considered normative.		N/A
	NOTE 1: A remotely actuated control function is a function providing any operation by control devices through external means. This includes, but is not limited to: a) The use of communication lines/protocols; b) IR/RF transmission; or c) All combinations of (a) – (b) above via Internet using, for example modems, portable telephones, etc.		N/A
	NOTE 2: Remote software updates require minimum or no interaction with the ESS. Software updates are received remotely without the use of external hardware such as a USB, SD card, etc.		N/A
16.2.4	Remotely actuated control functions may be connected to separate, independent devices, which may themselves contain control functions or provide other information. Any data exchange between these devices shall not compromise the integrity of the Class B control function.		N/A
16.2.5	User authorization is required prior to any remote update of Class B software, UL 60730-1 or CSA E60730-1. This will be evaluated in accordance with UL 60730-1 or CSA E60730-1, Clause H.11.12.4.4.3.		N/A
	NOTE: User authorization can be a one-time event. This one-time event may be when the homeowner registers their residential ESS with the manufacturer, or downloads the application needed to remotely operate the ESS on their smart device (e.g. cell phone, tablet, etc.).		N/A
16.2.6	The remote update of software shall occur when the ESS is in a risk addressed state.		N/A
16.2.7	The correct operation of the ESS's safety functions shall be maintained after the Class		N/A

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	B software is updated per UL 60730-1 or CSA E60730-1.		
16.2.8	Compliance is checked by a functional test of a remote software update using the procedure outlined in Operational Verification of Remote Software Update Capability in 36.9 after implementing a remote software update. Consideration shall be made for a functional test (based on an impact analysis of the changes made to Class B software) to verify the proper operation of the ESS protective control functions.		N/A
	NOTE: When determining which safety functions need to be verified after the update has been completed, consideration is to be given to the specific aspects of the software that have been updated.		N/A
17	**Remote Controls**		P
17.1	Energy storage systems which have the ability to be controlled and operated remotely shall be provided with an accessible means to disconnect the system from the remote control for maintenance or other local servicing of the system. The remote control disconnect shall either be provided on the system or instructions in the installation manual shall provide the location and type of disconnect to be provided in the end use installation. The use of a remote control systems shall not lead to an unsafe condition as determined by the system safety analysis and shall not be able to override local safety controls. If the remote control disconnect is to be provided as part of the installation (not built into the ESS), the instructions shall include information on the electrical connections including means to prevent the disconnect from being overridden by the remote control system.	Isolation switch is provided in the high voltage controlling box of each battery string. DC breaker shall also be installed between ESS and PCS according to the Operating Instruction and Maintenance Manual . The disconnection of the system shall be according to the user manual.	P
17.2	Remote disconnect controls such as Emergency Power Off (EPO) buttons shall be marked to clearly indicate what system or part of the system they control. Remote disconnect control such as EPOs that disconnect and de-energize the complete ESS, need to not be marked in this manner.	The Emergency stop button could trigger the contactors in high voltage controlling box to disconnect the battery strings input/output of the ESS.	P
18	**Communication Systems**		P
18.1	General		P

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18.1.1	Instructions for installation and operation of the ESS shall identify the communication protocols used by the ESS for communication with external systems intended to be connected to the ESS. Energy storage system components and subassemblies that need to communicate with each other to ensure safe operation of the system, shall utilize harmonized communication protocols, and evaluation of the compatibility of these interconnecting communication systems shall be included in the safety analysis of Section 15.	RS485/CAN communication protocols are used	P
18.2	External warning communication system (EWCS)		P
18.2.1	Electrochemical ESS using lithium-ion batteries as the storage mechanism that have an energy capacity of 500 kWh or greater shall be provided with an external warning communication system, as outlined in 18.2.2 – 18.2.6, that gives an advance notification to operators of a potential safety issue with the ESS.		P
18.2.2	The information inputs to the EWCS shall come from those devices in the ESS that can supply information of potential problems that could lead to a hazardous state of the system, including from the battery management systems (BMS) or the energy storage management system (ESMS). The EWCS shall use compatible communication interface methods with its various sources of information from the ESS.	The MBMU PCB in the master control box is considered as the EWCS. The internal information inputs to MBMU by CAN communication, MBMU outputs the battery related signal to external EMS through fiber transferred by ETH, output the fire system related signal to external EMS through TCP/IP transferred by FSS.	P
18.2.3	The EWCS shall communicate with an operator station that is monitoring the ESS. The EWCS shall be capable of sending information to an external operating station. The EWCS shall also communicate to a local warning system that utilizes audio and visual warning signals when the ESS is operating in a hazardous state. Those conditions that require immediate intervention and notification of the fire service shall result in operation of an external warning signal such as a warning light and audio alarm.	The data of communication protocols from EWCS (MBMU in ESS) includes the operation status information. When the operator station received the specified signals from ESS, the necessary audio and visual warning, fire service shall be operated in accordance with requirements in final installation.	P
	NOTE: The methods of communication to the external operating station can vary depending upon the design of the system.		N/A

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18.2.4	The EWCS and the sources providing information to the EWCS shall be evaluated as part of the safety analysis of the system in Section 15. The analysis shall identify those signals/information from the various sources that would warrant the EWCS to provide warning communications to operators and local alarms that the system may have a potential safety issue that needs to be addressed to prevent further escalation. Those signals that signify the need for an escalation of the warning to the local fire department shall also be identified in the analysis. The analysis shall determine that the EWCS is capable of receiving the signals from the various sources to send communication to the operators as necessary.	The information from EWCS communicates to external operators includes the necessary information of battery system and fire detection system.	P
	NOTE: Examples of information that may be fed into the EWCS from the BMS or EMS are overvoltage conditions, over temperature conditions, excessive BMS error messages, operation of overcurrent devices, integral gas detection indicating cell venting, etc.		P
18.2.5	The EWCS shall be installed as an integral component of the ESS. It can be supplied by the lithium batteries it is monitoring, but the EWCS shall also have a dedicated backup power source independent of the batteries is monitoring to prevent data to and from the EWCS being lost or interrupted as part of the primary power source failure, or delayed by more than 10 s. The backup power source shall be capable of providing power for at least 5 h for the data input and operator communication portion of the system. This back power source need not supply any visual or audible sirens supplied as a part of the system for more than 5 min.	The power supply of BMS and EWCS is backup by the UPS or 24V power module. The capacity of the backup power is capable of providing 5 h of communication system and 5 min for visual or audible warning devices.	P
18.2.6	Instructions on the installation, operation and any ongoing maintenance of the EWCS including its back up power source shall be provided with the ESS instructions. If installed indoors, the instructions shall reference applicable criteria from the Notification Appliances Chapter of NFPA 72, for location and required intensity of visual and audio alarms to be installed in the installation. Visual alarms shall be in accordance with UL 1638, and audio alarms shall be in	For outdoor use only. The visual alarms and audio alarms installed in the final installation shall be in accordance with the clause requirements.	P

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	accordance with UL 464/ULC 525. The maximum sound level for audio alarms shall not exceed 110 dBA at the minimum hearing distance. For outdoor installations, visible alarms installed on the ESS, shall be located no less than 203.2 cm (80 in) nor more than 243.8 cm (96 in) above the ground.		
19	**Heating and Cooling Systems**		P
19.1	Energy storage systems that rely upon thermal management systems, either integral to the system or provided at the installation site, to prevent overheating or operation outside the specified safe operating range of the energy storage technology shall be designed to safely shutdown upon failure of the thermal management system unless it can be demonstrated, that the thermal management system failure does not result in a hazardous situation.	Inspected and failure mode is tested	P
20	**Piping Systems, Pressure Vessels, Fuel and Other Fluid Supply Connections and Controls**		P
20.1	Piping systems, pressure vessels, fuel and other fluid supply connections and controls shall comply with 20.2 – 20.10.		N/A
	Exception No. 1: Systems that are evaluated as part of a battery to UL 1973 need not comply with 20.2 –20.10.	Liquid chiller is certified to UL 60335-1, UL 60335-2-40, and Piping systems were evaluated as part of battery system to UL 1973.	P
	Exception No. 2: Coolant systems can be evaluated to the Performance requirements of the Cooling Systems section of UL 508C.		N/A
20.2	Piping systems utilized to carry fluids in an ESS such as water, heated air, fuel gases, etc. shall comply with ASME B31 (all applicable parts), or CSA B51, or CSA B52, or CSA Z662, or CSA B149.1 as applicable.		N/A
20.3	Pressure vessels and related equipment including pressure relief devices that fall under the scope of ASME BPVC, or CSA B51, shall comply with the applicable requirements.		N/A
20.4	Flammable fuel supply connections on the ESS shall be suitable for the material contained and in accordance with the applicable part of ASME B31 based upon the fluid, temperatures and pressures they are subjected to.		N/A

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20.5	A means shall be provided to prevent backflow of process gases, etc. into the fuel supply lines either as part of the ESS design or indicated in the installation instructions.		N/A
20.6	The ESS shall be designed so that process water used in the system shall be prevented from contaminating potable water sources in accordance with local regulations through the use of check valves or other means as part of the system design.		N/A
20.7	Piping, hose, and tubing containing fluids, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard (e.g. liquid leaking onto electrical circuits that can lead to short circuits). Pressure relief valves shall be located so that fluids are not directed toward live parts or safety critical circuits should they operate.		N/A
20.8	ESS containing liquids, including ESS with coolant systems containing liquid coolant, shall be provided with some means of leak detection to monitor for loss of coolant that could lead to a potential hazardous condition. Coolant leaks that are detected shall result in a warning signal to the ESS monitoring and control system and shall initiate an alarm if provided.		N/A
20.9	Manual shut off valves shall be provided on or near the ESS in a location where they can be accessed to allow for disconnection of the fuel or water supply to the ESS for maintenance, etc. If not provided on the system itself, installation instructions shall indicate type, ratings and location for installation of appropriate manual shut off valves. Automatic (nonelectric type) and manual valves intended for the use in flammable fluid lines shall comply with UL 842 or ULC/ORD-C842. Solenoid valves shall comply with UL 429 or CSA C22.2 No. 139. Where flammable liquids are in use, an automatic shutoff valve shall be provided to limit the release of fuel during an abnormal condition.		N/A
20.10	Pressure regulators used on flammable or other hazardous gas lines shall comply with UL 252, CSA Z662, or CSA B149.1, as applicable.		N/A
21	**Containment of Moving Parts in Mechanical ESS**		N/A

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21.1	Mechanical ESS having moving parts with the capacity to store kinetic energy (flywheel systems) shall be provided with a means to contain the parts in the event they could become loosened during operation or through the influence of external forces. If it is possible for moving parts to become dislodged upon breakage or damage to their securement means, the containment mechanism shall adequately contain the loosened parts to prevent hazards to persons or the surrounding built environment. See Section 37.	Electrochemical ESS	N/A
21.2	The alternator/generator elements associated with mechanical ESS shall comply with UL 1004-1 and other parts (UL 1004-2, UL 1004-3, UL 1004-5, UL 1004-6, UL 1004-7, UL 1007-8, UL 1004-9) as applicable or CSA 22.2 No. 100.		N/A
22	**Noise Levels**		N/A
22.1	The noise level from an ESS during operation, including noise levels in walk-in ESS that can be entered during operation, shall be limited to an 8-hr time-weighted average of 85 dBA when tested in accordance with 29 CFR 1910.95 (C)(1)(2). Measurements of the sound are determined in accordance with 29 CFR 1910.95 or equivalent method. Systems that have noise levels in excess of this limit shall be provided with warning labels and instructions that address hearing protection and other protective measures to be taken for those who may be exposed to the noise in accordance with 29 CFR 1910.95.		N/A
	NOTE: 29 CFR 1910.95 (C) (1)(2) indicates an 8-hr limit of 90 dBA, unless exposures can exceed 85 dBA greater than 50 % of the time. The lower 85 dBA is chosen as this is a limit in accordance with NIOSH limits and other standards. This still exceeds the limits of the EU machinery directive, which is 80 dBA		N/A
23	**Hazardous Fluid Control**		N/A
23.1	Where the system contains fluid in excess of 208 L (55 gal) in a single vessel or an aggregate of more than 3785 L (1000 gal), secondary containment shall be provided. Methods utilized for spill control shall be	No such fluid contained	N/A

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	sufficient to contain all of the fluid from the largest liquid vessel within the system and designed to prevent inadvertent filling with rain if located outdoors. Where flammable liquids are contained, any applicable fire detection and protection systems shall be specified or included as determined per Section 26. The spill control system shall accommodate additional water from any specified fire protection system for a period of 10 min. Automatic leak detection to annunciate the spillage of fluid shall be provided.		
	Exception: If containment is not provided as part of the product, then instructions regarding the need to provide containment, fire detection and protection systems and leak detection shall be included in the instruction manual. The instructions shall also specify the minimum volume of the containment and information about compatibility of the containment system with the fluid to be contained. See 46.12.		N/A
23.2	Where a system contains conductive fluids, the system shall be designed in a manner to prevent the fluids from causing a short circuit in the event of a spill. If spill control is not provided with the system, then the instruction manual shall provide directions on the spill control system design to prevent any short circuits from fluid spilled.		N/A
23.3	Neutralization of spills of any hazardous fluids shall be provided if necessary to insure compatibility with any materials the fluids may contact when in the spill control system. Such neutralization shall occur without the intervention of people and shall have the capacity to neutralize the volume of fluid specified in 23.1 to a pH level that is compatible with the materials in the spill control system. If required, neutralization shall be provided to insure safe clean up and disposal of the spill.		N/A
	Exception: If neutralization is not provided as part of the product, then instructions regarding the need to provide neutralization shall be included in the instruction manual. The instructions shall also specify the type and quantity of neutralizing material required to meet the requirements of 23.3. See 46.12.		N/A

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21.4	Energy storage systems that contain fluids shall be designed to prevent venting of toxic vapors in concentrations considered to be hazardous based on an evaluation conducted in accordance with Sections 38 and 39.		N/A
24	**Combustible Vapor Concentrations**		N/A
24.1	Enclosures of ESS that contain flammable fluid systems or batteries that vent hydrogen or other flammable gases to the atmosphere under normal operations shall be ventilated to prevent hazardous vapor concentrations unless electrical equipment located within the classified area/zone within the enclosure is rated for a Class 1 Division classification or Zone 1 area/zone. Concentrations in non-hazardous areas/zones of the ESS shall be limited to 25% of the lower flammability limit (LFL) under normal maximum operating conditions. Mechanical ventilation relied upon to maintain concentrations below the required limits shall be interlocked, so that the system shuts down upon failure of the ventilation system.	Electrochemical ESS with lithium-ion batteries. No flammable gas vented under normal operations	N/A
	Exception: Vented battery systems with aqueous electrolytes such as lead acid or nickel cadmium that are provided with ventilation openings in their enclosures in accordance with 24.3, need not comply.		N/A
24.2	Electrochemical ESS which are not addressed in 24.1 and which are dependent on mechanical ventilation as a protection measure against emission of flammable gas that can occur during fault conditions to prevent hazardous gas concentrations within the system, shall be equipped with a fault detection system that activates the mechanical ventilation in a manner which prevents the LFL from exceeding 25% in any non-hazardous area/zone within the ESS.	The ESS provided with flammable gas detector for fault condition and with mechanical ventilation (fan). Refer to the NFPA 69 simulation report, the average flammable gas concentration can be kept below 25% LFL in fault condition, but there may be flammable pockets of gas that could ignite and cause a partial volume deflagration.	N/A
24.3	For ESS that contain batteries or similar storage devices, openings to prevent hazardous concentrations of flammable gases within an enclosure can be used. Openings in the enclosure provided for ventilation shall be constructed to prevent accumulation of flammable gases that could lead to a hazardous condition from concentrations of hydrogen gas due to electrolysis of aqueous		N/A

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	electrolytes for applicable battery technologies, such as vented or valve regulated lead acid and nickel batteries and applicable electrochemical capacitor technologies, greater than 25% of the LFL of hydrogen (equivalent to 1% concentration in a volume of air).		
24.4	As an alternative to 24.3, ventilation openings shall have a minimum opening area of: $A = 0.005NC_5$ (cm^2) Where: A = Total cross sectional net free area of ventilation openings required (cm^2) N = Number of cells in battery C_5 = Capacity of battery at the 5-h rate (Ah)		N/A
	Exception: The area of ventilation openings can be reduced if it can be demonstrated that there is sufficient ventilation within the battery to prevent hydrogen accumulations above 25% of the LFL of hydrogen.		N/A
24.5	Electrochemical ESS with integral enclosures where there is the potential for a flammable gas concentration within the enclosure from an abnormal condition such as thermal runaway and propagation, shall be provided with deflagration or explosion protection in accordance with NFPA 68 or NFPA 69. This protection shall be installed on the ESS or its enclosure depending upon the type of protection and installed in a location where its operation shall not result in the introduction of a hazard after installation. See the figure for BESS Deflagration Protection Analysis, in the Annex for Test Concepts and Application of Test Results to Installations in UL 9540A for reference and guidance.	Explosion protection according to NFPA 69 provided.	P
	Exception No. 1: The protection is not required if the testing in accordance with UL 9540A with a deflagration hazard analysis demonstrates that the concentration of flammable gas measured during testing remains under 25 % LFL within the room, building, ESS cabinet, or walk-in ESS and there is no potential for partial volume deflagration.		N/A
	Exception No. 2: For ESS abinets/enclosures, protection other than as noted can be used if it has been determined that the ESS		N/A

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	cabinet/enclosure has been designed to effectively protect against hazards due to combustible concentrations when the ESS has been tested in accordance with the Unit Level or Installation Level test of UL 9540A.		
24.6	Portions of ESS, in which flammable vapor concentrations above 25% LFL may be present during normal operating conditions, shall be provided with construction suitable for the classification in accordance with NFPA 70, CSA C22.1, or IEEE C2 as applicable to the intended installation.	Electrochemical ESS with lithium-ion batteries. No flammable gas vented under normal operations	N/A
24.7	Electrical compartments adjacent to classified zones within the ESS enclosure shall be maintained at positive pressure in accordance with NFPA 497, UL 60079-2 or CAN/CSA-C22.2 No. 60079-2.		N/A
25	**Flammable Solids**		N/A
25.1	ESS containing hazardous solids (i.e. pyrophoric or water reactive metals) shall be designed and installed in accordance with NFPA 484.		N/A
26	**Fire Detection, Suppression and Propagation**		P
26.1	General		P
26.1.1	Fire detection and fire suppression equipment provided as an integral part of an ESS shall comply with applicable product safety standards and shall be installed in accordance with the applicable safety product standards and the manufacturer's instructions.	See CDF	P
26.1.2	Energy storage systems with integral fire detection or fire suppression systems shall be provided with instructions for installing, commissioning, maintaining and testing these systems in accordance with applicable installation codes and standards. NFPA 1 and ICC IFC provide information on applicable requirements and codes for fire suppression systems. See also Appendix A.		P
26.1.3	If the ESS manufacturer's instructions indicate that an integral fire detection or fire suppression system is optional, the ESS shall comply with all applicable performance requirements in this standard with and without the integral fire detection or fire suppression system in place and operational.		P

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Clause	Requirement + Test	Result – Remark	Verdict
23.2	Large scale fire testing		P
23.2.1	Electrochemical type ESS, including but not limited to capacitor and battery ESS, shall be subjected to the large scale fire testing in accordance with UL 9540A as follows in (a) – (d). See Appendix E for guidance on code limits related to separation distances and energy capacity. a) Systems with increased energy capacities as required in codes and standards; b) Systems with decreased separation distances to adjacent ESS units, doors and windows, or exposures. See 46.2 and/or 46.4; c) Indoor systems; or; d) Systems for installation in dwelling units (where permitted).	UL 9540A cell level test, module level test and unit level test were performed to validate the fire hazards at cell, module and unit level. See UL cell test reports: 4791153929, module test reports: 4791072772 and unit level test reports: 4791072766. Although the unit level test showed that there was no fire or explosion, the risk still exists due to the concentration of flammable gas generated during thermal runaway in certain circumstances based on on-site installation and exhaust conditions. Shall take necessary measures to reduce fire and explosion hazards and comply with local regulations based on the test results during on-site installation.	P
26.2.2	Electrochemical ESS intended for use in the living or habitable space of a residential dwelling unit (where permitted) shall meet the Performance – Cell Level Test requirements in UL 9540A. Systems complying with these requirements shall be marked in accordance with 45.3(e)(1).	Non-residential use	N/A
	NOTE: CSA C22.1 indicates the following wording for this marking “This equipment meets the cell level performance criteria of UL 9540A”. See 45.3(e)(2).		N/A
26.2.3	Electrochemical ESS intended for use in dwelling units where UL 9540A testing is indicated per the codes and standards, shall minimally meet the Unit Level Performance Criteria for residential installations identified in UL 9540A with a test that aligns with the manufacturer’s installation instructions. These ESS shall be marked in accordance with 45.3(e)(3).		N/A
26.2.4	Electrochemical ESS intended for non-residential use shall be subjected to specific large scale fire testing in accordance with UL 9540A for installations described in the manufacturer’s instructions		P
27	**Power Conversion Equipment**		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
27.1	General		N/A
27.1.1	Inverters, chargers, and charging charge control equipment that are part of an energy storage system shall be designed and rated for use with the battery system employed in the energy storage system and evaluated to UL 1741, UL 62109-1 or CAN/CSA C22.2 No. 62109-1, UL 1012, UL 1564, or CAN/CSA C22.2 No. 107.1 as applicable to the power conversion equipment and its application in the system.	External power conversion equipment shall comply with the requirements in the final installation system.	N/A
	Exception: UL 1778/CSA C22.2 No. 107.3 may be used as an alternative to the power conversion and charger equipment standard references if applicable to the ESS application serving an uninterruptible power system (UPS).		
27.2	Utility Grid Interaction		N/A
27.2.1	Energy storage systems intended to export energy to the electric power systems (EPS)/electric utility shall be designated as utility-interactive, grid support utility-interactive, or special purpose utility-interactive and shall utilize the appropriately evaluated power conditioning systems. See 6.41, 6.44, and 6.45.		N/A
27.2.2	The inverter shall be designed to properly interconnect with the particular energy storage technology it is connected to as determined by the system safety analysis.		N/A
27.2.3	Products that rely upon internal or external utility interconnection protection functions or devices shall be specifically identified for the particular product in the ESS instructions.		N/A
27.3	Utility grid interactive inverter		N/A
27.3.1	A utility-interactive inverter, grid support utility-interactive inverters, or subassembly of an ESS shall comply with UL 1741, UL 62109-1 or CAN/CSA C22.2 No. 62109-1, or CSA C22.2 No. 107.1.		N/A
27.3.2	Utility-interactive ESS inverters shall be evaluated for compliance with additional utility interactive document (s) and standard (s) if those specific documents or requirements are referenced in the product ratings or instructions.		N/A
27.4	Standalone and multi-mode power conditioning systems		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
27.4.1	Power conditioning systems for standalone and multi-mode applications shall comply with UL 1741, UL 62109-1 or CAN/CSA C22.2 No. 62109-1, or CSA C22.2 No. 107.1.		N/A
28	**Energy Storage System Technologies**		P
28.1	Electrochemical ESS		P
28.1.1	Batteries, electrochemical capacitors, hybrid battery-capacitor systems or flow batteries used in an electrochemical ESS shall comply with the requirements of UL 1973. Testing and evaluation of the battery system, which would include the battery and its battery management system is conducted as part of evaluation to UL 1973. Inverters and charging equipment that are part of the ESS shall be designed for use with the battery system employed in the ESS. For general information on battery safety, see also informative Appendix B.	Batteries certified to UL 1973	P
	Exception: For valve regulated or vented lead acid or nickel cadmium battery systems, see Appendix D for an alternative approach.		N/A
28.2	Chemical ESS		N/A
28.2.1	A chemical ESS consists of storage of hydrogen fuel and the means to change the fuel into electrical energy using a fuel cell system or a hydrogen gas turbine. To convert electrical energy into hydrogen fuel, a hydrogen generator using water electrolysis is also part of the overall system. Fuel cell systems that are part of a chemical ESS shall comply with CSA FC 1, Fuel Cell Power Systems.		N/A
28.2.2	Stationary engine generators that are part of a chemical ESS shall comply with UL 2200 or CSA C22.2 No. 100, and CSA C22.2 No. 14.		N/A
28.2.3	Water electrolysis type hydrogen generators used in an ESS to provide hydrogen for storage shall be evaluated and found to be in compliance to an appropriate safety standard for the equipment.		N/A
28.2.4	Hydrogen fuel containing parts of a chemical ESS shall be constructed of materials suitable for gaseous hydrogen service at the pressures and temperatures of use. Pressure vessels used for storage of gaseous		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	hydrogen and piping employed as part of a chemical ESS shall comply with Section 20.		
28.3	Mechanical ESS		N/A
28.3.1	Mechanical ESS such as, but not limited to, flywheel systems or compressed air energy storage (CAES) systems shall be evaluated to determine that hazards associated with moving parts with the capacity to store kinetic energy, and high pressure and high temperature fluids contained in the system are mitigated. Compliance is determined by evaluation to the requirements of this standard.		N/A
28.3.2	Flywheel systems and other systems with moving parts with the capacity to store kinetic energy shall comply with the Containment of Moving Parts tests of Section 37 and the Strength Tests of Section 39. Parts containing hazardous fluids shall comply with the Leakage Tests of Section 38 and the Strength Tests of Section 39.		N/A
28.4	Thermal ESS		N/A
28.4.1	A thermal ESS consists of gases, fluids, and/or solids storing heat energy that can be turned into electrical energy when needed through the use of energy conversion equipment (e.g. engines, generators).		N/A
28.4.2	Thermal ESS shall be evaluated to determine hazards associated with containment of high temperature and high pressure and potentially hazardous fluids are mitigated. Compliance is determined by evaluation to the requirements of this Standard. Parts containing hazardous fluids and fluids at high temperatures and pressures shall comply with the Leakage Tests of Section 38 and the Strength Tests of Section 39.		N/A
28.4.3	Stationary engine generators that are part of a thermal ESS shall comply with UL 2200 or CSA C22.2 No. 100, and CSA C22.2 No. 286. Generators that are part of a thermal ESS shall comply with UL 1004-4 or CSA C22.2 No. 100		N/A
28.4.4	Hazardous fluid containing parts of a thermal ESS shall be constructed of materials suitable for use with that fluid at the pressures and temperatures of use. Pressure vessels used for storage and piping employed as part of a		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	thermal ESS shall comply with Section 20. Stresses on containment parts associated with swings of high and low temperature extremes shall be considered when evaluating the suitability		
28.4.5	Containment systems for combustible materials (solids or fluids) shall be designed to prevent the potential for explosion hazards as a result of contact with moisture, contaminants, etc.		N/A
28.4.6	A thermal ESS shall have sufficient pressure controls, fluid level controls and temperature controls to prevent the potential for a hazardous condition from occurring through an out of specification operation. Compliance is determined through the safety analysis of the system and the functional safety investigation of the controls per Section 15 and the abnormal operations tests for thermal ESS in accordance with Section 31.		N/A

PERFORMANCE – GENERAL

29	**General**		P
29.1	The energy storage technologies employed as part of an ESS shall be tested and determined compliant to an applicable technology safety standard. Where no applicable safety standard exists, they shall be tested in accordance with this standard.	Considered during testing	P
29.2	All tests conducted in accordance with this standard shall be conducted in an environment with a room ambient temperature of 25 ±5°C (77 ±9°F), unless otherwise noted in the test method. Any cooling systems or other auxiliary systems that are part of the ESS shall be operating during testing when their operation can affect the outcome of the test or when otherwise noted in the test method. For testing purposes, samples and parameters used for testing shall consider smallest size conductors and maximum allowed overcurrent protection in addition to worse case loading and temperatures conditions.	Considered during testing	P
29.3	Temperature shall be measured using thermocouples consisting of wires not larger	Considered during testing	P

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	than 0.21 mm^2 (24 AWG) and not smaller than 0.05 mm^2 (30 AWG) connected to a potentiometer-type instrument. Temperature measurements shall be made with the measuring junction of the thermocouple held tightly against the component/location being measured. For those tests that require the sample to reach thermal equilibrium (also referred to as steady state conditions), thermal equilibrium is considered to be achieved if after three consecutive temperature measurements taken at intervals of 10% of the previously elapsed duration of the test but not less than 15 min, indicate no change in temperature greater than ±2°C (±3.6°F).		
29.4	The tests contained in this standard may result in explosions, fire and emissions of flammable and/or toxic fumes as well as electric shock. It is important that personnel use extreme caution and follow local and regional worker safety regulations when conducting any of these tests and that they be protected from flying fragments, explosive force, and sudden release of heat and noise that could result from testing. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases. As an additional precaution, the temperatures on surfaces of parts that may get hot or cold during testing may be monitored during the test for safety and information purposes. All personnel involved in the testing shall be instructed to never approach the device under test (DUT) until temperatures have returned to within room ambient temperatures.		N/A

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PERFORMANCE – ELECTRICAL TESTS

30	**Normal Operations Test**		P
30.1	A normal operations test can be waived for equipment of an ESS where a similar evaluation such as a temperature test has already been conducted under the specific technology standard.	Normal operation test were performed	N/A
30.2	In conducting the electrical tests required in this Standard, the ESS shall be operated through a minimum of 2 cycles of charge and discharge of the system at the maximum loading rates as specified by the manufacturer. If a duty cycle is specified as noted in 45.4, then the discharge and charge cycles shall be repeated at the specified duty cycle until maximum temperatures during each part of the cycle achieve equilibrium. For each cycle, the ESS shall be discharged completely, recharged immediately to a full state of charge, followed by a delay to achieve the specified duty cycle.	2 cycles considered	P
	Exception: Normal operations testing on a subassembly may be conducted instead of the complete ESS if through analysis it can be determined to be representative of the ESS. The rationale used to determine the suitability of the subassembly to represent the complete ESS shall be documented.		N/A
30.3	During the test, consideration shall be given to maximum and minimum room ambient conditions. During operation, temperatures on critical components that are temperature sensitive shall be monitored and operating parameters of components of the system monitored to determine that they are operating within their ratings. If the ESS is intended for mounting on a wall, it shall be mounted as intended in accordance with installation instructions on a flat wall in an alcove that is painted a dull black, and temperatures shall be monitored on the wall surfaces during the test.	Considered during testing	P
30.4	During the normal operations test, the manufacturer's specified limits shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications in accordance with Table 30.1. Temperatures on accessible surfaces of the	Considered during testing	P

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	ESS shall not exceed the limits in accordance with Table 30.2.		
31	**Abnormal Operation Tests for Thermal Energy Storage Systems**		N/A
31.1	General		N/A
31.1.1	Thermal ESS shall remain in a safe state should the thermal controls, fluid controls or pressure controls of the system fail.		N/A
31.2	Faiure of thermal controls		N/A
31.2.1	The thermal ESS shall be operated during charging and discharging with a single fault within the thermal control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.		N/A
31.2.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the test, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.		N/A
31.3	Exposure to out of specification thermal conditions		N/A
31.3.1	The thermal ESS shall be subjected to a temperature conditions outside of the operating specifications of the system to determine if the controls will prevent an over temperature condition or other condition that could lead to a hazard. The ESS or a representative subassembly shall be subjected to an ambient of 70 °C (158 °F) or 20 °C (36 °F) above the maximum specified operating ambient, whichever is higher and then an ambient of -30 °C (-22 °F) or 20 °C (36 °F) below the lowest specified operating ambient, whichever is lower. The ESS shall be operated during this conditioning. For example, if supplied by solar, so that charging takes place during the day, the high temperature exposure shall take place during the charging phase. If the discharging phase is in the evening, the cold temperature exposure shall take place during the		N/A

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	discharge phase. Only one complete cycle of charge and discharge is required, and the DUT shall be charged or discharged until the end of each condition or until thermal controls stop the operation		
31.3.2	As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids. Thermal controls shall prevent the system from operating outside of safe limits.		N/A
31.4	Failure of pressure controls		N/A
31.4.1	The thermal ESS shall be operated during charging and discharging with a single fault within the pressure control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.		N/A
31.4.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.		N/A
31.5	Failure of fluid controls		N/A
31.5.1	The thermal ESS shall be operated during charging and discharging with a single fault within the various fluid level control systems relied upon for safety. Examples of these systems can include a gas system used to provide an inert atmosphere within containment chambers, a liquid leak control, etc. The test shall be repeated with the single fault in each separate fluid level control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one		N/A

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	discharge cycle.		
31.5.2	The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.		N/A
32	**Dielectric Voltage Withstand Test**		P
32.1	The dielectric voltage withstand test is an evaluation of the electrical spacings and insulation associated with the hazardous voltage circuits within the DUT.	See appended table	P
32.2	Circuits at 42.4 Vpeak/ 30 Vrms or 60 Vdc or higher shall be subjected to a dielectric withstand voltage in accordance with the "Determining clearances using required withstand voltage" clause of UL 62368-1/CSA C22.2 No. 62368-1.	Considered during testing	P
	Exception No. 1: Semiconductors or similar electronic components liable to be damaged by application of the test voltage shall be bypassed or disconnected.		N/A
	Exception No. 2: The dielectric voltage withstand test need not be conducted on integral ESS, fuel cells, and inverter systems, etc. that have already been evaluated in accordance with their individual standard requirements. Only those electrical parts external to the tested systems and their connections not previously evaluated need to be tested.		N/A
32.3	The voltage applied during the dielectric voltage withstand test is to be applied between the hazardous voltage circuits of the DUT and accessible non-current carrying conductive parts.	Considered during testing	P
32.4	The voltage applied during the dielectric voltage withstand test is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the DUT.	Considered during testing	P
32.5	The voltages applied during the dielectric voltage withstand test shall be applied for a minimum of 1 min.	Considered during testing	P
32.6	The test equipment shall consist of a 500 VA or larger capacity transformer, the output		P

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	voltage, which is variable and which is essentially sinusoidal if using ac test method, a dc output if using a dc test method. There is no trip current setting for the test equipment since the test is checking for insulation breakdown, which results in a large increase of current. Setting a trip current may result in a false failure of this test, as it is not necessarily indicative of insulation breakdown.		
	Exception: A 500 VA or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.		N/A
32.7	There shall be no evidence of a dielectric breakdown (breakdown of insulation resulting in a short through insulation/arcing over electrical spacings) as evidenced by an appropriate signal from the dielectric withstand test equipment as a result of the applied test voltage. Corona discharge or a single momentary discharge is not regarded as dielectric breakdown (i.e. insulation breakdown).		P
33	**Impulse Test**		P
33.1	The impulse voltage test is intended to evaluate the ESS's ability to withstand lightning or similar surges. Systems provided with protection that has already been evaluated for voltage surges (e. g. inverters meeting IEEE 1547 criteria) need not be tested if it can be determined that the parts connected to the power conditioning system can withstand any let through current that may occur.	See appended table	P
33.2	The impulse voltage test shall be performed with an impulse generator able to provide voltage having a 1.2/50 µs waveform (see the Full Impulse Voltage Time Parameters figure of IEC 61180) at voltages in accordance with Table 33.1, and is intended to simulate an overvoltage condition due to lightning or switching of equipment.	See appended table	P
33.3	Pulses shall be applied at 1.2/50 µs for each polarity in ≥ 1 s time intervals at the peak voltage for the rating of the circuit under test ±5% per Table 33.1. The test voltage is to be applied between the terminal/circuit under test and accessible parts. For circuits at 1000 V or	See appended table	P

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	less, three pulses at each polarity shall be applied. For circuits over 1000 V, 5 pulses at each polarity shall be applied.		
	Exception: Impulse test levels can be based on the transient voltage surge suppression device rating if provided.		N/A
33.4	As a result of the applied impulse voltage test, there shall be no puncture of insulation (i.e. electrical breakdown through solid insulation), occurrence of flashover (i.e. electrical breakdown over the surfaces of solid insulation), or spark-over (i.e. electrical breakdown through fluids such as air).	Considered during testing	P
34	**Equipment Grounding and Bonding Test**		P
34.1	The impedance of the system grounding and bonding circuit shall be determined using one of the following methods: a) The circuit between the grounding terminal and the part to be grounded is measured using impedance measuring equipment; b) In accordance with the Continuity of the Equipment Grounding Circuit section, Section 18.2 of NFPA 79 (voltage drop measurement of the circuit using a 10 A low voltage supply source); or c) In accordance with test in the Resistance of Earthing Conductors and Their Terminations clause, Clause 2.6.3.4 of UL 60950-1/CAN/CSA-C22.2 No. 60950-1 (measuring voltage drop in circuit using a low voltage supply source providing a current based upon circuit protection rating). d) The fault loop impedance measurement in accordance with IEC 60364-4-41. In Canada, the circuit under test is referred to as the bonding circuit per CSA C22.1.	Considered during testing	P
34.2	The impedance for all grounding and bonding circuits tested shall not exceed 0.1 Ω, or if using the test method in 30.1(d), the compliance criteria shall be in accordance with IEC 60364-4-41.	Considered during testing	P
35	**Insulation Resistance Test**		P
35.1	The resistance of insulation used on hazardous voltage circuits within an ESS shall be greater than or equal to 1 MΩ.	Considered during testing	P
35.2	The insulation resistance shall be measured using high impedance measuring equipment	Considered during testing	P

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	(e. g. mega ohmmeter) while applying a voltage of 500 Vdc between the live parts of the circuit under test and accessible conducting parts including the equipment grounding circuit, for 1 min.		
	Exception No. 1: Energy storage systems need not be tested if the insulation resistance has been previously evaluated as part of the particular technology safety standard.		N/A
	Exception No. 2: The insulation resistance test of IEC 60364-6 can be conducted instead.		N/A
	Exception No. 3: This test can be waived if the permanently connected wiring has: *a) A cross-section of the protective earthing conductor of at least 10 mm^2 if copper, or 16 mm^2 if aluminum; or* *b) Provision of an additional terminal for a second protective earthing conductor of the same cross-sectional area as the original protective earthing conductor and installation instructions requiring a second protective earthing conductor to be installed.*		N/A
	Exception No. 4: The touch current measurement test of IEC 62040-1 may be conducted instead.		N/A
35.3	Resistor (s) and/or resistor networks may be removed when conducting the insulation resistance test.		N/A
36	**Electromagnetic Immunity Tests**		P
36.1	General		P
36.1.1	Electronics and software controls determined to be critical for safety shall demonstrate sufficient immunity to electromagnetic interference by complying with the tests specified in these sections. Alternate test procedures and levels specified in other standards may be used, but only if they are equivalent or more severe than the test procedures and levels specified below. This testing is not required if EMI testing has already been conducted as part of the control's functional safety investigation.	The electromagnetic immunity tests were performed on the battery string or the BESS according to clause 27 of UL 1973:2022 which the test requirements considered equivalent with UL 9540:2023. Refer to 64.772.24.30223.01 for details.	P
	Exception: This testing does not apply to controls within components of the ESS that have already been evaluated for EMI exposure in accordance to their applicable		N/A

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	component standard such as UL 1741 for power conditioning systems.		
36.1.2	Each test shall begin with an operational DUT.	Considered	P
36.1.3	During the tests in this section, the DUT shall be operated in mode (s) that include the safety function (s) being evaluated. If multiple modes are to be considered (example: equipment controlling the charging and discharging of the energy storage device), the DUT shall either be cycled through those modes during the tests, or the tests repeated in each mode. While cycling through modes, the DUT shall not exhibit any signs of loss of safety functions or risk of fire, electric shock, or personal injury.	Safety function maintained during the test	P
36.1.4	After each test in this section, the DUT shall be inspected to verify that it is still operational. This may require Operational Verification (36.8) of the DUT if it is not possible to determine that it is fully operational by inspection. If the DUT is no longer operational, a failure analysis shall be conducted to determine the reason for the failure and to verify that the DUT has failed safely. A DUT that is no longer operational shall not be used on any remaining test.	Safety function maintained during the test	P
36.1.5	In addition, after all tests in this section have been completed, all samples used during the tests specified in Section 36 shall comply with the Operational Verification in Section 36.8.	Safety function maintained during the test	P
36.2	Electrostatic discharge		P
36.2.1	The DUT shall demonstrate immunity to electrostatic discharges in accordance with the test procedure specified in IEC 61000-4-2 and the modes of operation stated in 36.1.3.	Refer to test result of UL 1973:2022 clause 27.2 of 64.772.24.30223.01.	P
36.2.2	The following test levels shall be used: a) ±6 kV contact discharge; and b) ±8 kV air discharge.		P
36.2.3	After the test, the DUT shall comply with 36.1.4.		P
36.3	Radio-frequency electromagnetic field		P
36.3.1	The DUT shall demonstrate immunity to radio-frequency electromagnetic fields in accordance with the test procedure specified in IEC 61000-4-3 and the modes of operation stated in 36.1.3.	Refer to test result of UL 1973:2022 clause 27.3 of 64.772.24.30223.01.	P

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36.3.2	The following test levels shall be used: a) 10 V/m from 80 MHz to 1 GHz, 1 kHz (80% AM); and b) 3 V/m from 1.4 GHz to 6.0 GHz, 1 kHz (80% AM).		P
36.3.3	During the test, the DUT shall comply with 36.1.3.		P
36.3.4	After the test, the DUT shall comply with 36.1.4.		P
36.4	Fast transient/burst immunity		P
36.4.1	The DUT shall demonstrate immunity to electrical fast transients/bursts in accordance with the test procedure specified in IEC 61000-4-4 and the modes of operation stated in 36.1.3.	Refer to test result of UL 1973:2022 clause 27.4 of 64.772.24.30223.01.	P
36.4.2	The following test levels shall be used: a) On signal/control ports intended to be connected to cables longer than 3 m (118.1 in), ±1 kV (5/50 ns, 5 kHz); capacitive clamp shall be used: b) On input and output DC ports, ±1 kV (5/50 ns, 5 kHz); and c) On input and output AC ports, ±2 kV (5/50 ns, 5 kHz).		P
36.4.3	With reference to 36.4.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.4.2(c). External accessible DC ports shall be conducted using the test level specified in 36.4.2(b).		P
36.4.4	After the test, the DUT shall comply with 36.1.4.		P
36.5	Surge immunity		P
36.5.1	The DUT shall demonstrate immunity to surges in accordance with the test procedure specified in IEC 61000-4-5 and the modes of operation stated in 36.1.3.	Refer to test result of UL 1973:2022 clause 27.5 of 64.772.24.30223.01.	P
36.5.2	The following test levels shall be used: a) For I/O signal/control ports intended to be connected to long-distance cables longer than 30 m (118.1 in), which leave the building, and/or are for outdoor use, ±1 kV line-to-ground;		P

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	b) For input and output DC ports, ±0.5 kV line-to-line, and ±1 kV line-to-ground; and c) For input and output AC ports, ±1 kV line-to-line, and ±2 kV line-to-ground.		
36.5.3	With reference to 36.5.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.5.2(c). External accessible DC ports shall be conducted using the test level specified in 36.5.2(b).		P
36.5.4	After the test, the DUT shall comply with 36.1.4.		P
36.6	Radio-frequency common mode		P
36.6.1	The DUT shall demonstrate immunity to radio-frequency conducted disturbances in accordance with the test procedure specified in IEC 61000-4-6 and the modes of operation stated in 36.1.3.	Refer to test result of UL 1973:2022 clause 27.6 of 64.772.24.30223.01.	P
36.6.2	The following test levels shall be used: a) For I/O signal/control ports intended to be connected to cables longer than 3 m (118.1 in), 10 V (150 kHz to 80 MHz, 1 kHz, 80% AM); b) For input and output DC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80% AM); and c) For input and output AC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80% AM).		P
36.6.3	With reference to 36.6.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.6.2(c). External accessible DC ports shall be conducted using the test level specified in 36.6.2(b).		P
36.6.4	During the test, the DUT shall comply with 36.1.3.		P
36.6.5	After the test, the DUT shall comply with 36.1.4.		P
36.7	Power-frequency magnetic field		P
36.7.1	The DUT shall demonstrate immunity to power-frequency magnetic fields in accordance with the test procedure specified in IEC 61000-4-8 and the modes of operation stated in 36.1.3.	Refer to test result of UL 1973:2022 clause 27.7 of 64.772.24.30223.01.	P
36.7.2	The following test level shall be used: 10 A/m.		P

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Clause	Requirement + Test	Result – Remark	Verdict
36.7.3	During the test, the DUT shall comply with 36.1.3.		P
36.7.4	After the test, the DUT shall comply with 36.1.4.		P
36.8	Operational verification		P
36.8.1	After the tests in 36.2 – 36.7 have been completed, all samples used during these tests shall comply with the following.		P
36.8.2	The manufacturer shall declare the anticipated performance of all safety functions performed by electronics and software controls.		P
36.8.3	The manufacturer shall provide test procedures to verify that each of the safety functions performed by electronics and software controls is working correctly. This may include, for example, verification of correct safety function performance by simulation.		P
36.8.4	During the test procedures specified in 36.8.3, each DUT shall exhibit one of the following behaviors: a) No loss of safety functions; or b) Transition to an appropriate state to ensure safe operation of the DUT.		P
36.9	Operational verification of remote software update capability		N/A
36.9.1	The test of 36.8 shall be conducted on safety controls intended for remote software updates in accordance with Section 16 to ensure that they are operational after the update. See 16.1.7 and 16.2.8.		N/A

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PERFORMANCE – MECHANICAL TESTS

37	**Containment of Moving Parts**		N/A
37.1	Control system fault overspeed test		N/A
37.1.1	An ESS with moving parts having the capacity to store kinetic energy that is capable of being subjected to over speed conditions through a fault in the system controls shall be subjected to an over speed test.		N/A
37.1.2	The system controls shall be subjected to single fault in the controls that would allow over speed of the moving parts. The DUT shall be operated at over speed conditions until a secondary protection control operates to stop operation of the DUT.		N/A
37.1.3	As a result of the over speed condition, the moving part (s) shall not become loosened or disconnected in a manner that would result in a hazardous condition. If completely loosened or disconnected as a result of the over speed conditions, the containment means shall safely contain the part (s) in accordance with the Faulted Securement Test in 37.2.		N/A
37.1.4	The system controls shall limit the overspeed to a level less than the speed defined in 37.4.		N/A
37.2	Faulted securement test		N/A
37.2.1	An ESS with moving parts with the capacity to store kinetic energy shall be subjected to the faulted securement test when a fault in primary securement means of the moving part has the potential to result in a hazard.		N/A
37.2.2	The moving parts of the system shall be subjected to a single fault of the primary means of securement while operated at the maximum speed anticipated during normal operation. The primary means of securement to be removed, such as a failed bearing, shaft, or other part of the securement of the moving part with respect to the stationary housing, shall be determined through a safety analysis that identifies failure of the selected means as representing the potential worst case condition. Refer to Section 15 for the safety analysis requirements.		N/A
37.2.3	This test is not required in cases where test or field data is available to support the safety analysis indicating that there is not a hazard		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	associated with the loss of primary securement.		
37.2.4	The system shall be operated until one of the following occurs: a) The part has operated for 30 min under the faulted condition; b) A protection control operates to stop operation of the DUT or hazardous moving part; or c) The part has loosened and is completely or partially disconnected from its securement means.		N/A
37.2.5	As a result of the operation with a faulted securement condition, the moving part (s) shall not become loosened or disconnected to result in a hazardous condition. If completely loosened or disconnected, the containment means for the part shall safely contained the part(s).		N/A
37.3	Blocked shaft test		N/A
37.3.1	An ESS with moving parts with the capacity to store kinetic energy shall be subjected to the blocked shaft test if blocking the shaft or moving parts has the potential to result in a hazard.		N/A
37.3.2	With the moving part blocked to prevent movement, the system shall be operated at maximum operating conditions.		N/A
37.3.3	The system shall be operated: a) With the part blocked for 30 min and then stopped; b) Until a protection control operates to stop operation of the DUT with the blocked part; or c) Until any moving parts break off or become completely or partially disconnected from its securement means.		N/A
	Exception: Moving parts already evaluated for blocked shaft conditions as part of a component evaluation, need not be tested.		N/A
37.3.4	As a result of operating the system with a blocked shaft/moving part condition, the part shall not become loosened or disconnected to result in a hazardous condition. If the part becomes completely loosed or disconnected, the containment means for the part shall safely contain the part(s). There shall be no		N/A

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	overheating of parts that will result in a hazard such as fire or explosion.		
37.4	Mechanical integrity test		N/A
37.4.1	An ESS with any moving part having the capacity to store kinetic energy shall have the mechanical (i.e. rotating) energy storage elements designed to have a minimum margin factor of safety. The factor of safety requirements vary depending on the material of construction. The factor of safety based on material type shall be as follows:		N/A
	a) For assemblies composed of laminated composite materials, the minimum factor of safety shall be at least 2.0 between the maximum principal stress that exists at the point of highest stress in each layer of the mechanical energy storage element and the ultimate strength of that layer at that point. The factor of safety shall be evaluated at maximum normal operating speed and at a room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F).		N/A
	b) For assemblies composed of ductile metallic materials exhibiting a traditional nonlinear stressstrain curve, the minimum factor of safety shall be at least 1.3 between the maximum von Mises stress that exists anywhere in the mechanical energy storage element at maximum normal operating speed and the tensile yield strength of the material where the stress exists at room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F).		N/A
	c) For other material types and combinations of materials including metals and laminated composites, the minimum factor of safety shall be at least 2.0 between the maximum combined stress that exists anywhere in the mechanical energy storage element at maximum normal operating speed and the ultimate tensile strength of the material where the highest stress exists at room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F).		N/A
37.4.2	The mechanical energy storage element shall be subjected to an overspeed type test demonstrating the required factor of safety. The DUT shall be representative of the latest design revision and subjected to an		N/A

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	overspeed and corresponding stress as follows in (a) or (b). For the purpose here, rotor working stress is presumed to scale exactly as the square of the rotation speed.		
	a) Where the minimum required factor of safety is 2.0, the overspeed shall be at least 139 %. The DUT shall sustain the overspeed for a time period of 1 min without ruptures in of any part of the assembly.		N/A
	b) Where the minimum required factor of safety is 1.3, the overspeed shall be 120 % minimum. The DUT shall sustain the overspeed for a time period of 1 min. Yielding of the material during the test is permitted as long as the test requirement is met and the DUT can be shut down afterward in a normal manner (i.e. through braking or discharge of the stored energy). This condition implies that margin between the maximum Von Mises stress in the part at normal operating speed and the ultimate tensile strength of the material must be greater than 1.45 to successfully pass the overspeed test		N/A
37.4.3	With reference to 37.4.2, for a hollow cylindrical mechanical energy storage element, as an alternative to the dynamic test, a static test (e.g. hydrostatic or pneumatic strength test) may be performed whereby the DUT is subjected to an internal pressure that creates maximum stress in the DUT that is greater than 2x the maximum stress under normal operating conditions.		N/A
37.4.4	With reference to 37.4.2 and 37.4.3, the mechanical energy storage element DUT shall: a) Be a production mechanical energy storage element; b) Be according to the latest design revision; and c) Meet the manufacturer's quality assurance requirements for production units.		N/A
37.4.5	Alternatively to the overspeed test requirements of 37.4.2, the standard installation of the energy storage element shall demonstrate containment of a failure of the mechanical energy storage element.		N/A

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	Containment is defined as NO primary particles (energy storing components, their fragments, or other moving parts) and NO secondary projectiles (stationary components of the product or their fragments set into motion by the failure event) are to exit the device's outermost housing, containment media, or installation area. This test shall be performed at 100 % of maximum rated operating stress or above.		
37.4.6	With reference to 37.4.1 – 37.4.5, the testing shall be repeated in the event of a deviation of any mechanical characteristic or material property that results in an increase of more than 10 % between calculated stress in production energy storage elements and demonstrated stress in the previously qualified mechanical energy storage element		N/A
37.5	Bearing failure test		N/A
37.5.1	An ESS with moving parts with the capacity to store kinetic energy that relies upon a primary set of bearings in its moving mechanism, in any form, shall be subjected to a bearing failure test if failing the bearings has the potential to result in a hazard. Refer to Section 15 for the safety analysis requirements		N/A
37.5.2	With the system operating at maximum operating conditions, a failure in the primary bearings shall be induced that results in the loss of the primary bearing function and forces the DUT to spin down on its backup bearing or other suitable support system..		N/A
37.5.3	The system shall be operated: a) Until the DUT's energy is dissipated and it has come to a stop; b) Until a protection control operates to stop operation of the DUT; or c) Until any moving parts break off or become completely or partially disconnected from its securement means.		N/A
37.5.4	This test is intended to verify that the backup bearing or support system for the energy storage element is effective. This test may also suffice as the faulted securement test described in 37.2 if the safety analysis indicates a bearing failure as the worst case condition.		N/A

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37.5.5	As a result of operating the system with a failed bearing condition, the moving parts shall not become loosened or disconnected to result in a hazardous condition. If the part becomes completely loosed or disconnected, the containment means for the part shall safely contain the part(s). There shall be no overheating of parts that will result in a hazard such as fire or explosion.		N/A
38	**Leakage Tests**		N/A
38.1	Energy storage systems that contain hazardous fluids shall be subjected to the Leakage Test in accordance with 38.2 and 38.3.		N/A
	Exception: Leakage testing need not be conducted if parts containing hazardous fluids and their connections have already been evaluated for external leakage as part of a component standard such as the appendix for Test Program for Flowing Electrolyte Batteries, Appendix C, of UL 1973 or CSA FC 1 for fuel cell systems.		N/A
38.2	Leakage from ESS containing hazardous fluids shall not result in the risk of fire, electric shock, or injury to persons.		N/A
38.3	Compliance is determined by subjecting the fluid-containing parts and their connections to a fluid pressure of 1.5 times the maximum operating pressure (if testing with liquid) or 1.1 times the maximum operating pressure (if air pneumatic testing) of intended use during operation of the system. There shall be no leaks from fluid-containing parts or their connections as a result.		N/A
39	**Strength Tests**		P
39.1	General		P
39.1.1	Energy storage systems that contain hazardous fluids shall comply with the Strength Tests in accordance with 39.2 and 39.3.	Pneumatic strength test performed for cooling system carried with coolant	P
39.2	Hydrostatic strength test		N/A
39.2.1	Parts of the ESS containing hazardous fluids (gases or liquids) shall be subjected to a hydrostatic strength test of 1.5 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased		N/A

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	until the maximum pressure is reached in approximately 1 min using either the liquid used in the system or water. Testing is done at room ambient temperature.		
39.2.2	As a result of the hydrostatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.		N/A
39.3	Pneumatic strength test		P
39.3.1	The pneumatic strength test is an alternative to the hydrostatic strength test of 39.2 and is conducted in accordance with 39.3.2.		P
39.3.2	Parts of the ESS containing hazardous fluids (gases or liquids) shall be subjected to a pneumatic strength test of 1.3 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either air or inert gas. Testing is conducted at room ambient temperature.	Design maximum pressure rating is 350 kPa. Test pressure is 525 kPa absolute pressure (425 kPa gauge pressure).	P
39.3.3	As a result of the pneumatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.		P
40	**Enclosure and Mounting Tests**		N/A
40.1	Wall mount fixture/test		N/A
40.1.1	A wall mounting apparatus of a wall mounted ESS shall have sufficient strength to support the system. Compliance is determined by the following test.		N/A
	Exception: Individual components of an ESS that are provided with their own wall mount apparatus previously tested as part of their component evaluation, need not be tested.		N/A
40.1.2	The wall mounting apparatus and ESS shall be installed in accordance with the manufacturer's specifications. A force equal to three times the weight of the ESS is additionally applied to the center of the mounting apparatus in a downward direction. The force shall be held for 1 min.		N/A
40.1.3	As a result of the applied force, there shall be no damage to the mounting apparatus and its securement means when testing the wall mounting fixture.		N/A
40.2	Enclosure impact		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
40.2.1	The purpose of this test is to evaluate the mechanical integrity of the enclosure and its ability to provide mechanical protection to the ESS enclosure contents. This test is conducted on electrochemical ESS that are for residential applications or for non-residential applications that are less than or equal to 50 kWh.		N/A
40.2.2	A fully charged DUT shall be subjected to a minimum of three impacts of 6.8 J (5 ft-lb) on any surface that can be exposed to a blow during intended use. The impact shall be produced by dropping a steel sphere, 50.8 (2 in) in diameter, and weighing 535 g (1.18 lb) from a height, H, of 1.29 m (50.8 in). For surfaces other than the top of an enclosure, the steel sphere shall be suspended by a cord and swung as a pendulum, dropping through the vertical height of 1.29 m (50.8 in), with the product being impacted placed against a restraining vertical wall. See Figure 40.1. A different sample may be used for each impact		N/A
40.2.3	After the impacts, the DUT shall be subjected to a Dielectric Voltage Withstand Test in accordance with Section 32. The DUT shall be examined for signs of rupture or damage that could lead to a hazard.		N/A
40.2.4	As a result of the impact test, there shall be no damage to the enclosure that could result in a hazard such as exposure of hazardous parts or result in a dielectric breakdown.		N/A
40.4	Mold stress		N/A
40.4.1	The purpose of this test is to determine if an enclosure made from molded polymeric material can withstand an accelerated aging test without compromising the safety of the enclosure.	Metal enclosure	N/A
40.4.2	One complete fully discharged sample shall be placed in a full-draft circulating-air oven maintained at a uniform temperature of at least 10 °C (18 °F) higher than the maximum temperature of the enclosure measured during the Normal Operations Test in Section 30, but not less than 70 °C (158 °F). The sample shall remain in the oven for 7 h.		N/A
40.4.3	After removal from the oven the DUT shall be subjected to a Dielectric Voltage Withstand Test in accordance with Section 32. The DUT		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	shall be examined for signs of rupture and damage		
40.4.4	As a result of the mold stress conditioning, the sample shall show no evidence of mechanical damage, such as cracking of the enclosure exposing hazardous parts or result in a dielectric breakdown.		N/A

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PERFORMANCE – ENVIRONMENTAL TESTS

41	**Special Environment Installations**		P
41.1	General		P
41.1.1	Energy storage systems intended for installation in special environments shall be evaluated for their ability to operate safely in those environments. These environmental conditions can include exposure to salt fog for marine environments, testing for seismic ratings, high altitudes, etc. The requirements of 41.2, 41.3 and 42.4 shall apply depending upon the particular exposure. The installation instructions and nameplate labels on the ESS shall identify the special environmental conditions in accordance with 45.3, 45.17, and Section 46.		P
	Exception No.1: Testing need not be conducted on systems or parts of the system if already covered as part of the specific technology safety standard.		N/A
	Exception No 2: Environmental testing on a subassembly may be conducted instead of the complete ESS if through analysis it can be determined to be representative of the ESS. The rationale used to determine the suitability of the subassembly to represent the complete ESS shall be documented.		N/A
41.2	Outdoors installations subject to moisture exposure		P
37.2.1	Energy storage systems intended for installation outdoors where they will be subject to rated levels of moisture exposure shall be tested in accordance with their environmental ratings outlined in their nameplate labels and installation instructions of 45.17 and 46.13.		P
41.2.2	Based upon the ratings of the system, moisture resistance testing shall be done in accordance with either IEC 60529, UL 50E, or C22.2 No. 94.2.	IP55 (Battery Room) IP55 (Electrical Room) IP67 (Electrical Control Box of Chiller)	P
41.2.3	At the conclusion of the test, the sample is to be subjected to the electric insulation tests of Sections 32 and 35 and examined for signs of water in the system that could result in a hazardous condition.		P
41.2.4	As a result of the water exposure, there shall be no evidence of water on parts that could		P

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	result in a hazard and no reduction of spacings or breakdown/deterioration in insulation levels.		
41.3	Outdoor installation in marine environments		P
41.3.1	Energy storage systems intended for installation outdoors in marine environments in accordance with the installation instructions in 46.13 where they will be subject to salt fog exposure, shall be tested as outlined below.		P
41.3.2	The systems shall be tested in accordance with IEC 60068-2-52 for Severities 1 or 2.	Severities 2 considered.	P
41.3.3	At the conclusion of the testing, the systems shall be subjected to the electrical insulation tests of Sections 32 and 35 to determine that insulation has not been damaged in a manner that would result in an electric shock hazard.		N/A
41.3.4	The system shall be examined for signs of damage as a result of salt exposure that would indicate a potential for a safety hazard (e.g. corrosion of parts that could result in weakening of a securement or an enclosure, damage to insulation). If operational, the system is to be operated to determine that it can do so without hazard.		N/A
41.3.5	As a result of the test, the ESS shall not show evidence of damage from salt fog exposure that could result in a hazard such as electrical, shock, overheating or damage that could result in a physical hazard.		P
41.4	Installation in seismic environments		N/A
41.4.1	Equipment of an ESS that contains the energy storage mechanism and is intended for installation where they will be subject to seismic activity shall be evaluated and if necessary tested in accordance with their seismic ratings and installations instructions per 45.3 and 46.13. The installation instructions shall indicate the limitations of the particular seismic rating of the equipment. Standards that provide guidance on seismic evaluation such as IEEE 693, IEC 60980, the seismic testing in GR-63-CORE, or similar, shall be used for this evaluation. Compliance is determined through review of documentation of the seismic evaluation for the appropriate seismic level (i.e. level marked on the equipment) or through testing	Not intended for installation in seismic environments	N/A

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	for the specific seismic level in accordance with a testing standard for this purpose		
	Exception No. 1: There is equipment that cannot be practically evaluated by testing alone because of the size of the equipment. For those situations, it may be necessary to do a combination of analysis with testing of parts of the system. This approach is outlined in IEEE 344.		N/A
	Exception No. 2: Some standards allow for calculations and modelling as an approach for determining compliance for seismic ratings in lieu of testing.		N/A
41.4.2	The ESS shall be examined for signs of explosion, fire, combustible concentrations (if applicable to technology), rupture of the enclosure, electrolyte leakage, electric shock and loss of protection controls that lead to any of the other non-compliant results in 41.4.3.		N/A
41.4.3	As a result of the test, any of the following results in (a) – (g) are considered a non-compliant result: a) Explosion; b) Fire; c) Combustible Concentrations (if applicable to technology); d) Rupture (enclosure); e) Electrolyte Leakage (external to enclosure); f) Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown); g) Loss of protection controls.		N/A

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MANUFACTURING AND PRODUCTION TESTS

42	**Electrical Production Tests**		P
42.1	Dielectric Voltage Withstand Test		P
42.1.1	A dielectric withstand test as outlined in the Dielectric Voltage Withstand Test in Section 32 shall be conducted on 100% production of ESS with working voltage exceeding 60 Vdc or 30 Vrms/42.4 Vpeak.	Manufacturing and production tests shall be performed in accordance with clause requirements.	P
	Exception No. 1: The time for the production Dielectric Withstand Test can be reduced to 1 s.		N/A
	Exception No. 2: Testing can be conducted on subassemblies of the system.		N/A
	Exception No. 3: Testing can be waived if conducted as part of the specific technology evaluation (i. e. tested per UL 1973, etc.).		N/A
42.2	Grounding and bonding system check		P
42.2.1	The grounding and bonding system of an ESS shall be subjected to a check using an impedance measuring device. The measurements shall occur between any two locations of the grounding and bonding system.	Manufacturing and production tests shall be performed in accordance with clause requirements.	P
42.2.2	No resistance measurements of the grounding and bonding system shall exceed 0.1 Ω or allowed limits per 34.2.		P
	Exception: This testing can be waived if it is determined that the ESS construction and production methods to ensure good grounding and bonding of the system production can be determined through a review of production practices. However, if any point of the grounding system is maintained through a single fastener, a ground bond test shall be conducted.		N/A
43.3	Check of safety controls		P
43.3.1	Energy storage systems shall be subjected to 100% production screening to determine that any active controls utilized for safety are functioning.		N/A
	Exception: This check of the safety controls can be conducted on subassemblies or components of the system before final assembly.	Manufacturing and production tests shall be performed in accordance with clause requirements.	P
43	**Mechanical Production Tests**		P

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Clause	Requirement + Test	Result – Remark	Verdict
43.1	Maximum abnormal operating speed		N/A
43.1.1	Every production mechanical storage element shall be subjected to a maximum abnormal operating speed test. The test shall be performed at the maximum speed reached during the Over Speed Test of 37.1. The test shall be performed in an environment which will safely contain any mechanical failure of the mechanical storage element.		N/A
43.1.2	As an alternative to 43.1.1, the components of a mechanical energy storage element (e.g. forged disk) shall be processed consistently and tested to ensure that the materials used in its construction meet the minimum requirements assumed during the design and analysis of the element. The engineering development and production testing protocol for the components of the energy storage element shall demonstrate the level of uniformity of the material properties throughout critical sections of the component and that the material properties meet required minimum values consistently.		N/A
43.2	Production screening of rotors		N/A
43.2.1	Rotor assemblies for mechanical ESS shall be subject to 100% production screening through the use of ultrasonic testing or other means to check for cracks and other flaws in the rotor in order to determine that the rotor is manufactured in accordance with the manufacturer's specifications.		N/A
43.2.2	As an alternative to 43.2.1, additional in progress quality checks and testing can be incorporated into the manufacturing assembly process to limit the presence of cracks or flaws in finished product. Refer to 44.1.		N/A
43.3	Leak check of hazardous fluid systems		P
43.3.1	ESS that contain hazardous fluids including ESS with liquid coolant systems shall be subjected to a leak check in accordance with Section 38 of the assembled fluid containment system.		P
44	**Production Quality Control**		P
44.1	Manufacturers of ESS shall have documented production process controls in place that continually monitor the following key elements of the manufacturing process that can affect		P

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	safety, and shall include measured parametric limits enabling corrective/preventative action to address defects (out of limit parameters) found affecting these key elements: a) Supply chain control; and b) Assembly processes.		

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MARKINGS

45	**General**		P
45.1	The markings including signage required for compliance to this standard shall be legible and permanent such as metal stamped, etched, adhesive labels, etc. An adhesive-backed label shall comply with the requirements in UL 969 or CSA C22.2 No. 0.15, for the intended exposure conditions and surface adhered to.	Metal stamped	P
45.2	Markings and signage shall be in lettering that is sized so that it is legible from the distance from which it must be read and shall have lettering in a color that contrasts with the background. Guidance for markings and signs can be found in standards such as ISO 3864-2, NEMA Z535.1, NEMA Z535.2, NEMA Z535.3, NEMA Z535.4, and NEMA Z535.5.	Inspected	P
45.3	An ESS shall be provided with a nameplate marking (main label) that includes the following:	Inspected	P
	a) The ESS model, catalog number or similar identifier and technology of the ESS; b) Identifies that the system is a DC ESS or AC ESS as applicable; c) Identifies the manufacturer responsible for the evaluated ESS; d) Provides the contact information per 45.10; e) Residential ESS on or in a dwelling unit shall be marked as follows: 1) If meeting the requirements of 26.2.2: “Suitable for Use in Residential Habitable Spaces”; or 2) For systems intended for installation in Canada, systems meeting the cell level performance criteria of UL 9540A shall be marked with “This equipment meets the cell level performance criteria of UL 9540A”; 3) If meeting the requirements of 26.2.3 "Suitable for Use in Residential Non-Habitable Spaces"; f) Includes the following information and ratings: 1) Output and input current (maximum continuous) for each power port in Amps; 2) Output and input voltage (minimum and maximum) for each power port in Volts;	Inspected, non-residential ESS, see label information	P

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	3) Power input and output (maximum continuous) for each power port in W / kW or VA /kVA; 4) Energy storage capacity in Wh / kWh (maximum); 5) DC or Frequency in Hz and number of phases for each power port; 6) Auxiliary output and input voltage (V), current (A) and frequency (Hz) if applicable; 7) Input short-circuit current rating (SCCR) in A / kA; 8) Maximum overcurrent protective device rating in Amps; 9) Output available fault current (as defined in Article 100 of NFPA 70) and time duration that the equipment can provide; 10) Special environmental ratings and limitations as applicable (e.g. seismic, indoor/outdoor only, etc.); and 11) Suppression system to be installed if applicable.		
45.4	With reference to 45.3, if the system is intended to be operated in a duty cycle, the intended duty cycle shall be included on the nameplate.		N/A
45.5	With reference to 45.3, the suppression system to be installed, if applicable, shall be marked on the system.		N/A
45.6	With reference to 45.3, the operating ambient conditions in °C or °F, the weight of the system in kilograms or pounds, and the overall dimensions of the system can either be marked on the system or provided in the installation instructions.		P
45.7	For multi-part ESS, a nameplate marking (main label) noted in 45.3 shall be provided on at least one of the parts and shall identify that the system has been evaluated as a multi-part ESS.	Not multi-part ESS	N/A
45.8	The items in 45.4 – 45.6 shall be included as applicable to the system. With reference to 45.7, each separate part of the multi-part ESS shall have a nameplate marking as required by the equipment safety standard to which it was evaluated..		N/A
45.9	With reference to 45.7, where not included in the end-product standard or label, the	Not multi-part ESS	N/A

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	following information shall be included in the ESS installation instructions as applicable to the ESS:		
	a) Single-line electrical diagram of the ESS identifying all interconnections and ports; b) Input short circuit current rating (SCCR) in A / kA that each component can withstand from other parts of the ESS if the connection point is a power input or bi-direction power connection; and c) Available fault current (as defined in Article 100 of NFPA 70) and time duration that the ESS part can provide to other parts of the ESS if the connection point is a power output or bi-directional power connection.		N/A
45.10	Contact information for the system in the event of an emergency or problems with the system shall be marked on the system.	To be provided in the final installation	N/A
45.11	Energy storage systems shall also be marked with the date of manufacture, which is permitted to be in the form of a code that does not repeat within 20 years. All external terminals and connections shall be provided with identification.	Inspected	P
45.12	The point of connection to the charger earth grounding system shall be identified by the word "Ground" or the letters "G" or "GR" or the grounding symbol IEC 60417 Database, No. 5019 (upside down tree within a circle) or otherwise identified by a distinctive green color. Any other grounding terminals shall also be identified in a manner that is distinctive from the main earth ground terminal for the charger system.	Inspected	P
45.13	The ESS that contains hazardous voltage circuits shall be marked "WARNING: Hazardous Voltage Circuits" or be marked with the electric shock hazard symbol ISO 3864 No. 5036 (lightning bolt within a triangle). Electrical equipment parts of the ESS such as control panels and the enclosures of disconnecting devices shall also be marked with arc flash markings according to NFPA 70E or CSA Z462 and arc flash personal protective equipment (PPE) requirements, to warn service personnel of potential for arc flash hazards, and necessary protection to be worn if applicable. See also	Inspected	P

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	10.11 regarding arc flash label requirements for equipment.		
45.14	ESS other than electrochemical ESS that contain hazardous materials such as flammable solids or fluids or toxic or other hazardous materials shall be marked in accordance with NFPA 704.		N/A
45.15	Energy storage systems shall be marked as follows: "WARNING: To Reduce the Risk of Injury, read all instructions" or marked with the symbols W001 (i. e. exclamation point in triangle) and M002 of ISO 7010.	Inspected	P
45.16	Energy storage systems with walk-in enclosures shall be provided with necessary cautionary markings per 10.9 and 10.10, and shall be marked with the following or equivalent: “WARNING: Risk of Electric Shock or Other Serious Injury. Care shall be taken when entering enclosure – Authorized personnel only.”	Not walk-in enclosure	N/A
45.17	An ESS intended for installation where exposed to moisture shall be marked with the environmental rating of its enclosure (i.e. IPX2, Type 4X, etc.) suitable for that type of exposure. See 41.2.	Inspected	P
45.18	The control devices and indicators required for operation or maintenance shall be marked with their function on or adjacent to the control. See also 10.7 and 45.19 regarding door signs.	Inspected	P
45.19	An egress door per 10.7 shall be marked with the word "Exit" and the line-of-sight to an exit sign shall not be interrupted. Any doorway or passage that might be mistaken for an exit shall be marked "Not an Exit" or with an indication of its actual use.	Not walk-in enclosure	N/A
45.20	A non-residential use electrochemical ESS that complies with 1.6(b) shall be marked, "ESS with capacities exceeding 50 kWh shall include the additional fire suppression and/or fire protection identified in the installation instructions."	Risk assessment shall be further performed at final installation location according to UL 9540A report	N/A
45.21	A non-residential use electrochemical ESS intended for use in remote outdoor locations per 1.6(d) shall be marked "For use only in remote outdoor locations as permitted in applicable installation codes and standards."	Risk assessment shall be further performed at final installation location according to UL 9540A report	N/A

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45.22	ESS disconnect controls, such as manual Emergency Power Off (EPO) disconnects, shall be marked to clearly indicate what system or part of the system they control. An EPO need not be provided with this marking if it disconnects and de-energizes the entire ESS.	The Emergency stop button could triger the contactors in high voltage controlling box to disconnect the battery strings input/output of the ESS.	P

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INSTRUCTIONS

46	**General**		P
46.1	The ESS shall be provided with complete instructions for installation, commissioning, operation and maintenance that includes the following information: a) Procedures for system commissioning and decommissioning; b) Complete installation instructions, including calibration, programming, control sequence descriptions for battery management and other monitoring systems; c) Initial acceptance testing procedures; d) Ongoing inspection and testing procedures; e) Instructions for retrofitting system components (non-residential use systems); and f) Instruction for providing working clearances.	Installation manual reviewed	P
46.2	The installation instructions shall identify the maximum rated energy capacity for the system and minimum separation distances from other ESS and from exposures (e. g. combustibles, structures) in accordance with the limitations to the system based on applicable codes or in accordance with the large scale fire testing of 26.2.	Refer to the Operating Instruction and Maintenance Manual	P
46.3	Installation instructions for exterior wall-mounted ESSs shall identify the minimum separation distances from other ESS or from openings (e.g. windows, doors, HVAC inlets or other operable openings) in accordance with the code limitations or in accordance with the large scale fire testing of 26.2.		N/A
46.4	For non-residential use systems that require large scale fire testing of 26.2 in order to exceed code capacity limitations or reduce separation distances for their anticipated installation, the instructions shall identify the UL 9540A test report that was used to validate the anticipated installation including the testing organization, report designation, and date.		N/A
46.5	For ESS requiring large scale fire testing per 26.2, any additional fire suppression and/or fire protection and explosion protection identified in the UL 9540A test report shall be included in the installation instructions.		N/A

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46.6	Unless further limited by manufacturer's installation instructions, instructions for electrochemical ESS for indoor residential use shall indicate that the units are only intended to be installed in attached or detached garages, sheds, enclosed utility closets, basements, storage or utility spaces within dwelling units and are not intended for installation in habitable spaces and livings spaces in dwelling units.	Outdoor non-residential use	N/A
46.7	Installation instructions for indoor electrochemical ESS marked "Suitable for Use in Residential Habitable Spaces" shall be permitted to indicate the units are suitable for use in residential dwelling units, including in the living or habitable spaces, provided that they meet the criteria as noted in 26.2.2.	Outdoor non-residential use	N/A
46.8	The instructions shall be in accordance with the Technical Documentation section, Section 17 of NFPA 79, or CSA C22.2 No. 301, and in accordance with 46.2 – 46.10. For additional guidance see NEMA Z535.6. Instructions for installation, operation and maintenance of the ESS shall address electrical safety including arc flash in accordance with NFPA 70E or CSA Z462.		P
46.9	All cautionary markings and ratings provided on the system, as well as system specifications needed for installation and operation of the system, shall be included in the instructions. If provided with remote controls, the system installation, operation and maintenance instructions shall be provided with instructions regarding operation of the remote controls and disconnecting the remote control in accordance with 17.1.		P
46.10	The installation information shall include instructions for making all necessary connections for electrical, communications, piping for fuels and other fluids, etc. as well as connections to other equipment that are part of the system. Multi-part ESS shall have all parts identified in the installation instructions with instructions for the installation and interconnection of those parts. The instructions shall include information on electrical disconnects, shut off valves and other devices required to be installed with the system. The installation instructions shall include the parameters required for electrical		P

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	connections and installed devices in electrical circuits (communication protocols, circuits and devices) as well as parameters for fuel and other fluid connections and control devices necessary for the operation of the ESS. If the ESS controls were required to undergo a functional safety evaluation, the installation instructions shall include the functional safety standard to which the ESS was found compliant as well as the specific critical functions that were evaluated and found compliant.		
46.11	The installations instructions shall specify that the system be installed in accordance with local electrical, building, fire and other codes or utility requirements as applicable to the installation and equipment, by qualified service personnel in accordance with the installation instructions and appropriate practices. Systems intended for installation in restricted access locations per 6.35 shall be designated by the manufacture as to the specifics of those locations if they are to be considered under this standard. If restricted access locations are identified by the manufacturer, the training required to gain access shall also be identified by the manufacturer including information in the installation, operation and maintenance instructions. Any specific application location information that limits the location of the system to specific facilities, buildings, or locations such as for utility premise installations, residential buildings or commercial buildings, etc. shall be identified in the installation instructions.		P
46.12	With reference to 46.9, the installation instructions for ESS, such as flow batteries, lead acid batteries, etc., containing free electrolyte (greater than 208 L (55 gal) in a single vessel or an aggregate of 3785 L (1000 gal)) shall be provided with instructions for location of eye wash stations. In addition, if necessary in accordance with building codes, installation instructions shall provide information on spill control to be installed with the system per 23.1 and 23.3.		N/A
46.13	Energy storage systems intended for installation only in certain environments such as indoors only or where exposed to moisture, seismic activity or marine environments, or to		P

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	be installed in restricted access locations, shall indicate this in the installation instructions. Systems intended for exposure to moisture, marine environments or seismic activity per installation instructions shall be evaluated per Section 41.		
46.14	The installation instructions for a DC ESS shall include specifications for the equipment performing electric power conditioning or conversion function that is intended to be connected for supplying the DC ESS as shown in Figure 6.1, including if it is part of the DC load that the DC ESS is supplying. The instructions can include the specific equipment or systems to be used or can provide sufficient parameters required to safely connect to the DC ESS such as, but not limited to electrical ratings, communication requirements, environmental requirements, short circuit tolerance as applicable to the DC ESS.		P
46.15	Indoor installation instructions for residential use ESS shall provide instructions on smoke alarms to be provided in the residence in accordance with building, fire and installation codes.		N/A
46.16	The installation instructions shall include any special handling and safeguard measures to be followed during installation and shall include details of support structures such as concrete pads, etc. required for installation at the site.		P
46.17	An ESS shall be provided with instructions for the proper operation of the system including charging and discharging for battery systems, and operation of system controls, including identification of the communication protocols used for the system per 18.1.1. The operating instructions shall include safety measures and applicable safety warnings for operation and any instructions necessary for emergency procedures. See also 10.1 for all systems and 10.6 for systems with walk-in enclosures.		P
46.18	The ESS shall be provided with maintenance instructions for service personnel as well as a separate set of instructions for any basic maintenance procedures, including fuse replacement per 12.1, that would be handled by operators of the system. Maintenance		P

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	instructions shall include frequency of routine maintenance to be performed including annual checks on any subsystems such as HVAC, Fire Suppression System, etc., as well as operational tests to be performed. The maintenance instructions shall include safety measures to be followed during maintenance of the system whether by service personnel or for basic maintenance procedures handled by system operators.		
46.19	The maintenance instructions shall be provided with information on field replacement of replaceable materials, components and parts for ongoing maintenance and repair of the system. These instructions shall include detailed information on where to obtain and how to install the replaceable items. The instructions shall indicate that all servicing and replacement of parts are to be done by qualified persons only and that only approved materials, components and parts are to be used for replacements.		P
46.20	Mechanical ESS utilizing bearings for their moving parts, shall have a scheduled routine inspection and maintenance for bearings outlined in the manual. Instructions shall indicate that bearings shall be inspected for signs of wear either through visible examination or review of bearing monitoring system data and replaced if worn. In the absence of visible signs of wear or monitoring data indicating wear, the instructions shall indicate that the bearings shall be replaced by the scheduled out of service date for the bearings.		N/A
46.21	The installation instructions shall contain all ESS operation mode/settings, operation function/settings and protection/settings, which the inverters can provide.		P

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APPENDIX A – Standards for Components (NORMATIVE)

A1	**Standards for Components**		P
A1.1	The CSA Group and UL standards listed below are used for evaluation of components and features of products covered by this standard. Components shall comply with all the applicable CSA Group and UL component standards. These standards shall be considered to refer to the latest edition and all revisions published to that edition. **CSA Group Standards…** **UL Standards…**	See CDF	P

APPENDIX B – General Battery Safety Considerations (Informative)

B1	**General**		N/A
B2	**Design Recommendations**		N/A

APPENDIX C – Safety Marking Translations (Informative)

C1	**Safety Marking Translations** See Table C.1		N/A

APPENDIX D – Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Battery Systems (NORMATIVE)

D1	**General**		N/A
D1.1	This appendix is provided as an alternative approach to evaluating valve regulated or vented lead acid and nickel cadmium battery systems to UL 1973. This appendix considers the fact that these systems are often assembled at the ESS stage using standardized lead acid or nickel cadmium batteries and are not first assembled as battery systems and evaluated in accordance with UL 1973.	Lithium ion type battery	N/A

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ANSI/CAN UL 9540			
Clause	Requirement + Test	Result – Remark	Verdict
	Therefore, the evaluation according to this appendix in lieu of a UL 1973 evaluation can be conducted to meet the battery technology requirements of this standard for these types of batteries.		
D1.2	It is understood that due to the typically standardized, monobloc design of the lead acid and nickel cadmium batteries used in these systems and their general robustness, they do not require the complex controls that a chemistry such as lithium ion requires. Their safety controls typically monitor and control for current and temperature although they can include voltage controls. The failure mechanisms for these batteries that have led to safety concerns are the result of external abuse such as short circuiting over terminals or overcharging conditions.		N/A
D1.3	The lead acid and nickel cadmium batteries off gas hydrogen under ambient pressure conditions such as the case with vented types or when under pressure due to overheating in the case of valve regulated. The installation of these types of batteries whether they are in open racks within rooms or installed within enclosed containers needs to consider the potential for hydrogen off gassing and address venting of this gas in the ESS or in its installation to prevent hazardous concentrations of hydrogen gas. Systems using vented type batteries needs to address spill control of hazardous electrolytes in accordance with building code regulations for installations of these types of batteries.		N/A
D2	**Construction**		N/A
D2.1	The batteries and components of the battery systems shall be installed in accordance with NFPA 70 or CSA C22.1. The applicable construction criteria of Sections 7 – 14, Section 19, and Sections 23 – 27 shall apply to an ESS system using lead acid or nickel cadmium batteries.		N/A
D2.2	Valve regulated or vented lead acid or nickel cadmium cells and monobloc batteries shall comply with the requirements of the Annex for Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries in UL 1973 for these types of batteries.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
D2.3	Cells and monobloc batteries shall be installed in an ESS in accordance with the battery manufacturer's instructions for spacings between batteries and other required spacings, cell/battery installation orientation, wiring and connection requirements, environmental and other protections to be provided in the installation.		N/A
D2.4	port structures for vented and valve regulated lead acid and nickel cadmium batteries shall be suitable for handling the maximum anticipated weight of the installed cells and batteries. The rack system shall comply with the criteria outlined in the Annex for Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries of UL 1973.		N/A
D2.5	ESS employing lead acid or nickel cadmium batteries shall comply with the applicable criteria outlined in this Standard with regard to materials, enclosures, electrical safety, insulation levels and protective earthing, combustible concentrations, fire detection and suppression, and power conversion equipment as applicable to the ESS. Short circuit protection used in the system to protect the batteries and limit their short circuit current output shall be rated for dc applications.		N/A
D2.6	The charging system for these batteries shall prevent charging outside of the battery specifications through the use of current and temperature monitoring and control on the batteries. The system may also use voltage monitoring and controls to prevent out of condition specifications. Charging systems for these batteries shall comply with the requirements for power conversion equipment in Section 27 and shall also comply with the battery manufacturer's specifications for chargers.		N/A
D2.7	Ventilation provided for the ESS shall maintain hydrogen concentration within the ESS to less than 25 % LFL. If relying upon mechanical ventilation to maintain the safe concentrations within an ESS enclosure, it shall be monitored and alarmed at a constantly attended location, should the mechanical ventilation fail. Hot parts such as electronics and switching devices that can ignite combustible concentrations shall not be		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	located in locations in the exhaust gas stream where the hydrogen can be ignited or near vents or valves of the batteries. See Section 24.		
D2.8	The battery system exceeding 240 Vdc shall be provided with disconnects in accordance with Article 706 of NFPA 70 or Section 64 of CSA C22.1, for servicing of the battery system.		N/A
D2.9	Installation of ESS systems of lead acid or nickel cadmium batteries, shall abe installed with ventilation in accordance to applicable fire and building code requirements and the battery manufacturer's installation instructions.		N/A
D2.10	Vented lead acid or nickel cadmium battery installations shall be provided with spill control in accordance with the building, fire and installation codes. See 23.1.		N/A
D2.11	ESS systems with lead acid or nickel cadmium cells or batteries shall be marked in accordance to Section 45 as applicable to the system.		N/A
D2.12	Installation instructions for an ESS with lead acid or nickel cadmium batteries shall provide sufficient details of installation including any separation distances, limits to the installations such as indoors only installation in accordance with Section 46. Installation instructions for ESS employing open racks of lead acid or nickel cadmium batteries shall indicate that they are for installation in restricted access locations.		N/A
D2.13	Maintenance and operating instructions for ESS employing lead acid or nickel cadmium cells and batteries, shall indicate the need for any ongoing maintenance of the batteries such as ensuring sufficient electrolyte for vented types or checking the state of terminals of the cells or batteries in accordance with the battery manufacturer's instructions. The instructions shall indicate the frequency for monitoring and maintenance of the cells and batteries in the instructions and shall align with the instructions provided by the cell or battery manufacturer.		N/A
D3	**Performance**		N/A
D3.1	**General**		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
D3.1.1	Table D3.1 below outlines the ESS tests of this Standard that shall be applied to an ESS system using lead acid or nickel cadmium batteries, which have been evaluated to the Annex for Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries of UL 1973.		N/A

APPENDIX E – Guidance On Capacity and Separation Distance Limits for Electrochemical EES (Informative)

E1	**General**		N/A
E1.1	Installation Codes control fire and other hazards in electrochemical ESS installations through the use of limitations on energy capacity and through separation distances between ESS and exposures (e.g. walls, openings, etc.). These limitations may be revised based upon large scale fire testing and authority having jurisdiction (AHJ) approval at the installation site. The information provided below in Table E1.1 and Table E1.2 is based upon the limitations for energy capacity and separation distances for electrochemical ESSs in accordance with the model fire and installations codes in the United States. Since the limitations in these codes are subject to revision and also because they are subject to local adaptation, this information should be used for guidance only.		N/A

APPENDIX F – Metal compatibility Table (NORMATIVE)

F1	**Metal compatibility table** Avoid conductive parts with dissimilar metals per section 8.2. Combinations used within Figure F.1 .....:		P

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Clause	Requirement + Test	Result – Remark	Verdict

ANNEX G – CLEAN AGENT DIRECT INJECTION BATTERY RACK COOLANT SYSTEM UNITS (NORMATIVE)

G1	**General**		N/A
G1.1	These requirements cover the construction and operation of halocarbon clean agent direct injection battery rack coolant system units intended to be installed, inspected, tested, and maintained in accordance with NFPA 2001, NFPA 855, and NRC NFC.		N/A
G1.2	These clean agent direct injection battery rack coolant system units are intended to distribute clean agent directly onto lithium ion or similar battery modules following detection by the system that the cells are overheating and/or venting. The clean agent serves as a coolant to stop fire development from the effected module rather than serve as a total flooding fire suppression system that is typical of clean agent fire extinguishing systems. The design of the integral battery rack clean agent coolant system is dependent upon the battery module and rack assembly and is ultimately evaluated for effectiveness through large scale fire testing in accordance with UL 9540A.		N/A
G2	**Glossary**		N/A
G3	**Construction**		N/A
G3.1	**Piping**		N/A
G3.1.1	Piping and tubing used in the system shall have a piping thickness in accordance with ASME B31.1. Piping, tubing, fittings, and the joints so formed shall comply with the Valve Leakage Test and Hydrostatic Pressure Test of UL/ULC 2166. The assembled piping system shall comply with the Leakage Tests of UL 9540.		N/A
G3.2	**Pressure relief valves**		N/A
G3.2.1	Pressure relief valves in the agent distribution network shall be subjected to the Start-To-Discharge Test of UL 1973 unless the pressure release valves comply with ASME BPVC. The relief valve shall not release to an area where the agent can result in a hazard		N/A
G3.3	**Pressure regulators**		N/A
G3.3.1	Pressure regulators shall be evaluated in accordance with UL/ULC 2166, UL 252 or UL 144 for suitability.		N/A

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G3.4	**Solenoid valves**		N/A
G3.4.1	Electrically operated valves shall comply with UL 864, ULC S527, UL 429 or CSA C22.2 No. 139 and be suitable for the conditions of service.		N/A
G3.5	**Electrical controls**		N/A
G3.5.1	An analysis of the direct injection battery rack coolant system unit control assembly consisting of the various input sensors, the fire alarm control panel and outgoing signals to the agent supply cylinder shall be analyzed to ensure that all components of the control system work in coordination as anticipated to react to a cell propagation event in the modules. Methods outlined in Section 15 of this Standard shall be utilized to perform this analysis.		N/A
G3.5.2	Fire Alarm Control Panels shall comply with UL 864 or ULC S527 and shall have sufficient input and output channels for the system. The input signals to the fire control panel shall be compatible with the panel		N/A
G3.5.3	Manual pull switches shall comply with UL 38 or ULC S528 and be compatible with the fire alarm control panel and rated for the circuit. The manual pull switch shall be located where it is accessible.		N/A
G3.6	**Input sensors and detectors**		N/A
G3.6.1	Detectors and other input sensors to the fire alarm control panel shall be evaluated in accordance with the appropriate standard for that device. Applicable standards for these devices utilized for detection are, but not limited to:		N/A
	a) UL 268; b) UL 268A; c) UL 521; d) ULC S529; e) ULC S530; f) ULC S588; g) UL 2075; or h) UL 60079-29-1.		N/A
G3.6.2	The signals from these various detection devices shall be compatible with the fire control panel in accordance with G3.5		N/A
G3.6.3	If input signals from the battery management system (BMS) to the fire control panel are		N/A

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	relied upon for the operation of the direct injection coolant system, these communication signals shall be determined compatible with the fire control panel in accordance with G3.5. The functional safety evaluation of the BMS controls shall consider the inputs and signals to the fire control panel when determining the reliability if this input is part of the direct injection coolant system.		
G3.7	**Alarms**		N/A
G3.7.1	A visual and audio alarm shall be provided with the direct injection coolant system and they shall operate when the direct injection coolant system operates.		N/A
G3.7.2	Visual alarms shall be in accordance with UL 1638 or ULC 526, and audio alarms shall be in accordance with UL 464/ULC 525. The maximum sound level for audio alarms shall not exceed 110 dBA at the minimum hearing distance.		N/A
G3.8	**Wiring and terminals**		N/A
G3.8.1	Wiring within the direct injection coolant system shall be in accordance with NFPA 70, NFPA 72 or CSA C22.1 and this Standard.		N/A
G3.8.2	The wiring and connections between parts of a direct injection coolant system shall be protected or enclosed, or they shall be in a cord or cable that has been evaluated and determined to be rated for the application.		N/A
G3.8.3	Internal wiring shall be routed and secured so that the wires and electrical connections are not subjected to stress or mechanical damage in accordance with this Standard.		N/A
G3.8.4	Internal wiring of circuits that operate at different potentials shall be separated by barriers or shall be segregated, unless the conductors of the circuits of lower voltage are provided with insulation for the highest voltage in accordance with this Standard.		N/A
G3.8.5	Duplicate terminals or leads, or an equivalent arrangement, shall be provided for circuits of devices intended to be connected to initiating-device circuits of the fire control unit; one for each incoming and one for each outgoing wire. It is not prohibited that a common terminal be used in lieu of duplicate terminals when it is intended to prevent the looping of an unbroken wire around or under a terminal screw in a manner that permits the		N/A

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	looped wire to remain unbroken during installation, thereby precluding supervision in the event the wire becomes dislodged from under the terminal. A notched clamping plate under a single securing screw, where separate conductors are intended to be inserted in each notch, is an equivalent arrangement.		
G3.9	**Clean agent assembly component requirements**		N/A
G3.9.1	The clean agent tank assembly shall be located where it can be inspected, recharged and subjected to any other specified maintenance activities without impacting its ongoing protection functions.		N/A
G3.9.2	The following requirements of UL/ULC 2166 summarized in Table G3.1 shall apply. Where UL/ULC 2166 references “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A
G4	**Performance**		N/A
G4.1	**General**		N/A
G4.1.1	The direct injection coolant systems shall be subjected to the applicable performance tests as noted in this Annex.		N/A
G4.2	**Clean agent assembly tests (UL/ULC 2166 Tests)**		N/A
G4.2.1	The following requirements of UL/ULC 2166 summarized in Table G4.1 shall apply. Where UL/ULC 2166 references “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A
G4.3	**Start to discharge test**		N/A
G4.3.1	The start to discharge test shall be conducted on relief valves other than those employed on the clean agent cylinder assembly in accordance with UL 1973.		N/A
	Exception: This test may be waived on relief valves that comply with ASME BPVC and that are used within their ratings.		N/A
G4.4	**Direct injection coolant system tests**		N/A
G4.4.1	The direct injection coolant system shall be tested in accordance with the unit level test of UL 9540A when installed in the specific battery rack assembly with intended modules that the system is designed to protect. The UL 9540A unit level performance criteria shall be met for the intended battery assembly and		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	installation. If the unit level test performance criteria was not met, then the system shall then be evaluated as part of a UL 9540A installation level test with the intended battery rack assembly. Signals from the BMS shall not be relied upon for meeting the performance level criteria for this testing in accordance with the Module Level, Sample section of UL 9540A. Signals from devices external to the battery system such as from gas detectors can be utilized during the testing.		
G5	**Production Tests**		N/A
G5.1	The applicable production tests of the Manufacturing and Production Tests, General section of UL/ULC 2166 shall apply.		N/A
G5.2	The start-to-discharge production line test of the Manufacturing and Production Line Tests, General section of UL 1973 shall apply to relief valves that have not been determined to comply with the ASME BPVC and are used in the system.		N/A
G5.3	The following requirements of UL/ULC 2166 summarized in Table G5.1 shall apply. Where UL/ULC 2166 references “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A
G6	**Markings**		N/A
G6.1	Each direct injection battery rack coolant system unit shall be marked with an identifying part or model number and the manufacturer's or private labeler's name or other equivalent designation.		N/A
G6.2	A cylinder/valve assembly, in addition to being marked with operating, recharging, inspection and maintenance instructions (see G7.3), shall be marked with the year of manufacture, or the last two digits of the year of manufacture. A cylinder/valve assembly manufactured in the last 3 months of a calendar year is not prohibited from being marked with the following year as the date of manufacture and a cylinder/valve assembly manufactured in the first 3 months of a calendar year is not prohibited from being marked with the previous year as the date of manufacture.		N/A
G6.3	Operating, recharging, inspection and maintenance instructions shall be marked on		N/A

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ANSI/CAN UL 9540			
Clause	Requirement + Test	Result – Remark	Verdict
	the cylinder/valve assembly and shall include at least the following information:		
	a) Type of clean agent to be used; b) Operating pressure of the unit at the corresponding normal ambient temperature condition; c) Storage temperature range of the unit; d) Factory test pressure of the cylinder; e) Reference to: 1) NFPA 2001; 2) The manufacturer's installation, operation and maintenance instruction manual (identified by part number or date) for detailed instructions for correct system handling usage and maintenance; f) Weight of agent charge and gross weight of charged cylinder and valve assembly; g) Basic inspection instructions, which shall include the following or French equivalent text: 1) At least semiannually, the agent quantity and pressure of refillable containers shall be checked; 2) A container shall be refilled or replaced when it shows a loss in agent quantity of more than 5 % or a loss in pressure (adjusted for temperature) of more than 10 %; and 3) For a disposable unit, "Discard immediately after any use"; and h) The following statement shall appear in letters at least 3.2 mm (1/8 in) and not more than 6.4 mm (1/4 in) high: "WARNING: Risk of Injury. The discharge of clean agent systems can result in a potential hazard to personnel from the natural form of the clean agent or from the products of combustion that result from exposure of the agent to the fire or hot surfaces. Unnecessary exposure of personnel either to the natural agent or to the products of decomposition shall be avoided." i) Identification of contents as follows: 1) Contents product name as it appears on the manufacturer's Safety Data Sheet (SDS). 2) A listing of the hazardous material identification in accordance with the American		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	Coatings Association, Hazardous Materials Identification Systems (HMIS) or Workplace Hazardous Materials Information System (WHMIS). 3) A list of any hazardous materials that are in excess of 1.0 % of the contents. 4) A list of each chemical in excess of 5.0 % of the contents. 5) Information as to what is hazardous about the agent in accordance with the SDS. 6) The contents manufacturer's name, mailing address, and phone number as shown on the SDS.		
G6.4	Each clean agent container shall be legibly marked in accordance with UL/ULC 2166 as follows:		N/A
	‘’RECYCLING PROTECTS THE ENVIRONMENT DO NOT DISPOSE DISCHARGE ONLY IN CASE OF FIRE. IF CONTAINER CONTENTS MUST BE REMOVED FOR SERVICE, MAINTENANCE OR DISMANTLING OF THE CLEAN AGENT SYSTEM – PRIOR TO REMOVAL, CONTACT YOUR LOCAL INSTALLER OR ANUFACTURER FOR INSTRUCTIONS ON HANDLING EQUIPMENT AND RECLAIMING OR RECYCLING CLEAN AGENT. DO NOT COVER, REMOVE OR DEFACE THIS LABEL.’’		N/A
G6.5	The following requirements of UL/ULC 2166 summarized in Table G6.1 shall apply. Where UL/ULC 2166 references “extinguishing system unit”, it shall be replaced with “direct injection battery rack coolant system unit”.		N/A
G7	**Instructions**		N/A
G7.1	A copy of the installation, operating, recharging, inspection, and maintenance instruction manual is to be furnished for the direct injection coolant system. These instructions shall also be provided for the evaluation and testing of the system.		N/A
G7.2	The instructions shall reference the limitations of each direct injection coolant system and shall include at least the following items:		N/A
	a) Description and operating details of the direct injection coolant system and all		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	accessory equipment, including identification of the systems or accessory equipment by part or model number and all markings;		
	b) Details of the specific battery modules and rack assemblies that are protected by the system and the minimum clean agent quantity to be provided for the specific BESS rack assembly and details of the UL 9540A report of the battery module/rack assembly and direct injection coolant system tested;		N/A
	c) Type and schedule of pipe, tubing, and fittings to be used;		N/A
	d) Typical system layout and specific limitations and recommendations for correct system installation and effective protection;		N/A
	e) Specific information on piping limitations and nozzle placement battery rack systems;		N/A
	f) Description of all variations of each extinguishing system, including the limitations for each variation;		N/A
	g) Discharge nozzle limitations, including maximum dimensional and area coverage, nozzle locations with respect to the modules they are intended to cool;		N/A
	h) Details on installation of each extinguishing system unit, including accessory equipment;		N/A
	i) Reference to the specific types of detection and control panels (when applicable) to be connected to the equipment;		N/A
	j) Only those devices suitable for supervision shall be designated in the installation manual. When duplicate terminals or leads are not used and there is no provision to prevent looping an unbroken wire around or under one terminal, the information noted below shall be included in the installation wiring diagram or instructions included in the installation manual;		N/A
	k) When duplicate terminals are not provided to facilitate supervision of the installation wiring connections, and there is no provision to prevent looping an unbroken wire around or under a terminal, the word "CAUTION" and the following or equivalent text shall be included:		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	"FOR SYSTEM SUPERVISION – FOR TERMINALS ___ AND ___, DO NOT USE LOOPED WIRE UNDER TERMINALS. BREAK WIRE RUN TO PROVIDE SUPERVISION OF CONNECTIONS." The blanks are to be filled in with the applicable terminal identification.		
	l) Operating pressure of the unit at the corresponding normal ambient temperature condition;		N/A
	m) Operating temperature range limitations, which includes pressure/temperature references for the range of fill densities;		N/A
	n) Range of filling weights for each container size;		N/A
	o) Information on inspection of system after installation;		N/A
	p) Detailed instructions for recharging system after operation that shall: 1) Contain: i) Required warnings, and cautions; ii) A description of servicing equipment; and iii) A description of procedures for intended servicing; 2) Provide a list of part numbers of all replacement parts; 3) Indicate that: i) The pressure gauge attached to the extinguishing system is not to be used to determine when the intended charging pressure has been reached; and ii) A pressure regulator is to be used when the pressure source is a tank of high pressure gas;		N/A
	q) Description of requirements for maintenance of all equipment; r) Reference to design manual, when applicable; s) Reference to NFPA 2001, for installation, maintenance, and testing requirements and NRC NFC;		N/A
	t) Reference to use of clean agent system unit in accordance with the Environmental Protection Agency's Significant New Alternatives Program or equivalent;		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	u) The name of the manufacturer or private labeler, or equivalent designation;		N/A
	v) Date and manual designation number on each page;		N/A
	w) SDS sheets and cautionary instructions as specified in G6.3 (h) – (i);		N/A
	x) Delay time for time delay valve when such a valve is provided; and		N/A
	y) The system clean agent tank assembly and the manual pull switch shall be installed outside of the BESS enclosure. The manual pull switch shall be located where it is accessible.		N/A
G7.3	Routine maintenance of the system shall be outlined in the maintenance manual and shall include the maintenance procedures to be conducted and the frequency with which the maintenance procedures are conducted on the system. The maintenance schedule shall consist of monthly, semi-annual and annual intervals of routine inspection and maintenance in accordance with the manufacturer's specifications.		N/A
G7.4	The following requirements of UL/ULC 2166 summarized in Table G7.1 shall apply. Where UL/ULC 2166 references the "extinguishing system unit", it shall be replaced with "direct injection battery rack coolant system unit".		N/A

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Clause 2, APPENDIX A	list of critical components				P
Object / part No.	Manufacturer/ trademark	Type / model	Technical data	Standard	Mark(s) of conformity
Refer to CDF documentation.					

Clause 13	Electrical Spacings and Separation of Circuits						P
clearance cl and creepage distance dcr at / of:	System voltage (V)	OVC	U impulse (V)	required cl (mm)	cl (mm)	required dcr (mm)	dcr (mm)
Container (insulator CTI 600V)							
Positive/negative main bus bar to enclosure through insulator (BI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	6000	7.1	41.5	7.5	60.0
Battery module							
Between Bus bar and enclosure through battery terminals (BI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	6000	7.1	15.6	7.5	15.6
N/ACSC PCB							
Between DVC-C circuit (Sampling circuit) and DVC-A circuit (communication circuit) through PCB board (RI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	8000	10.4	24.7	15.0	24.7
Between DVC-C circuit (Sampling circuit) and DVC-A circuit (communication circuit) through transformer T9 (RI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	8000	10.4	21.9	15.0	23.7
High voltage controlling box							
Between DVC-C circuit (battery circuit) to enclosure through HV+/HV- terminal (BI)	1500Vd.c. 800Va.c.*	II (DC) III (AC)	6000	7.1	15.6	7.5	15.6
Between DVC-C circuit (battery circuit) to enclosure through B+/B- terminal (BI)	1500Vd.c. 800Va.c.*	II (DC) III (AC)	6000	7.1	15.6	7.5	15.6
N/ASBMU PCB							
Between DVC-C circuit (High voltage sampling circuit) and DVC-A circuit (communication circuit) through the sampling resistors (BI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	6000	7.1	1.4*8= 11.2	7.5	1.4*8= 11.2
Between DVC-C circuit (High voltage sampling circuit) and DVC-A circuit (communication circuit) through the Insulation chip OM18 (SI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	6000	7.1	8.3	7.5	8.3

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Between DVC-C circuit (High voltage sampling circuit) and DVC-A circuit (communication circuit) through Digital isolator (U21) (SI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	6000	7.1	8.0	7.5	8.0
Between DVC-C circuit (High voltage sampling circuit) and DVC-A circuit (communication circuit) through Isolation transformer T9 (SI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	6000	7.1	8.2	7.5	8.2
Between DVC-C circuit (High voltage sampling circuit B+) and DVC-A circuit (communication circuit) through Isolation width through PCB (RI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	8000	10.4	24.5	15.0	24.5
Between DVC C circuit and metal enclosure (BI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	6000	7.1	10.6	7.5	>10.6
IMM PCB							
Between DVC-C circuit and DVC-A circuit through sampling resistors (BI)	1500Vd.c. 800Va.c.*	II (DC) III (AC)	6000	7.1	1.4*9= 12.6	7.5	1.4*9= 12.6
Between DVC-C circuit and DVC-A circuit through Isolation optocoupler (OM15) (SI)	1500Vd.c. 800Va.c.*	II (DC) III (AC)	6000	7.1	7.6	7.5	7.6
Between DVC-C circuit (B-sampling circuit) and DVC A circuit through insulation width (RI)	1500Vd.c. 800Va.c.*	II (DC) III (AC)	8000	10.4	17.3	15.0	17.3
Between DVC C circuit and metal enclosure (BI)	1500Vd.c. 800Va.c*	II (DC) III (AC)	6000	7.1	10.6	7.5	>10.6
Supplementary information: 1. Above spacings were assessed according to IEC 60664-1 2. * Considering in the final installation with PCS, the max. PCS AC mains voltage is 800 V a.c., IT system. Considering altitude 4000 m for clearances.							

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Clause 30	Normal Operations Test	P
Model	The test was performed on the product with UPS supply type of auxiliary power supply.	
Operation mode	Charging and discharging, 2 cycles	

Cycle	Ambient (°C)	Humidity (RH)	Test time	Charge			Discharge		
				Vd.c.	Ad.c.	kW	Vd.c.	Ad.c.	kW
1st	55	-	8.5 h	1192.5 ~ 1461.6	1183.5 ~ 965.3	1411.0	1374.0 ~ 1093.9	1024.9 ~ 1287.0	1407.9
2nd	55	-	8.5 h	1258.1 ~ 1457.9	1121.8 ~ 967.8	1411.3	1374.8 ~ 1094.0	1023.9 ~ 1285.9	1407.8

No	Temperature rise (°C) of part/at:	Measured max. temperature (°C)	Permitted (°C)
High voltage controlling box			
1.	Insulation switch ambient	73.7	85
2.	Contactor ambient	79.3	85
3.	Hall ambient	75.8	85
4.	Insulator of bus-bar surface	73.3	100
5.	Fuse ambient	78.7	85
6.	Fan ambient	71.8	75
7.	Pre-charge relay ambient	70.0	85
8.	Negative connector bus-bar	83.8	125
9.	Voltage sampling wire	80.8	105
10.	SBMU Voltage sampling wires	68.5	105
11.	SBMU Voltage sampling connector	68.7	125
12.	SBMU PCB surface	72.6	130
13.	SBMU insulation chip	73.5	125
14.	SBMU insulation transformer	74.2	130
15.	SBMU MCU U914	77.1	125
16.	SBMU sampling chip U701	73.1	125
17.	Handle of insulation switch	49.6	130
18.	Front side of High voltage controlling box	64.5	70
Battery cabinet			
19.	Handle of battery cabinet door	56.5	70
20.	Surface of battery cabinet door	54.7	70
21.	Power cable surface between battery modules	67.7	125

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22.	Battery module ambient 1	45.3	Ref.
23.	Battery module ambient 2	45.3	Ref.
Electrical panel			
24.	HV+ cable surface	80.4	125
25.	HV- cable surface	97.2	125
26.	Positive bus-bar	87.7	125
27.	Negative bus-bar	106.8	125
28.	Insulator of positive bus-bar	83.9	140
29.	Insulator of negative bus-bar	102.1	140
30.	IMM sampling wire surface	85.6	105
31.	Relay ambient	64.1	75
32.	Auxiliary power cable (400V)	59.2	105
33.	Auxiliary power cable (230V)	63.7	105
34.	Auxiliary power cable (24V)	63.5	105
35.	Terminal XT0	67.9	105
36.	Terminal XT1	68.6	105
37.	Cable trunks of AC power cable	65.1	85
38.	Coil of transformer T1	68.8	70
39.	Coil of transformer T3	68.1	70
40.	UPS_AC-DC	61.7	70
41.	UPS_DC-DC	62.1	70
42.	SPD	62.7	85
43.	Fuse of SPD	64.9	130
44.	Enclosure of Electrical panel	61.4	70
45.	Handle of Electrical panel	60.4	70
Master control box in the electrical cabinet			
46.	24V input wire	59.5	105
47.	Low voltage terminal block	60.2	105
48.	High voltage terminal block	60.3	105
49.	Plastic trunking	60.2	85
50.	IMM insulation chip ADC (U10)	65.6	85
51.	IMM PCB surface	66.0	130
52.	IMM optocoupler OM2	67.4	85
53.	IMM transformer T9	66.7	130

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54.	MBMU MCU	69.4	130
55.	ETH MCU	59.8	130
56.	Optical fibre conversion module ambient	60.3	75

Supplementary information:
1. Between charging and discharging of each cycle, the system rested for 15 minutes.
2. Between the first and second cycle, the system rested for 2 hours.

Clause 30	**Normal Operations Test**	**P**
Model	The test was performed on the product with 24V power module type of auxiliary power supply.	
Operation mode	Charging and discharging, 2 cycles	

Cycle	Ambient (°C)	Humidity (RH)	Test time	Charge			Discharge		
				Vd.c.	Ad.c.	kW	Vd.c.	Ad.c.	kW
1st	55	-	8.1 h	1278.2 ~1461.1	1104.1 ~ 965.8	1411.3	1374.1 ~1071.4	1025.0~ 1314.0	1408.5
2nd	55	-	8.1 h	1240.8 ~1458.4	1137.5 ~967.5	1411.3	1375.1~ 1076.1	1024.0~ 1308.0	1408.0

No	Temperature rise (°C) of part/at:	Measured max. temperature (°C)	Permitted (°C)
High voltage controlling box			
1.	Insulation switch ambient	72.6	85
2.	Contactor ambient	78.0	85
3.	Hall ambient	74.7	85
4.	Insulator of bus-bar surface	72.5	100
5.	Fuse ambient	80.0	85
6.	Fan ambient	70.7	75
7.	Pre-charge relay ambient	69.0	85
8.	Negative connector bus-bar	87.0	125
9.	Voltage sampling wire	79.7	105
10.	SBMU Voltage sampling wires	67.5	105
11.	SBMU Voltage sampling connector	67.6	125
12.	SBMU PCB surface	71.7	130
13.	SBMU insulation chip	72.0	125
14.	SBMU insulation transformer	73.3	130
15.	SBMU MCU U914	76.2	125
16.	SBMU sampling chip U701	72.3	125

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17.	Handle of insulation switch	49.4	130
18.	Front side of High voltage controlling box	64.0	70
Battery cabinet			
19.	Handle of battery cabinet door	56.9	70
20.	Surface of battery cabinet door	55.2	70
21.	Power cable surface between battery modules	67.5	125
22.	Battery module ambient 1	42.8	Ref.
23.	Battery module ambient 2	44.2	Ref.
Electrical panel			
24.	HV+ cable surface	83.5	125
25.	HV- cable surface	104.3	125
26.	Positive bus-bar	98.3	125
27.	Negative bus-bar	58.5	125
28.	Insulator of positive bus-bar	65.8	140
29.	Insulator of negative bus-bar	116.0	140
30.	IMM sampling wire surface	94.0	105
31.	Relay ambient	63.0	75
32.	Auxiliary power cable (400V)	63.8	105
33.	Auxiliary power cable (230V)	64.1	105
34.	Auxiliary power cable (24V)	64.9	105
35.	Terminal XT0	64.3	105
36.	Terminal XT1	64.8	105
37.	Cable trunks of AC power cable	62.7	85
38.	Coil of transformer T1	62.9	70
39.	Coil of transformer T3	65.8	70
40.	24 power module AC-DC-PCB	65.4	130
41.	24 power module DC-DC-PCB	65.1	130
42.	SPD	63.2	85
43.	Fuse of SPD	63.2	130
44.	Enclosure of Electrical panel	62.2	70
45.	Handle of Electrical panel	61.1	70
Master control box in the electrical cabinet			
46.	24V input wire	60.3	105
47.	Low voltage terminal block	61.1	105

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48.	High voltage terminal block	61.1	105
49.	Plastic trunking	61.0	85
50.	IMM insulation chip ADC(U10)	66.1	85
51.	IMM PCB surface	66.6	130
52.	IMM optocoupler OM2	68.0	85
53.	IMM transformer T9	67.3	130
54.	MBMU MCU	70.0	130
55.	ETH MCU	60.5	130
56.	Optical fibre conversion module ambient	61.1	75

Supplementary information:

1. Between charging and discharging of each cycle, the system rested for 15 minutes.
2. Between the first and second cycle, the system rested for 2 hours.

Clause 32	**Dielectric Voltage Withstand test**				**P**
Test voltage applied between:	System voltage /OVC *	Insulation type (BI, SI, DI, RI)	AC or DC Test voltage	Breakdown	Pass/Fail
Electrical cabinet					
Auxiliary AC input and enclosure	277 V a.c., OVC II	BI	2120 V d.c.	☐ Yes ☒ No	P
Auxiliary AC input and communication terminal	277 V a.c., OVC II	RI	2120 V d.c	☐ Yes ☒ No	P
Positive Bus bar and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	2828 V d.c.	☐ Yes ☒ No	P
Negative Bus bar and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	2828 V d.c.	☐ Yes ☒ No	P
Battery module					
Positive terminal and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	2828 V d.c.	☐ Yes ☒ No	P
Negative terminal and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	2828 V d.c.	☐ Yes ☒ No	P
Positive terminal and communication terminal	1500 V d.c., OVC II 800 V a.c., OVC III	RI	5656 V d.c.	☐ Yes ☒ No	P
Negative terminal and communication terminal	1500 V d.c., OVC II 800 V a.c., OVC III	RI	5656 V d.c.	☐ Yes ☒ No	P
High voltage controlling box					
Positive terminal and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	2828 V d.c.	☐ Yes ☒ No	P
Negative terminal and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	2828 V d.c.	☐ Yes ☒ No	P
Positive terminal and communication terminal	1500 V d.c., OVC II 800 V a.c., OVC III	RI	5656 V d.c.	☐ Yes ☒ No	P

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Negative terminal and communication terminal	1500 V d.c., OVC II 800 V a.c., OVC III	RI	5656 V d.c.	☐ Yes ☒ No	P
Supplementary information: a) Dielectric voltage determined according to Table 9 of IEC 62477-1:2012 + A1:2016. b) Circuit breakers, contactors are closed before applying these tests.					

Clause 33	**Impulse Test**				**P**
Test voltage applied between:	System voltage /OVC *	Insulation type (BI, SI, DI, RI)	Impulse test voltage	Puncture or partial breakdown	Pass/Fail
Electrical cabinet					
Auxiliary AC input and enclosure	277 V a.c., OVC II	BI	2500 V	☐ Yes ☒ No	P
Auxiliary AC input and communication terminal	277 V a.c., OVC II	RI	4000 V	☐ Yes ☒ No	P
Positive Bus bar and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	6000 V	☐ Yes ☒ No	P
Negative Bus bar and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	6000 V	☐ Yes ☒ No	P
Battery module					
Positive terminal and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	6000 V	☐ Yes ☒ No	P
Negative terminal and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	6000 V	☐ Yes ☒ No	P
Positive terminal and communication terminal	1500 V d.c., OVC II 800 V a.c., OVC III	RI	8000 V	☐ Yes ☒ No	P
Negative terminal and communication terminal	1500 V d.c., OVC II 800 V a.c., OVC III	RI	8000 V	☐ Yes ☒ No	P
High voltage controlling box					
Positive terminal and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	6000 V	☐ Yes ☒ No	P
Negative terminal and enclosure	1500 V d.c., OVC II 800 V a.c., OVC III	BI	6000 V	☐ Yes ☒ No	P
Positive terminal and communication terminal	1500 V d.c., OVC II 800 V a.c., OVC III	RI	8000 V	☐ Yes ☒ No	P
Negative terminal and communication terminal	1500 V d.c., OVC II 800 V a.c., OVC III	RI	8000 V	☐ Yes ☒ No	P
Supplementary information: a) Impulse voltage determined according to Table 9 of IEC 62477-1:2012 + A1:2016. b) Circuit breakers, contactors are closed before applying these tests.					

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Clause 34	Equipment Grounding and Bonding Test		P
Test location A	Test location B	Resistance (mΩ)	Limit (mΩ)
PE terminal	Battery cabinet door	35.5	100
PE terminal	Electrical Cabinet door	7.6	100
PE terminal	Liquid chiller enclosure	12.3	100
Supplementary information:			

Clause 35	Insulation Resistance Test			P
Test voltage applied between:	Nominal circuit voltage	Test voltage	Insulation resistance	Pass/Fail
Integrated control panel				
Auxiliary AC input and enclosure	277 V a.c.	1000 V d.c	> 1 MΩ	P
Auxiliary AC input and communication terminal	277 V a.c.	1000 V d.c	> 1 MΩ	P
Positive Bus bar and enclosure	1500 V d.c., 800 V a.c.	1000 V d.c	> 1 MΩ	P
Negative Bus bar and enclosure	1500 V d.c., 800 V a.c.	1000 V d.c	> 1 MΩ	P
Battery Module				
Positive terminal and enclosure	1500 V d.c., 800 V a.c.	1000 V d.c.	> 1 MΩ	P
Negative terminal and enclosure	1500 V d.c., 800 V a.c.	1000 V d.c.	> 1 MΩ	P
Positive terminal and communication terminal	1500 V d.c., 800 V a.c.	1000 V d.c.	> 1 MΩ	P
Negative terminal and communication terminal	1500 V d.c., 800 V a.c.	1000 V d.c.	> 1 MΩ	P
High voltage controlling box				
Positive terminal and enclosure	1500 V d.c., 800 V a.c.	1000 V d.c.	> 1 MΩ	P
Negative terminal and enclosure	1500 V d.c., 800 V a.c.	1000 V d.c.	> 1 MΩ	P
Positive terminal and communication terminal	1500 V d.c., 800 V a.c.	1000 V d.c.	> 1 MΩ	P
Negative terminal and communication terminal	1500 V d.c., 800 V a.c.	1000 V d.c.	> 1 MΩ	P
Supplementary information: Circuit breakers, contactors are closed before applying these tests.				

……End of test report……..……..

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Appendix C

UL9540A Unit and Module Test Report

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

Project Number.....:	**4791072766**
Date of issue.....:	**2024-05-24**
Total number of pages.....:	**42**
UL Report Office .....:	**UL(Changzhou) Quality Technical Service Co., LTD**
Applicant's name.....:	**Contemporary Amperex Technology Co., Limited**
Address .....:	**No.2, Xingang Road, Zhangwan Town, Jiaocheng District Ningde City,352100 Fujian,P.R. China**
Test specification:	4th Edition, Section 9, November 12, 2019
Standard.....:	UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
Test procedure .....:	9.1 – 9.8
Non-standard test method .....:	N/A

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General disclaimer:

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

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

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Cell level information	
Cells in Module:	
●Manufacturer Name	**Contemporary Amperex Technology Co., Limited**
●Part Number	**CBLC0**
●Chemistry	**Lithium Iron Phosphate**
●Format	**Prismatic**
Ratings (Vdc, Ah) :	**3.2 Vdc, 530 Ah**
Cell certified? :	**Yes**
Standard the cell was certified to:	**UL 1973**
Organization that certified the cell:	**MH62898**
Average cell surface temperature at gas venting, °C:	**165**
Average cell surface temperature at thermal runaway, °C:	**215**
Gas Volume:	**343.5L**
Lower flammability limit (LFL), % volume in air at the ambient temperature:	**8.04**
Lower flammability limits (LFL), % volume in air at the venting temperature:	**7.34**
Burning velocity (S_u) cm/s:	**55.32**
Maximum pressure (P_{max}) psig:	**94.21**

Cell level Gas Composition:

Gas		Measured %
Carbon Monoxide	**CO**	**12.880**
Carbon Dioxide	**CO2**	**31.206**
Hydrogen	**H2**	**37.518**
Methane	**CH4**	**8.844**
Acetylene	**C2H2**	**0.197**
Ethylene	**C2H4**	**4.394**
Ethane	**C2H6**	**1.276**
Propadiene (Allene)	**C3H4**	**0.007**
Propylene	**C3H6**	**1.172**
Propane	**C3H8**	**0.426**
-	**C4 (Total)**	**0.572**
-	**C5 (Total)**	**0.068**
-	**C6 (Total)**	**0.035**
Benzene	**C6H6**	**0.010**
Dimethyl Carbonate	**C3H6O3**	**1.320**
Ethyl Methyl Carbonate	**C4H8O3**	**0.076**
Total	**-**	**100**

Module level Information	
Model No..... :	M02530P25L01

Ratings (Vdc, Ah)..... :	1060 Ah, 130-189.8V (166.4V)
Module dimensions (L x **W** x **H** (mm)**)…….:**	2231.1±200mm(L)*1193±100mm(W)*257±20mm(H)
Module cell configuration (xS/**y**P**) …...:**	52S/2P
Module weight (kgs)…… :	1100±110kg
Module enclosure material…….. :	Top Plastic enclosure: -Material: PP -Thickness: 2.5±0.2 mm -Size: L*W*H（mm）2183.6*1193*228.2 Bottom enclosure: -Material: HC340/590DP.Z -Thickness: ⩾1.5mm -Size: L*W*H (mm) 2231.1*1193*56.4
Was the module certified? ……..:	No
Standard the module was certified to ……..:	N/A
Organization that certified test item …….:	N/A
Number of initiating cells failed to achieve propagation.	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to at one adjacent cell.
External Flaming:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred
Flying Debris:	No flying debris occurred
Re-ignitions:	No further re-ignitions were observed during post test observation.
Test Maximum Smoke Release Rate (m^2/s)	0.64
Test Total Smoke Released: (m^2)	26.75
Test Peak Chemical Heat Release Rate: (kW):	No flaming occurred

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

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate(LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	105.51	No flaming	0.38
Carbon Monoxide	Carbon Containing	57.62	No flaming	0.40
Carbon Dioxide	Carbon Containing	137.31	No flaming	0.48
Hydrogen	Hydrogen	165.69	No flaming	7.41

Unit level Information	
Model No. :	C06530P25L01-R
Ratings (Vdc, Ah)..... :	1060Ah, 1331.2V
BESS dimensions (W x **D** x **H** (mm)**)…….:**	1205*2262.5*2452
BESS module configuration	1P8S
Number of modules in BESS	8
Module cell configuration (xS/**y**P**) …...:**	52S2P
Number of cells in module.:	104
BESS weight (kgs)…….. :	9000
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: outdoor ground 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.
Residential Indoor Use: Smallest volume room installations specified.	N/A
Original Equipment Manufacturer (OEM):	Contemporary Amperex Technology Co., Limited
Branding Manufacturer (if not OEM):	N/A
Was the unit certified? …….:	No
Standard the unit was certified to ……..:	N/A
Organization that certified the unit …….:	N/A
Cell failure test method performed (summary of method and test clause): ☒ External heating using thin film with 4°C to 7°C thermal ramp. ☐ Nail Penetration ☐ Overcharge ☐ External short circuit (***X*** Ω *external resistance*) ☐ Others	
Description of method used to fail cells if other than external thin film heater with thermal ramp, : N/A	
Description of components employed within the BESS unit that serve to suppress propagation (fire protection features)	

There is one MPP pad between two adjacent cells connected in parallel, total of 52 MPP pads in the module. **There is one aerogel pad between two adjacent cells connected in series, total of 48 aerogel pads in the module.** **There are 8 modules in one unit.**	
Deviation from the module level test **N/A**	
Number of initiating cell(s)	1
Thermal Runaway Propagation:	Initiating cell went into thermal runaway and propagated to one adjacent cell.
External Flaming from BESS:	No external flaming occurred
Location(s) of Flame Venting:	No flaming occurred
Maximum Target BESS Temperature[1], °C	27.3
Maximum Wall Surface Temperature[2], °C	25.8
Peak Chemical Heat Release Rate, kW	No flaming occurred
Peak Convective Heat Release Rate, kW	No flaming occurred
Maximum Smoke Heat Release Rate, m^2/s	0.04
Maximum Heat Flux on Target Modules, kW/m^2	0.1
Maximum Heat Flux of Egress Path, kW/m^2	0
Flying Debris:	No flying debris occurred
Re-ignitions:	No further re-ignitions were observed during post test observation

Gas Analysis:

☒ Flame ionization detection (FID)

☒ Non-Dispersive Infrared Spectrometer (NDIR)

☐ Fourier-Transform infrared Spectrometer

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

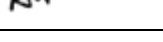
☒ White light source with photo detector (smoke release rate)

Summary of Unit level test Gas Analysis Data:

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

Gas Compound	Gas Type	Pre-Flaming (L)	Flaming (L)	Minimum detectable flow rate(LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	121.62	No flaming	2.42
Carbon Monoxide	Carbon Containing	53.14	No flaming	1.67
Carbon Dioxide	Carbon Containing	95.12	No flaming	4.02
Hydrogen	Hydrogen	28.44	No flaming	61.45

[1] Maximum Target BESS temperature averaged on 60 seconds.
[2] Maximum wall surface temperature averaged on 60 seconds.

Summary of BESS Unit Test Results		
Performance Criteria in accordance with Table 9.1 for Indoor Floor Mounted non-residential unit		
[X] Flaming outside the initiating BESS unit was not observed; **[X]** Surface temperatures of modules within the target BESS units adjacent to the initiating BESS unit did not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8; **[X]** For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces did not exceed 97°C (175°F) of temperature rise above ambient per 9.2.15; **[X]** Explosion hazards were not observed, including deflagration, detonation, and **[X]** Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.		
Necessity for an Installation level test		
[ ] The performance criteria of the unit level test as indicated in Table 9.1 of UL 9540A 4th edition has not been met, therefore an installation level testing in accordance with UL 9540A will need to be conducted on the representative the installation with this unit installed. **[X]** The performance criteria of the unit level tests as indicated in Table 9.1 of UL 9540A 4th edition has been met, therefore an installation level testing in accordance with UL 9540A need not be conducted.		
Testing Laboratory Information		
Testing Laboratory and testing location(s):		
Testing Laboratory:	Beijing Building Materials Testing Academy	
Testing location/ address..... :	Block 1, B15 Yaxin Road, Doudian Town, Fangshan District, Beijing 102402, CN	
Tested by (name, signature) ..... :	Zhang Qi /Oliver Zhao	
Witnessed by (for 3rd Party Lab Test Location) (name, signature) ..... :	N/A	N/A
Project Handler (name, signature)..... :	Arui Zhou	
Reviewer (name, signature) ……..:	Albert He	

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

Attachment A: Sample Charging, OCV and SOC Measurement Profiles - (*Pages **26** through**29***)

Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams - (*Pages **30** through **30***)

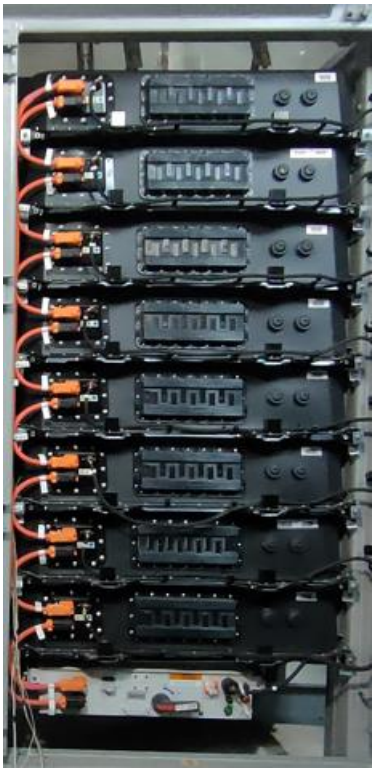
Attachment C: BESS and Equipment Instrumentation and Test Installation Layout Photos/Diagrams - (*Pages **31** through **33***)

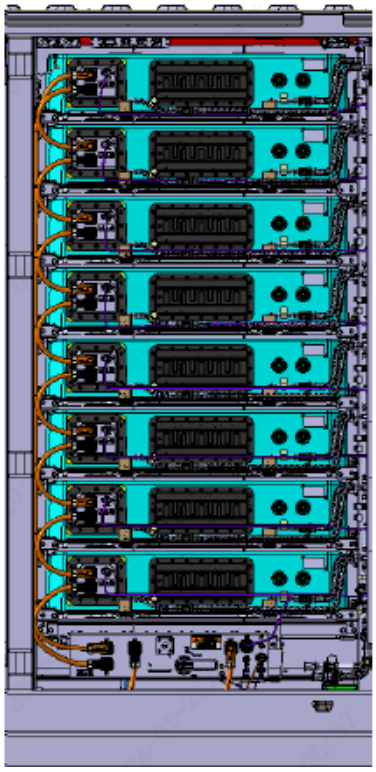
Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. - (*Pages **34** through **37***)

Attachment E: BESS Unit Testing and Post Testing Photos - (*Pages **38** through **39***)

Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles - (*Pages **40** through **42***)

Photo(s) of BESS unit:





Test Item Charge/Discharge Specifications:	**C06530P25L01-R**
• **Charge current, A:**	**265**
• **Charge power, kW:**	**44.1, then 22.05, then 11.025, then 8.82, for module** **352.77, then 176.38, then 88.19, then 70.55, for rack**
• **Standard Full charge voltage, Vdc:**	**Any cell reaches of 3.65 or total voltage 189.8 for module** **Any cell reaches of 3.65 or total voltage 1500 for rack**
• **Charge temperature range, °C:**	**0~55**
• **Discharge current, A:**	**265**
• **Discharge power, kW:**	**44.1 for module, 352.77 for rack**
• **End of discharge voltage, Vdc:**	**Any cell reaches of 2.5 or total voltage 130 for module** **Any cell reaches of 2.5 or total voltage 1040 for rack**
• **Discharge temperature range, °C:**	**-30~55**
• **storage temperature range, °C**	**-35~60**

Test item particulars .....:	
Possible test case verdicts:	
- test case does not apply to the test object.....:	N/A
- test object does meet the requirement .....:	P (Pass)
- test object does not meet the requirement.....:	F (Fail)
- test object was completed per the requirement...:	C(Complete)
- test object was completed with modification……:	M(Modification)
Testing.....:	
Date of receipt of test item .....:	2024-04-10
Date (s) of performance of tests.....:	2024-04-16

General remarks:

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

Throughout this report a point is used as the decimal separator.

Manufacturer's Declaration of samples submitted for test:

The applicant for this report includes samples from more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided..... :	☒ **Yes** ☐ **Not applicable**
Name and address of factory (ies).....:	Factory_1: Contemporary Amperex Technology Co., Limited Factory_1 address: No.2Xin'gangRoad,ZhangwanTown, Jiaocheng District,Ningde,Fujian,China Factory_2: Guangdong Ruiqing Contemporary Amperex Technology Limited Factory_2 address: No.1, Shidai Street, High-tech Industrial Development Zone, Zhaoqing City，Guangdong Province

General product information and other remarks:

Model C06530P25L01-R is lithium-ion Battery cabinet manufacturer by Contemporary Amperex Technology Co., Limited. The rack consists of 8 battery modules Model M02530P25L01 connected in series with a control box.

The container model number is C06530P25L01. The container consists of 4 battery racks of type C06530P25L01-R connected in parallel with a control box.

In the test, 3 racks were placed inside the container. Container size: (T)2438*(W)6058*(H)2896mm.

Battery module model M02530P25L01 employs cell Models CBLC0 manufactured by Contemporary Amperex Technology Co Limited, rated 166.4V(130V~189.8V), 1060Ah.

5.0	CONSTRUCTION		Verdict
5.3	**Battery energy storage system unit Construction**		—
5.3.1, 5.3.2	Construction information	See Test Item Description at the beginning of this report	—
5.3.2	General layout of BESS unit contents	See Attachment B	—
5.3.3	Details of integral fire suppression system	No fire suppression system	
5.3.1	BESS certified to UL 9540	**No**	
	Organization that certified BESS:	**N/A**	—
6.0	**PERFORMANCE**		**Verdict**
6.1	**General**		C
9.1	**Sample and test configuration**		C
9.1.1	The unit level test conducted with BESS units installed as described in the manufacturer's instructions.	See Attachment C for test installations Installation type: outdoor ground mounted in a container, non- residential use	C
9.1.2	The unit level test required 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 Attachment C for test installations	C
	Tests conducted for indoor floor mounted installations are representative of both indoor floor mounted and outdoor ground mounted installations.		C
	Tests conducted indoors with fire propagation hazards and separation distances between initiating and target units representative of the installation.		C
	Testing conducted outdoors for outdoor only installations with following in place: a) Wind screens with wind speed of ≤ 12 mph; b) Temperature range is 10°C to 40°C (50°F to 104°F); c) Humidity is < 90% RH; d) Sufficient light to observe the testing; e) There is no precipitation; f) There is control of vegetation and combustibles in the test area; and g) There are protection mechanisms in place to prevent inadvertent access by unauthorized persons in the test area.		N/A

9.1.3	Testing to determine fire characterization was done at the battery system level rather than a complete BESS	One initiating unit sample and two target unit samples were used for test. Power Conversion System was not involved in the test.	C
9.1.4	The initiating BESS contained components representative of a BESS unit in a complete installation.		C
	Combustible components that interconnect the initiating and target BESS units was included.		C
9.1.5	Target BESS units include the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components.		C
9.1.6	The initiating BESS was at the maximum operating state of charge (MOSOC),	See Table 2 and Attachment A	C
	After charging and prior to testing, the initiating BESS was at rest for a maximum period of 8 hours at room ambient.	See Table 2 All modules were fully charged before test for test setup. All module voltages were checked just before the test, and the voltages did not drop further compared to 1h to 8h after cycles.	M
9.1.7	The BESS unit included an integral fire suppression system.	No include integral fire suppression system.	N/A
9.1.8	Electronics and software controls such as the battery management system (BMS) are not relied upon for this testing.		C
	Included a fire suppression control in accordance with UL 864 that is external to the BESS.		N/A
9.2	**Test method – Indoor floor mounted BESS units**		C
9.2.1	Test room ambient temperature within 10°C (50°F) to 32°C (90°F).	See Table 2 See Attachment F	C
9.2.2	Access door(s) or panels on the initiating BESS unit and adjacent target BESS units were closed, latched and locked duration of the test.	There are no doors or panels for racks, racks are mounted on the container frame.	C
9.2.3	The initiating BESS unit was positioned adjacent to two instrumented wall sections.	Attachment C	C
9.2.4	Instrumented wall sections extend not less than 0.49 m (1.6 ft) horizontally beyond the exterior of target BESS units.	Front wall was 7.2m length, side wall was 7.2m length, rear wall was 7.2m length.	C
9.2.5	Instrumented wall sections were at least 0.61-m (2-ft) taller than the BESS unit height, but not less than 3.66 m (12 ft) in height above the bottom surface of the unit.	Front wall, side wall and rear wall were 3.7m high.	C
9.2.6	The surface of the instrumented wall sections were covered with 16-mm (5/8-in) gypsum wall board and painted flat black.	See Attachment C	C

9.2.7	The initiating BESS unit was centered underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.		C
9.2.8	The light transmission in the calorimeter's exhaust duct was measured using a white light source and photo detector. The smoke release rate was calculated.	See Table 11 See Attachment F	C
9.2.9	The chemical and convective heat release rates were measured for the duration of the test.	See Table 11 See Attachment F	
9.2.10	The heat release rate measurement system was calibrated using an atomized heptane diffusion burner. The calibration was performed using flows of 3.8, 7.6, 11.4 and 15.2 L/min (1, 2, 3 and 4 gpm) of heptane.		C
9.2.11	The chemical heat release rate was measured using the following equipment: ● Paramagnetic oxygen analyser ● Non-dispersive infrared carbon dioxide and carbon monoxide analyser ● Velocity probe ● Type K thermocouple		C
9.2.12	The chemical heat release rate at each of the flows was calculated.		C
9.2.13	The physical spacing between BESS units (both initiating and target) and adjacent walls was representative of the intended installation.	See Attachment C Racks were installed inside container frame. The spacing between the initiating rack and adjacent target racks (left and right of initiating unit) was 0mm. The spacing from the front wall to the container frame was 3500mm, side wall to the container frame was 150mm and rear wall to the container frame was 150mm	C
9.2.14	Separation distances were specified by the manufacturer for distance between: a) The BESS units and the instrumented wall sections; and b) Adjacent BESS units.	See Attachment C	C
9.2.15	Wall surface temperature measurements were collected	See Table 6 See Attachment D	C
	The intended installation is composed completely of non-combustible construction		N/A

9.2.16	Wall surface temperatures were measured in vertical array(s) at 152-mm (6-in) intervals for the full height of the instrumented wall sections using No. 24-gauge or smaller, Type-K exposed junction thermocouples.		C
	The thermocouples for measuring the temperature on wall surfaces were horizontally positioned in the wall locations to receive greatest thermal exposure from the initiating BESS unit.		C
9.2.17	Thermocouples were secured to gypsum surfaces and the thermocouple tip was depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement .		C
9.2.18	Heat flux was measured with at least two water-cooled Schmidt-Boelter gauges at the surface of each instrumented wall: a) Both are collinear with the vertical thermocouple array; b) One is positioned to receive the greatest heat from the initiating module; and c) One is positioned to receive the greatest heat flux during potential propagation within the initiating BESS unit.	See Table 7	C
9.2.19	Heat flux was measured with 2 water-cooled Schmidt-Boelter gauges at the surface of each adjacent target BESS units facing initiating BESS unit: a) One is positioned at the elevation estimated to receive the greatest heat flux from the initiating module; and b) One is positioned at the elevation estimated to receive the greatest surface heat flux due to initiating BESS.	See Table 7	C
9.2.20	Heat flux was measured with the sensing element of at least one water-cooled Schmidt-Boelter gauge positioned in the center of the accessible means of egress.	See Table 7	C
9.2.21	No. 24-gauge or smaller, Type-K exposed junction thermocouples were installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the initiating module.	See Attachment C	C
	Each non-initiating module enclosure within the initiating BESS unit was instrumented with at least one No. 24-gauge or smaller Type-K thermocouple(s) within non-initiating modules.	See Attachment C	C
	Additional thermocouples were placed to account for convoluted geometries.		N/A

9.2.22	For residential use, the DUT was covered with a single layer of cheese cloth ignition indicator. The cheesecloth was untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm^2 (1 in^2) area.	Non-residential use.	N/A
9.2.23	An internal fire condition in accordance with the module level test was created within a single module in the initiating BESS unit: a) The position selected to present the greatest thermal exposure to adjacent modules; and b) The setup was the same as that used to initiate and propagate thermal runaway within the module level test.	See Attachment C	C
9.2.24	The composition, velocity and temperature of the initiating BESS unit vent gases was measured within the calorimeter's exhaust duct. Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.		C
	Hydrogen gas shall be measured with a palladium-nickel thin-film solid state sensor.		C
	The hydrocarbon content of the vent gas may also be measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm-1 and a path length of at least 2 m (6.6 ft), or equivalent gas analyzer.	FTIR analysis was not used in accordance with the Certification Requirement Decision: Corrections to gas measurement methods to make FTIR as an option for measuring hydrocarbon contents of gas emissions and to include Hydrogen measurements during the Unit Level Test.	N/A
9.2.25	The hydrocarbon content of the vent gas was measured using flame ionization detection.	See Tables 8, 9, 10 and 11	
9.7	**Unit level test report**		

9.7.1	Installation type tested:	Outdoor ground mounted, non-Residential, container type 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.	C
9.7.2	Testing is intended to represent more than one installation type.	See Test Item Description in beginning of this report.	C
9.7.3	a. Unit manufacturer name and model number (and whether UL 9540 compliant);		C
	b. Number of modules in the initiating BESS unit		C
	c. BESS construction features;	See Attachment C See Critical Components Table See Also “Description of components employed within the module that impact propagation (fire protection features)” at the beginning of this report.	C
	d. Fire protection features/ detection/ suppression systems within unit		N/A
	e. Module voltages corresponding to the tested SOC;	See Table 13	C
	f. Thermal runaway initiation method used;	See Attachment C and F	C
	g. Location of the initiating module within the BESS unit;	See Attachment C	C
	h. Diagram and dimensions of the test setup including mounting location of the initiating and target BESS units, and the locations of walls, ceilings, and soffits;	See Attachment C	C
	i. Observation of any flaming outside the initiating BESS enclosure and the maximum flame extension;	See Table 14 No flame observed outside of the initiating rack.	C
	j. Chemical and convective heat release rate versus time data;	See Table 11 See Attachment F	C
	k. Separation distances from the initiating BESS unit to target walls	See Attachment C	C

	l. Separation distances from the initiating BESS unit to target BESS units	See Attachment C	C
	m. The maximum wall surface and target BESS temperatures achieved during the test and the location of the measuring thermocouple;	Tables 5 and 6	C
	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;	Table 7	C
	p) The maximum incident heat flux on target ceiling or soffit surfaces achieved during the indoor or outdoor wall mounted test;		N/A
	q. Flammable gas generation and composition data;	See Attachment F See Tables 7, 8, 9, and 10	C
	r. Peak smoke release rate and total smoke release data.	See Table 11 See Attachments F	C
	s. Indication of the activation of integral fire protection systems and if activated the time into the test at which activation occurred;	No fire protection systems	N/A
	t. Observation(s) of flying debris or explosive discharge of gases;	See Table 15	C
	u. Observation of re-ignition(s) from thermal runaway events	See Table 15	C
	v. Observation(s) of sparks, electrical arcs, or other electrical events;	See Table 15	C
	w. Observations of the damage to: 1) The initiating BESS unit; 2) Target BESS units; 3) Adjacent walls, ceilings, or soffits;	See Attachment E	C
	x. Video of the test.		C
9.8	**Performance at Unit level testing**		P
9.8.1	Installation level testing in Section 10 was not required if the following performance conditions outlined in Table 9.1 are met during the unit level test.	See Attachment F	P
Non-Residential Installations – Indoor floor mounted:			
	a) Flaming outside the initiating BESS unit is not observed;	No flaming observed	P
	b) Surface temperatures of modules within target BESS units do not exceed the cell venting temperature;	Max surface temperature 26.7°C didn't exceed the cell venting temperature 165°C	P
	c) For BESS units intended for installation in locations with combustible constructions, surface temperature measurements on wall surfaces do not exceed 97°C (175°F) rise above ambient;	Max wall surface temperature 26.2°C didn't exceed 97°C rise above ambient	P

	d) Explosion hazards are not observed, including deflagration, detonation or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases;	No explosion observed	P
	e) Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m^2.	Measured heat flux 0kW/m2 didn’t exceed 1.3 kW/m2	P

Table 1 – Specified Unit charging and discharging parameters			
Charging:		**Discharging:**	
Power (CP), kW	44.1, then 22.05, then 11.025, then 8.82, for module 352.77, then 176.38, then 88.19, then 70.55, for rack	Power (CP), kW	44.1 for module 352.77 for rack
Standard Full Charge Voltage ,Vdc	Any cell reaches 3.65 or total voltage 189.8 Any cell reaches 3.65 or total voltage 1500 for rack	End of discharge voltage, Vdc	Any cell reaches 2.5 or total voltage130 for module Any cell reaches 2.5 or total voltage 1040 for rack
End of charge Voltage, Vdc	Any cell reaches 3.65 or total voltage 189.8	Discharging Test Ambient, °C	-30~55
Charging Test Ambient, °C	0~55	N/A	N/A
Refer to Attachment A for charge/discharge profiles.			

Table 2 - Test Initiation Details	
Test Date	2024-04-18
Test Start Time (HH:MM:SS)	10:13:43
Initial Lab Temperature, °C	20.1°C
Initial Relative Humidity % RH	55% RH
Module OCV at Start of Test, Vdc	173.4V

Table 3 – Approximate time of thermal runaway propagation through module		
Locations (Cell #)	**Event**	**Time**
Cell 40	Vent	0:53:26
Cell 40	Thermal runaway	0:55:21
Cell 39	Thermal runaway	0:58:59

Table 4 – Test overview timeline		
Time (HH:MM:SS)	**Event**	**Description**
00:00:00	Test Start	The test was started and the heater was turned on to heat the initiating cell (Cell 40) at a ratio of 4 ~ 7 °C/min.
00:53:26	Venting of initiating Cell	Initiating cell (Cell 40) vented at around 177.4°C measured through T1-3 by an indication of sudden dip in cell's temperature curve. See Figure (b)
00:55:21	Thermal runaway of initiating cell	Initiating cell (Cell 40) was at around 177.4°C measured through T 1-3. The temperature of cell (cell 40) began to increase in an uncontrollable manner, top cover bulge See Figure (c)
00:58:59	Thermal runaway of initiating cell	Thermal runaway propagated to nearby cell (cell 39). See Figure (d)
01:40:00	Test Termination	Data acquisition was stopped. The module was left in the test overnight and with video monitored. See Figure (e)

Table 5 - Maximum Temperatures in Target Units			
Cell vent temperature from cell test data, °C		165°C	
Target Unit 1		**Target Unit 2**	
Module Location No.	Temperature (°C)	Module Location No.	Temperature (°C)
Module -1	23.7	Module -1	24.0
Module -2	24.7	Module -2	25.4
Module -3	25.4	Module -3	27.3
Module -4	25.5	Module -4	26.4
Module -5	25.6	Module -5	26.1
Module -6	25.5	Module -6	25.7
Module -7	25.4	Module -7	26.0
Module -8	25.6	Module -8	26.0
Note: Temperatures are measured constantly and then averaged every 60-seconds.			

Table 6.1 - Maximum Temperatures on Instrumented Wall- Front Wall					
Ambient Temperature: 20.1 °C					
UL 9540A performance criteria, Ambient + 97°C: 117.1°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	22.3	1368	23.1	2584	24.7
304	22.3	1520	24.5	2736	24.8
456	22.8	1672	24.7	2888	24.9
608	23.8	1824	23.1	3040	25.0
760	23.4	1976	24.1	3192	25.4
912	23.6	2128	25.1	3344	25.4
1064	25.6	2280	25.1	3496	25.5
1216	25.8	2432	23.3	3648	25.1
Note: Temperatures are measured constantly and then averaged every 60-seconds.					

Table 6.2 - Maximum Temperatures on Instrumented Wall- Side Wall					
Ambient Temperature: 20.1 °C					
UL 9540A performance criteria, Ambient + 97°C: 117.1°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	21.9	1368	23.5	2584	23.8
304	22.3	1520	23.6	2736	23.9
456	22.2	1672	23.5	2888	24.3
608	22.2	1824	23.7	3040	24.4
760	22.8	1976	24.1	3192	24.4
912	22.9	2128	24.3	3344	25.0
1064	23.1	2280	24.4	3496	24.9
1216	23.2	2432	24.4	3648	25.6
Note: Temperatures are measured constantly and then averaged every 60-seconds.					

Table 6.3 - Maximum Temperatures on Instrumented Wall- Rear Wall					
Ambient Temperature: 20.1 °C					
UL 9540A performance criteria, Ambient + 97°C: 117.1°C					
Height, mm	Maximum Temperature (°C)	Height, mm	Maximum Temperature (°C)	Height	Maximum Temperature (°C)
152	22.3	1368	20.4	2584	20.4
304	22.3	1520	20.8	2736	20.8
456	19.9	1672	21.0	2888	21.0
608	19.9	1824	21.5	3040	21.5
760	19.9	1976	21.0	3192	21.0
912	21.4	2128	21.3	3344	21.3
1064	20.8	2280	21.4	3496	21.4
1216	20.3	2432	21.0	3648	21.0
Note: Temperatures are measured constantly and then averaged every 60-seconds.					

Table 7 – Heat Flux Measurements			
Summary of maximum heat flux in target units		Summary of maximum heat flux measured on instrumented wall	
Maximum Heat Flux, kW/m^2			
Target Unit 1 Module No.3: 5#	0.1	Heat Flux Gauge No.	kW/m^2
Target Unit 1 Module No.4: 1#	0	Front wall 1450 mm high, 4#	0
Target Unit 2 Module No.3: 11#	0	Front wall 1650 mm high, 10#	0
Target Unit 2 Module No.4: 2#	0	Side wall 1450 mm high, 6#	0
-	-	Side wall 1650 mm high, 3#	0
-	-	Rear wall 1450 mm high, 7 #	0
-	-	Rear wall 1650 mm high, 9#	0
Egress path measurement: 8 #			0

Table 8 – Gases measured and measurement methods used in unit level testing			
Measurement Method	**Gases Measured**	**Chemical Formula**	**Gas Type**
Flame Ionization Detection (FID)	Total Hydrocarbons	-	Hydrocarbons
Solid-state Hydrogen Sensor	Hydrogen	H_2	-
Non-dispersive infrared spectroscopy (NDIR)	Carbon Dioxide	CO_2	Carbon Containing
	Carbon Monoxide	CO	Carbon Containing
# - This table was modified to reflect the gases measured during testing.			

Table 9 - Gas generation periods	
Time	**Condition**
From the venting point 0:53:26 to the end of test 1:40:00	Pre-Flaming
Flaming was not observed during the test.	Flaming
External Flaming of Gas	
Condition	**Duration (hh:mm:ss)**
External Flaming of Vent Gases:	Flaming was not observed during the test.

Table 10 – Summary of battery gas volumes for deflagration hazard calculations				
Gas Component	Gas Type	During Pre-flaming (L)	During Flaming (L)	Minimum detectable flow rate(LPM)
Total Hydrocarbons (Propane Equivalent)	Hydrocarbons	121.62	No flaming	2.42
Carbon Monoxide	Carbon Containing	53.14	No flaming	1.67
Carbon Dioxide	Carbon Containing	95.12	No flaming	4.02
Hydrogen	Hydrogen	28.44	No flaming	61.45

Table 11 – Smoke and heat release rate			
Heat Release Rate (HRR)		**Smoke Release Rate (SRR)**	
Peak Chemical HRR (kW)	No flaming observed	Maximum SRR (m^2/s)	0.04
Peak Convective HRR, (kW)	No flaming observed	Total Smoke Released (m^2)	0.73

Table 12 – Integral Fire suppression system Details of Operation
N/A

Table 13 - Module OCV voltage measurement comparison before and after testing			
Module Location In Rack	OCV Prior to Test (V)	OCV Post Test (V)	Difference (V)
1	173.4	173.4	0
2	173.8	173.6	0.2
3	173.4	169.8	3.6
4	173.2	173.2	0
5	173.1	173.1	0
6	173.6	173.5	0.1
7	173.5	173.4	0.1
8	173.4	173.3	0.1

Table 14 – Other Observations during Unit test			
	Observed, Yes/No	Comments/Location	
Flaming outside of Unit	No	Length of flame:	N/A
Flying debris	No	-	
Explosive discharge of gas	No	-	
Sparks or electrical arcs	No	-	

Table 15 - Post Test Observations	
Thermal runaway behaviour	No further thermal runaway after the test was completed
Re-ignitions	No re-ignition occurred
Explosions	No explosion occurred
Other Observations	N/A

	TABLE: Critical components information				
Object / Part No.	**Manufacturer/ trademark**	**Type / model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Module construction					
Cells	CATL	CBLC0	Nominal voltage: 3.2V Rated capacity: 530Ah	UL 1973:2022 IEC 62619:2022	UL MH62898 TUV 085-282460047-000
Metal enclosure	CATL	—	Material: HC340/590DP.Z Thickness: ≥1.5mm Size：L*W*H（mm） 2231.1*1193*56.4	--	--
Plastic enclosure	0000036890	NHPP-FR NHPP-FR-2	Material: PP Thickness: 2.5mm±0.2 Size: L*W*H（mm） 2183.6*1193*228.2 Fire rating: V-0 Maximum ambient temperature: 90°C	--	--
Connector(B+, B-)	0000007975	REA4-ZBOD2-A REA4-ZCBD2-A	Voltage: 1500vDC Current: 300A for UL,350A for TUV Fire rating: V-0	UL 4128 EN 61984	UL E526230 TUV J 50586193
Power supply wire	0000009966	3666	Voltage: 600V Wire diameter:（≥0.35mm2） Maximum ambient temperature: 105℃	UL 758 EN 50525 IEC 60227 IEC 60228:2004	UL E214184 UDEM M.2021.206.C63716
Harness isolation board	0000007541	430A	Fire rating: V-0 RTI: 65℃	UL 94	UL E225348
Mica piece	0000012182	Goode Shield T29	Fire rating: V-0 RTI temperature: 200℃ Size: (204*1968*0.35mm) lateral side (2119.4*1258.8*0.5mm) top	UL 94	UL E529419
Plastic（Output Pole Base）	0000007541	1460G(b)	Fire rating: V-0 RTI: 75℃	UL 94	UL E225348
Polypropylene Microporous Cushion	0000007929	FR-MPP	Fire rating：HF-1 RTI: 65℃ Size: 264.7±2mm*206.7±2mm*3.3±0.3mm	UL 94	UL E509966

Glass fiber Cushion	0000003940	FRA-C650(TX)	Fire rating: V-0 Maximum ambient temperature: 675℃ Size: 264.7±2mm*206.7±2mm*2±0.2mm	--	--
Insulation Plastic	0000007929	PP BK-10-2	Fire rating: VTM-0 RTI: 110℃ Size: 1960±5mm*20±2mm*0.175±0.02mm	UL 94	UL E315185
Cover of CSC	0000003592	BWFRFO-AF01	Thickness: 0.8mm, Fire rating: V-0 RTI: 80°C	UL 94	UL E525490
Explosion relief valve	–	M32	Discharge pressure: 5±1kPa Plastic material: PBT+15GF Spring material: SUS304 Sealing ring material: VMQ Two provided	--	--
NTC	0000008559	103AP-2	10 kΩ, Tmoa:110 °C	UL 1434	UL E92669
Container					
Enclosure	0000014067	—	Material: steel High weather resistance rolled steel Thickness: 1.6mm~12mm Size: 6058*2438*2896(mm)	--	--
High voltage output cable	0000009966	3932	Voltage： 2000V Maximum ambient temperature: 125℃	UL 758	UL E214184
Heat shrinkable wiring pipe	0000009818	CB-DWT	Voltage Rating: 600V Temperature Rating:125 °C	UL 224	UL E180908
Terminal block	0000026799	Terminal blocks Cat. Nos. RCT16,RCT35,RDK16 and RDK35,RBT16 NT,RCT16 NT,RNK16	Fire rating： V-0	UL 1059 UL 94	UL E306887 SGS GZIN1905026740MR
Main control box					

Enclosure	0000015210	—	Material：steel DC51D+Z&DC01 Thickness：≥1.5mm Size： 813.5±5*741.4±5*179.3±5 mm	--	--
Connector(B+、B-、HV+、HV-)	0000007975	REA4-ZABD2-A REA4-ZBOD2-A REA4-ZCBD2-A REA4-ZDOD2-A	Voltage：1500vDC Current： 300A for UL,350A for TUV Fire rating：V-0	UL 4128 EN 61984	UL E526230 TUV J 50586193
Connecting wire for HV	0000009966	3932	Voltage：2000V Maximum ambient temperature: 125°C	UL 758 EN 50525 IEC 60227 IEC 60228:2004	UL E214184 UDEM M.2021.206.C63716
Insulating column	0000007989	YD0304E	Fire rating：V-0 RTI:130℃	UL 94	UL E240680
Power supply wire	0000009966	3666	Voltage：600V Wire diameter： （0.5~4mm2） Maximum ambient temperature: 105℃	UL 758 EN 50525 IEC 60227 IEC 60228:2004	UL E214184 UDEM M.2021.206.C63716
Sealing element	0000008177	GM-30	Fire rating：V-0 RTI:150℃	UL 94 IEC 60695-11-10 UL 746B	UL E499089

Attachment A: Sample Charging, OCV and SOC Measurement Profiles - (*Pages **26** through**29***)

Note: There were 8 modules in the initiating unit. Due to the voltage limitation of the charging device, the modules in the unit were divided into 8 groups and were then fully charged separately. The charging current of each module is 44.1 kW, then 22.05 kW, then 11.025kW, then 8.82kW and the charging ends when any cell reaches of 3.65V or total voltage 189.8V for module.

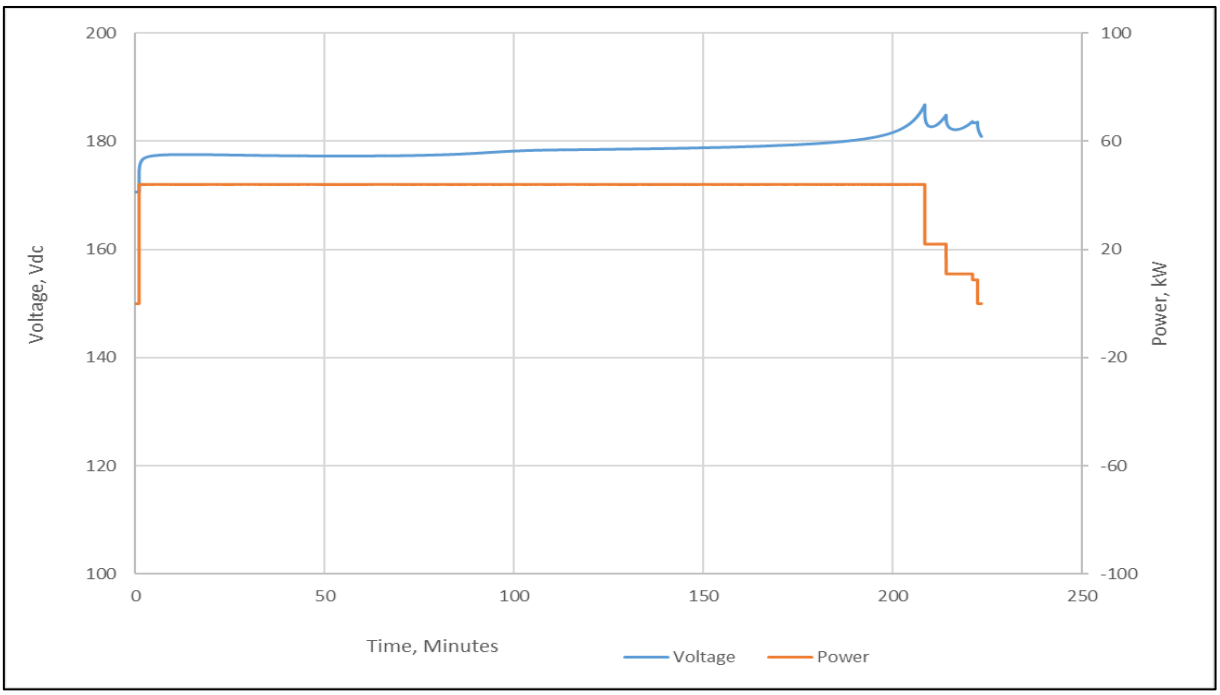


Figure 1: Initiating unit, module 1 charge to 100% SOC

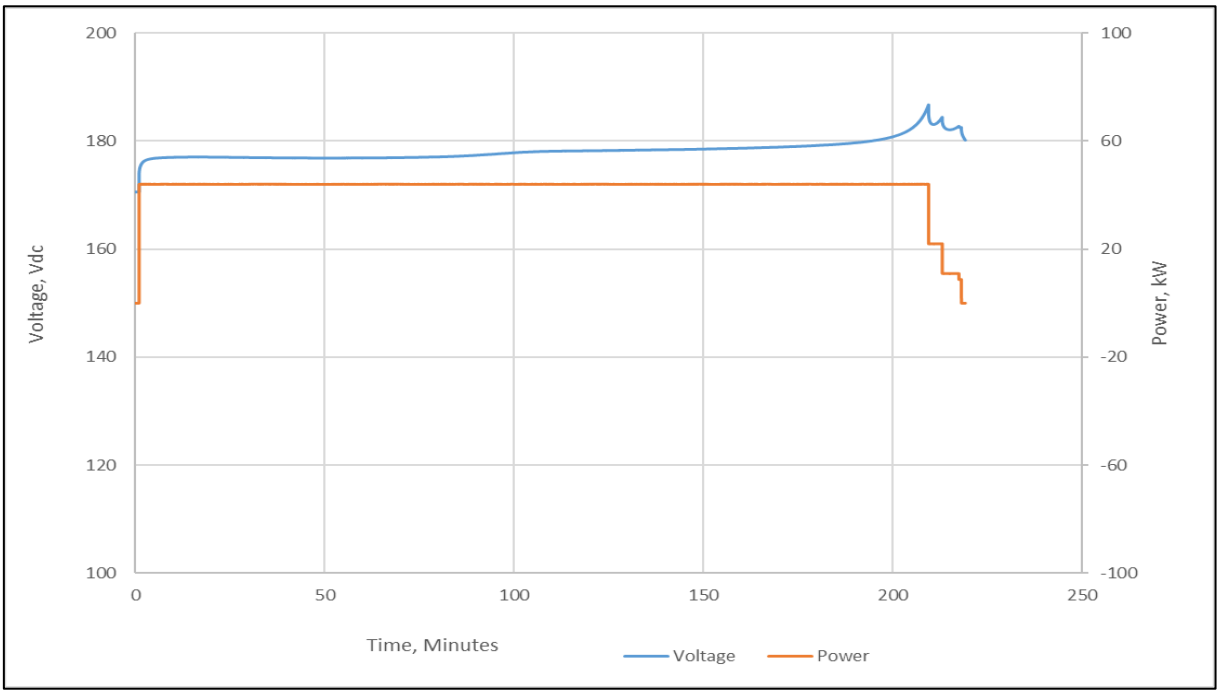


Figure 2: Initiating unit, module 2 charge to 100% SOC

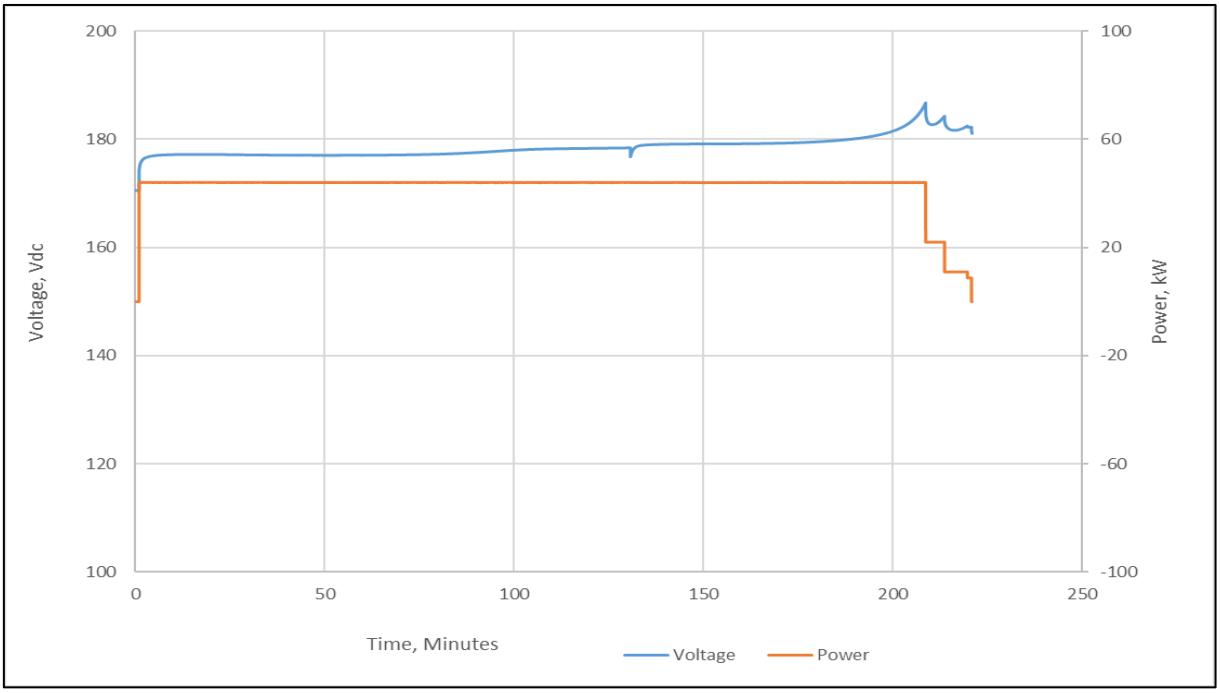


Figure 3: Initiating unit, module 3 charge to 100% SOC

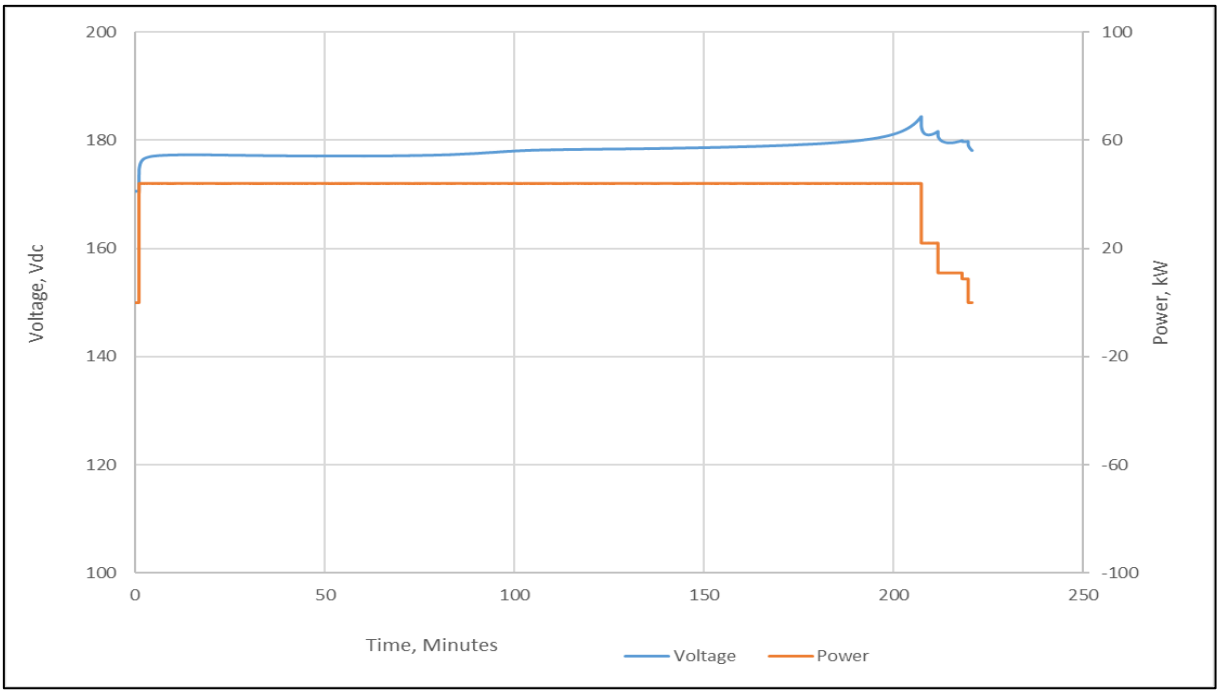


Figure 4: Initiating unit, module 4 charge to 100% SOC

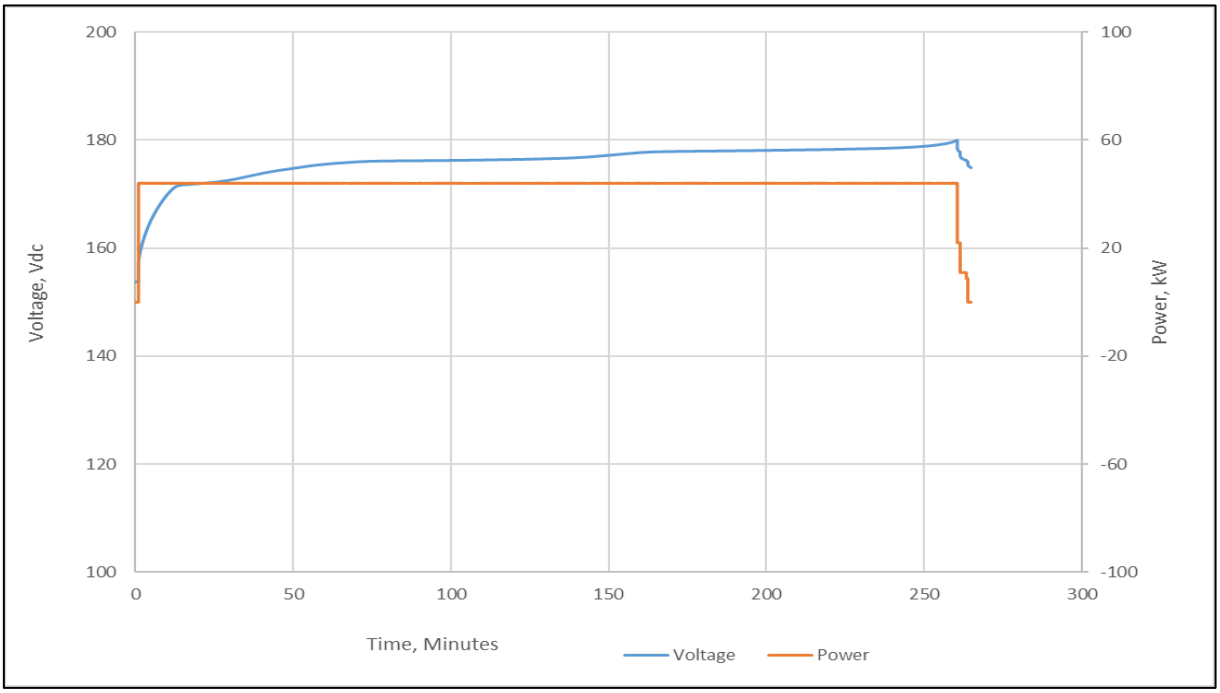


Figure 5: Initiating unit, module 5 charge to 100% SOC

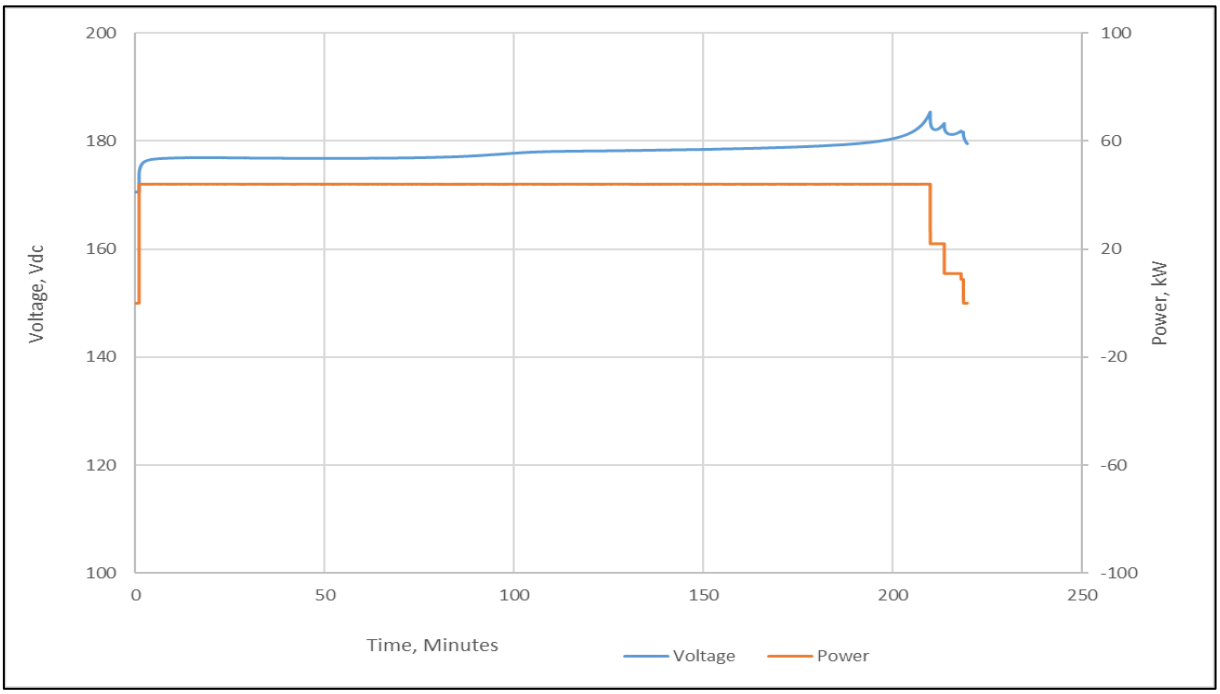


Figure 6: Initiating unit, module 6 charge to 100% SOC

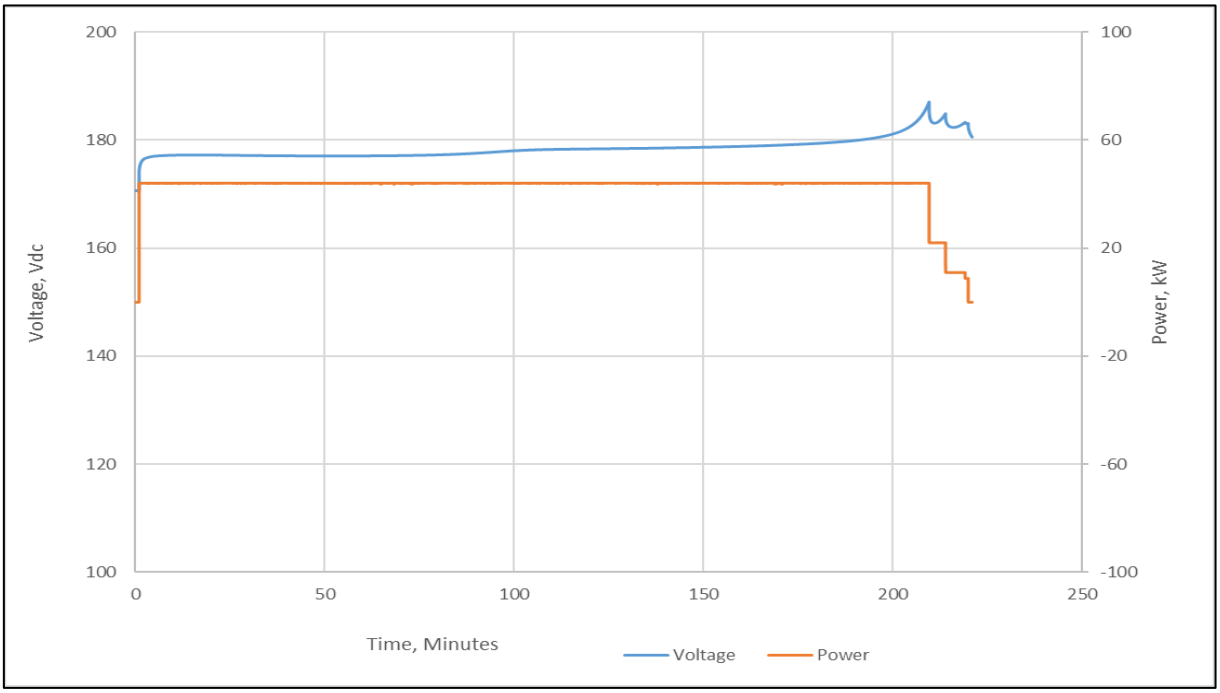


Figure 7: Initiating unit, module 7 charge to 100% SOC

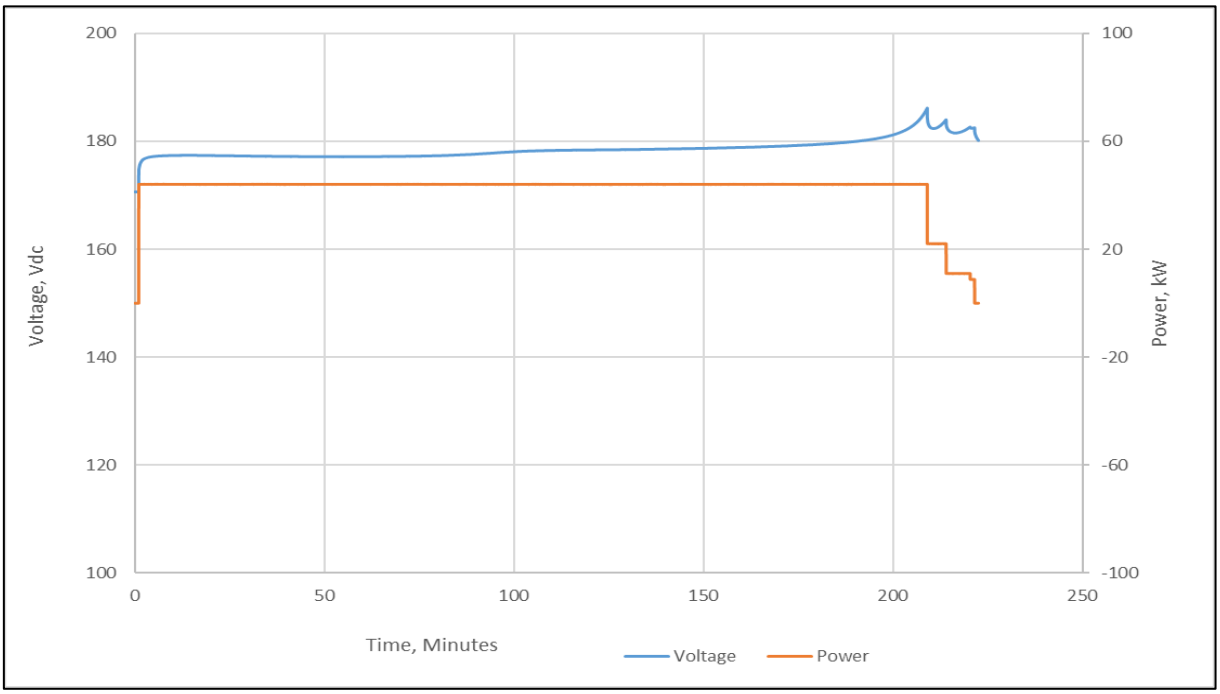
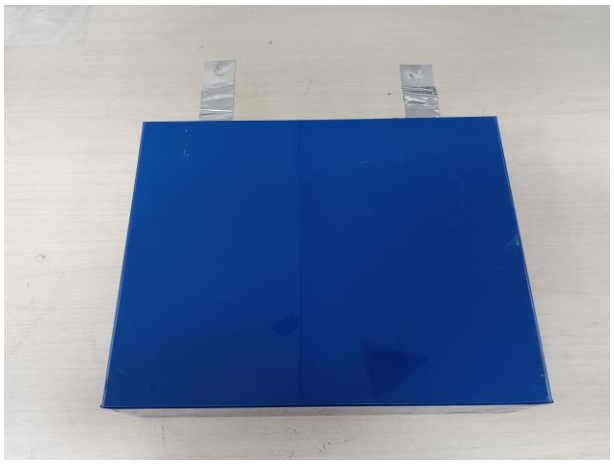


Figure 8: Initiating unit, module 8 charge to 100% SOC

Attachment B: BESS (including module and any integral fire detection and suppression systems) Construction Photos/Diagrams - (*Pages **30** through **30***)



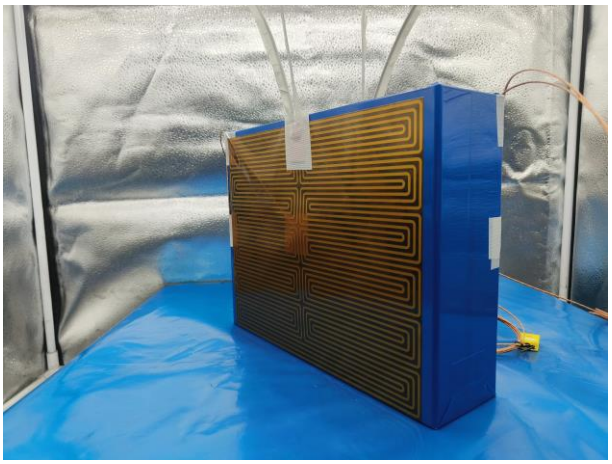


Figure 9: BESS unit and module Construction Photos

Note: there is no fire detection and suppression systems in the Unit BESS.

Attachment C: BESS and Equipment Instrumentation and Test Installation Layout Photos/Diagrams - (*Pages **31** through **33***)

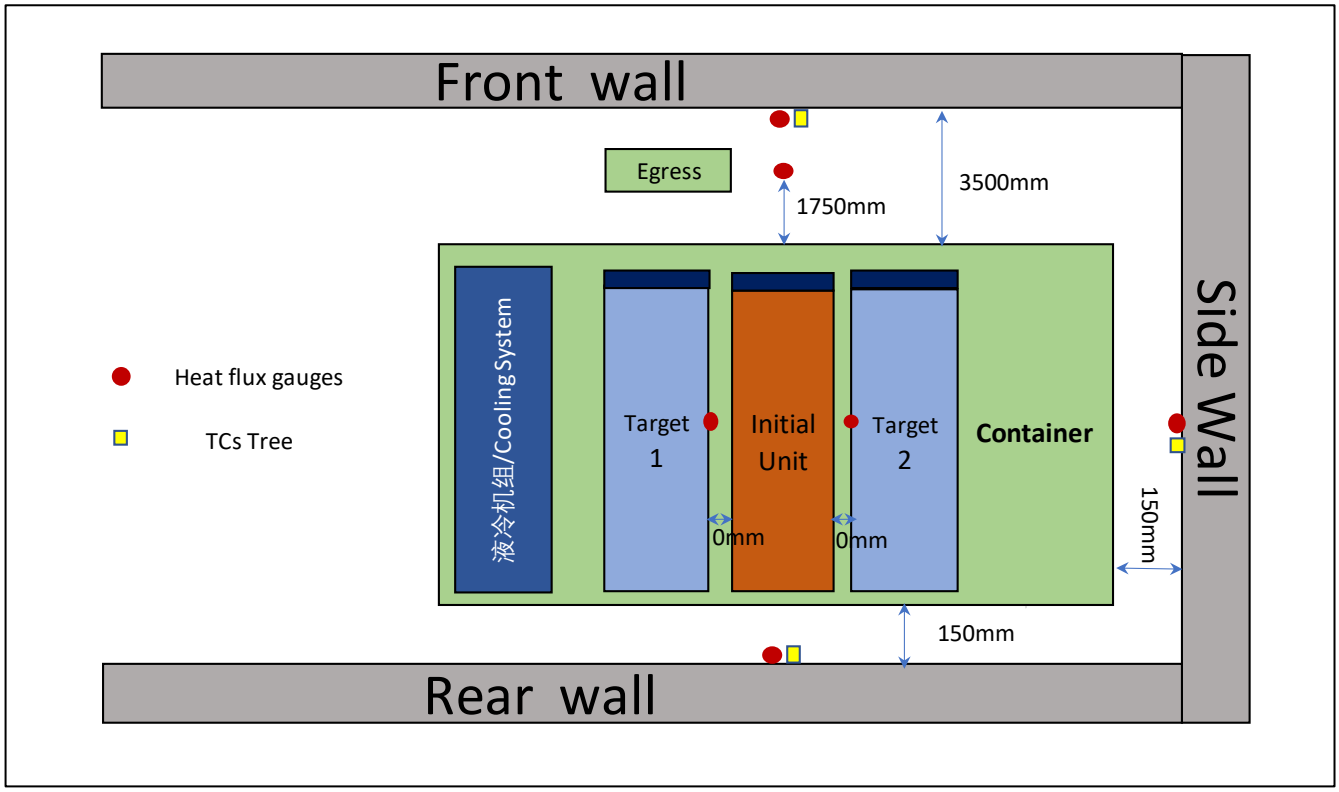


Figure 10: Test area layout

Front view - TC Location of front wall. From the bottom to up, TCs were FW-1 to FW-24

Side view - TC Location of side wall. From the bottom to up, TCs were SW-1 to SW-24

	N/A
Rear view - TC Location of side wall. From the bottom to up, TCs were RW-1 to RW-24	

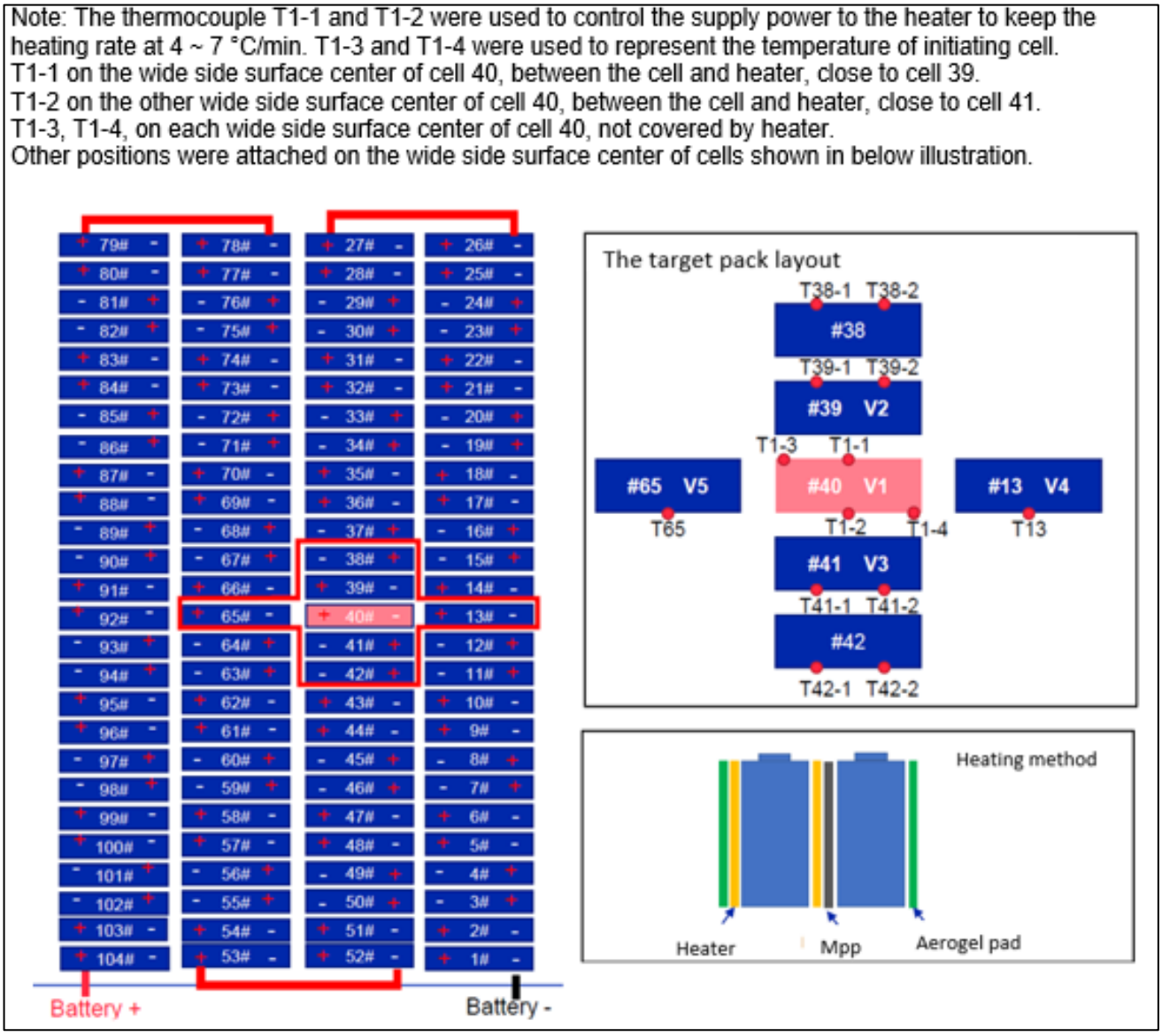


Figure 11: TC Location in the initiating module

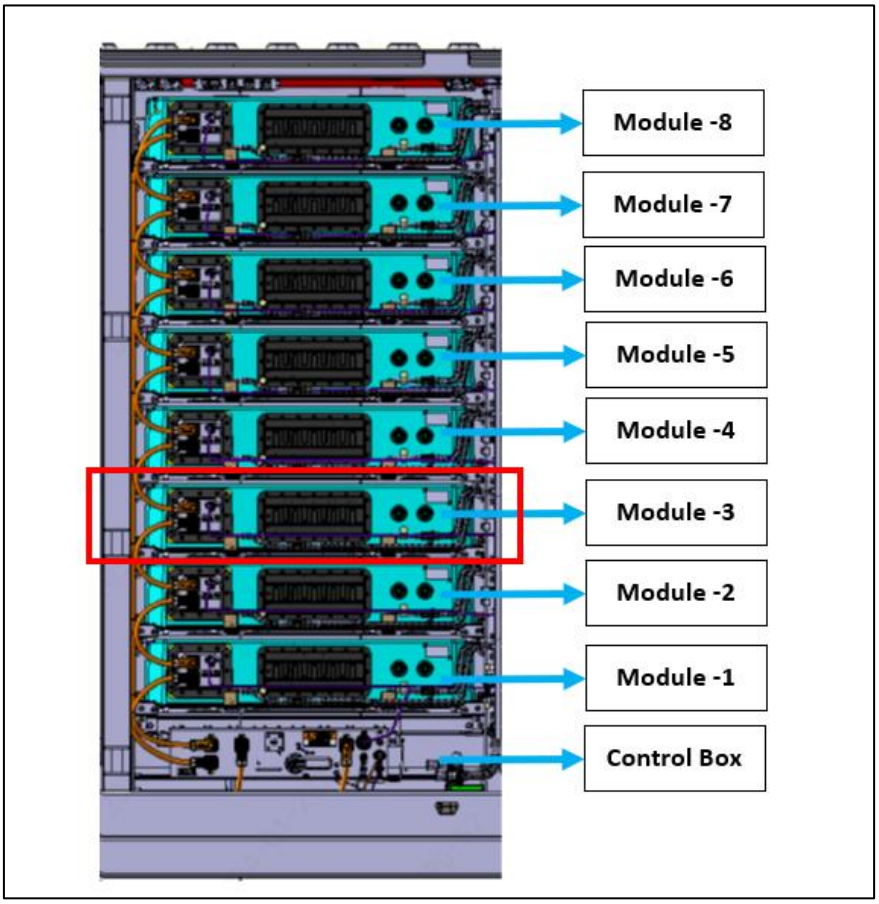
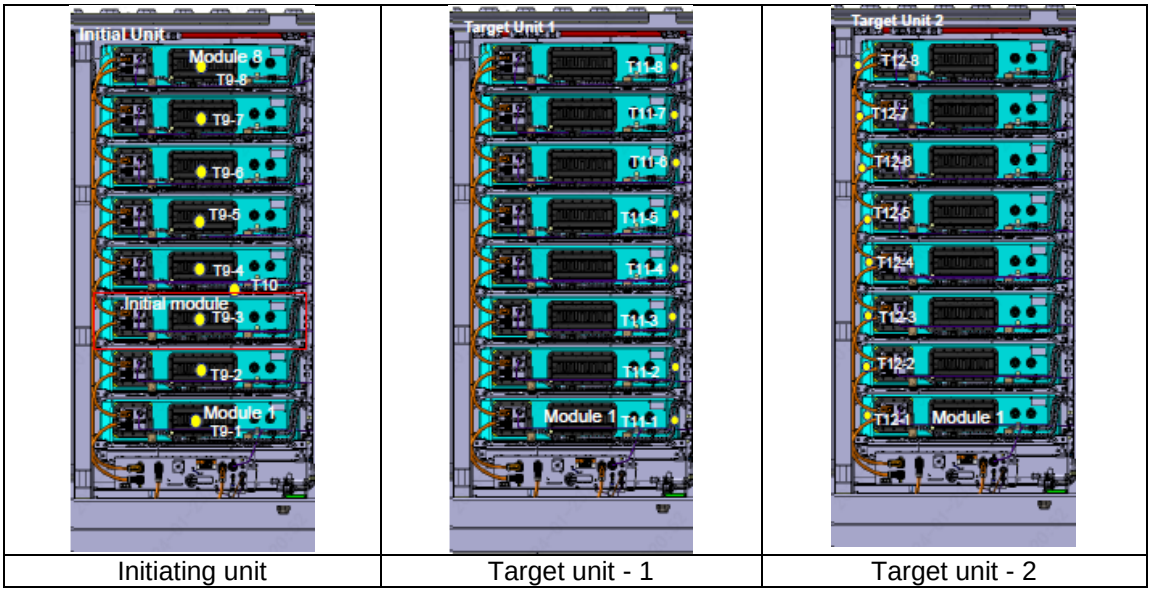


Figure 12: The initiating module 3 location in the initiating unit



Initiating unit	Target unit - 1	Target unit - 2

Figure 13: TC location in the initiating and target units, T11 series for target unit-1, T12 series for target unit-2

(Note: Except T10 affixed to the top frame of the initiating module, other T9 affixed to the middle height of the module frame.)

Attachment D: Temperature Profiles and Heat Flux Measurements During Testing (Initiating Cell and Module, Target Modules, Wall Surfaces, etc. - (*Pages **34** through **37***)

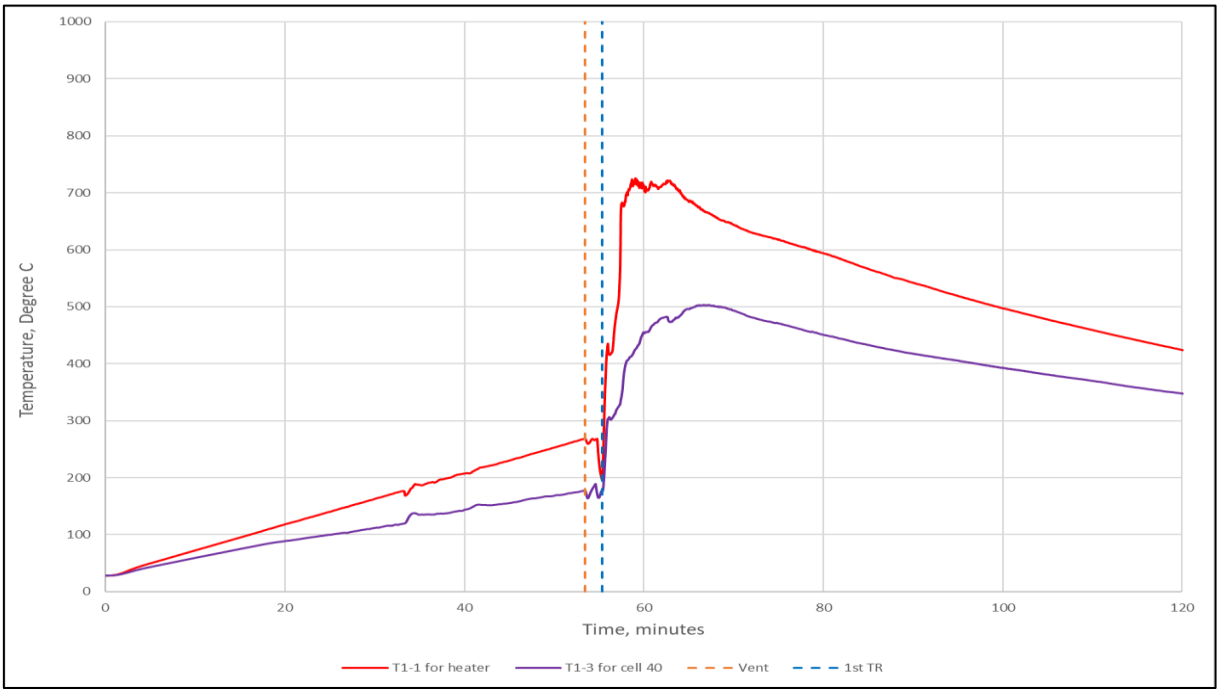


Figure 14: Initiating cells vent and Thermal runaway Initiating cell Temperature Profiles During Testing

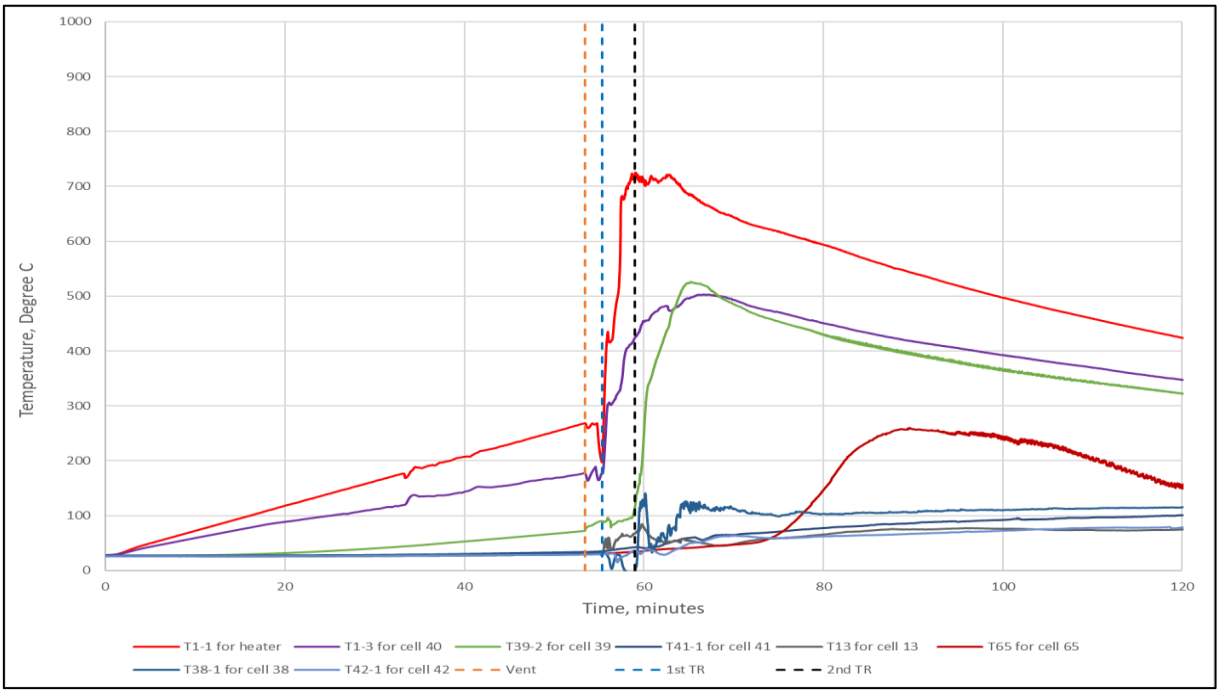


Figure 15: Initiating module temperature

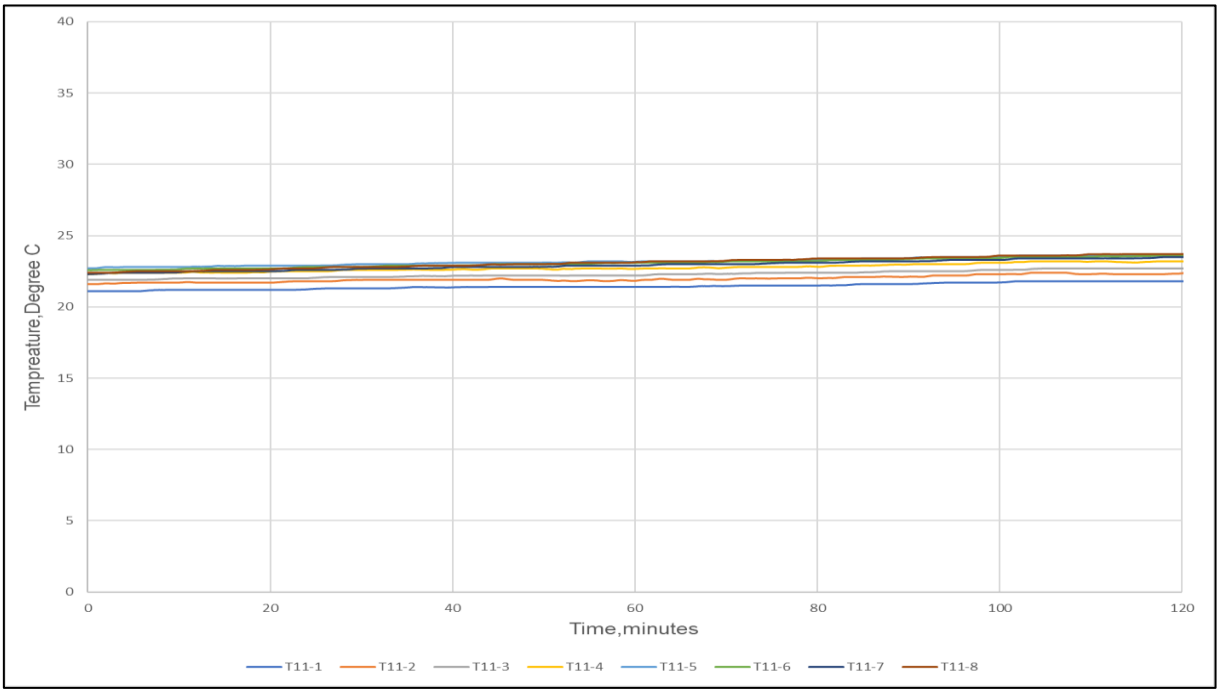


Figure 16: Target unit-1 temperature

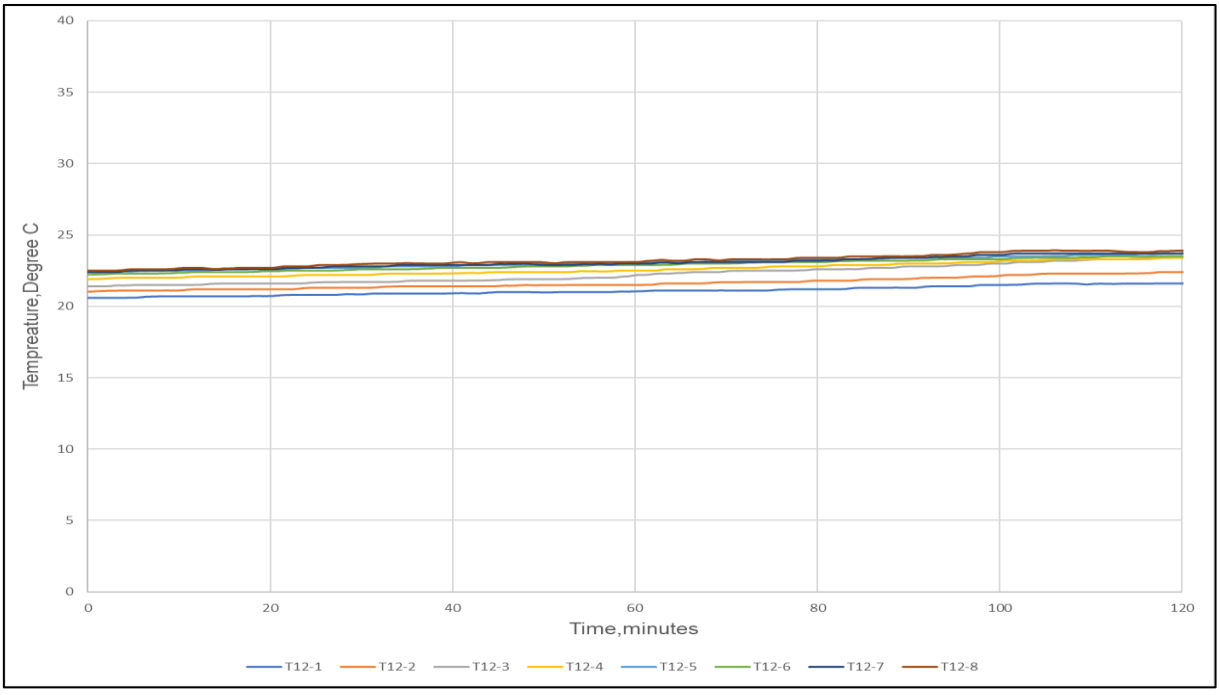


Figure 17: Target unit-2 temperature

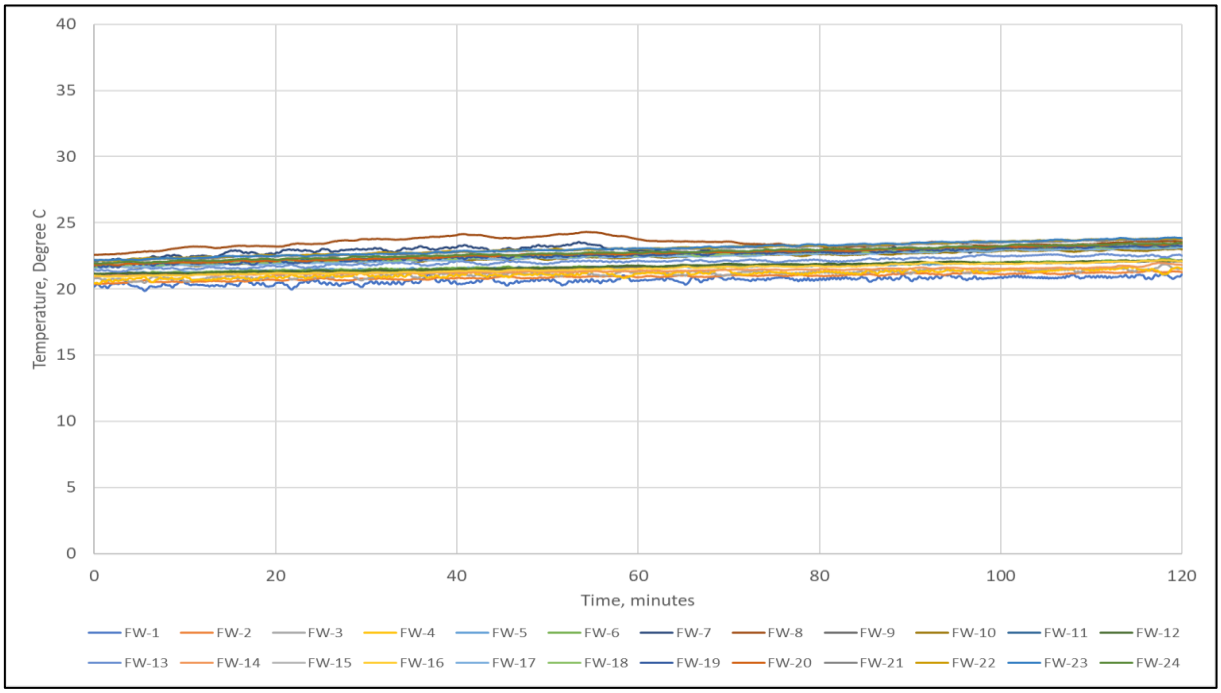


Figure 18: Front wall temperature

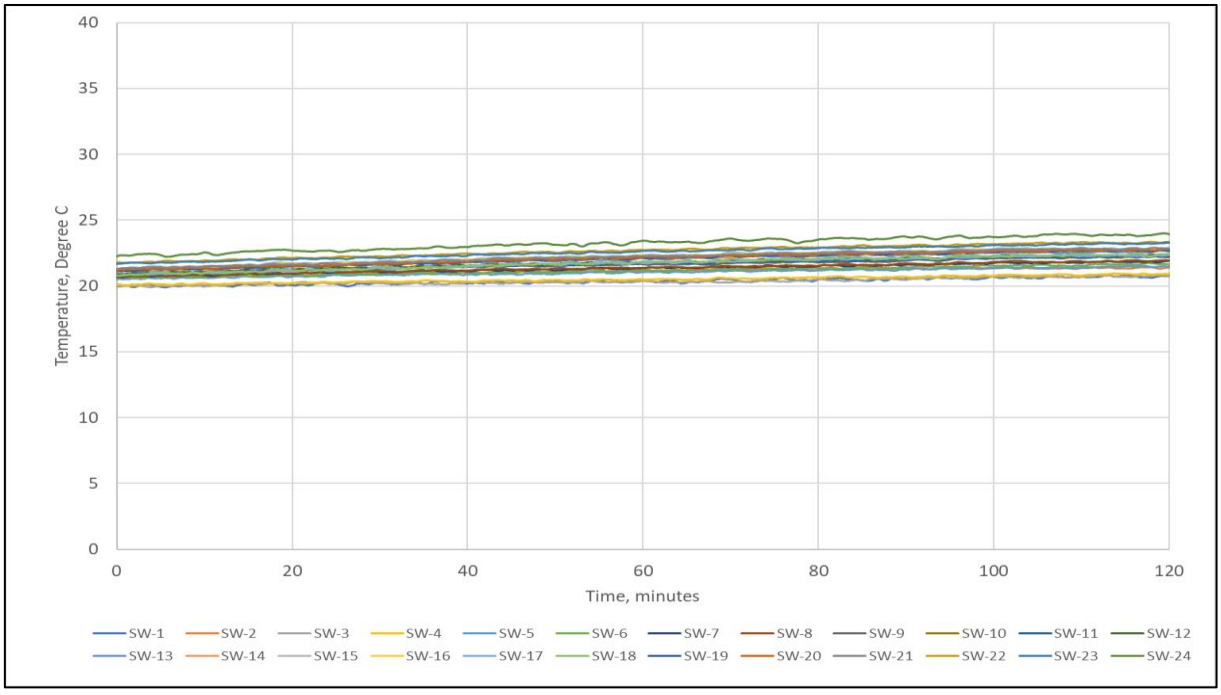


Figure 19: Side wall temperature

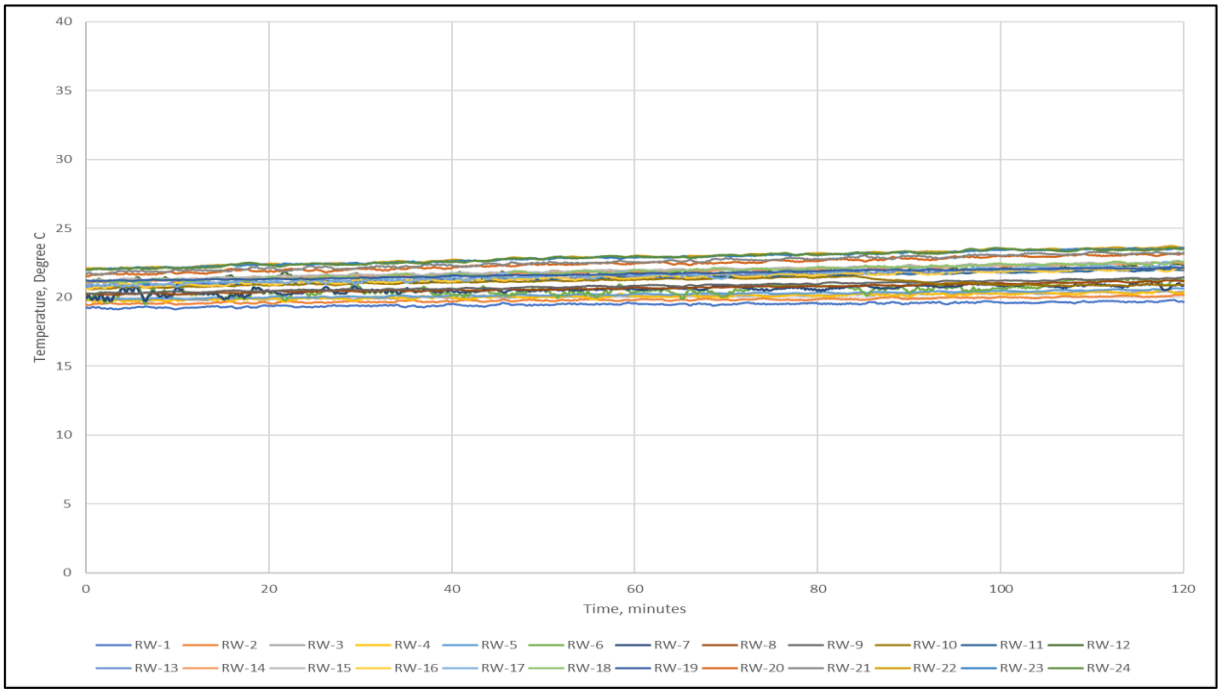


Figure 20: Rear wall temperature

Attachment E: BESS Unit Testing and Post Testing Photos - (*Pages **38** through **39***)

(a) Test s tart
[00:00:00]

(b) Vent of initiating cell
[00:53:26]

(c) Initiating cell thermal runaway
[00:55:21]

(d) Cell 39 thermal runaway
[00:58:59]

(e) Test end
[01:40:00]

N/A

Figure 21: BESS Unit Testing Photos

Figure 22: BESS Unit Photos after test

Attachment F: BESS Unit Gas Flow Rate and Heat Release and Smoke Release Profiles - (*Pages **40** through **42***)

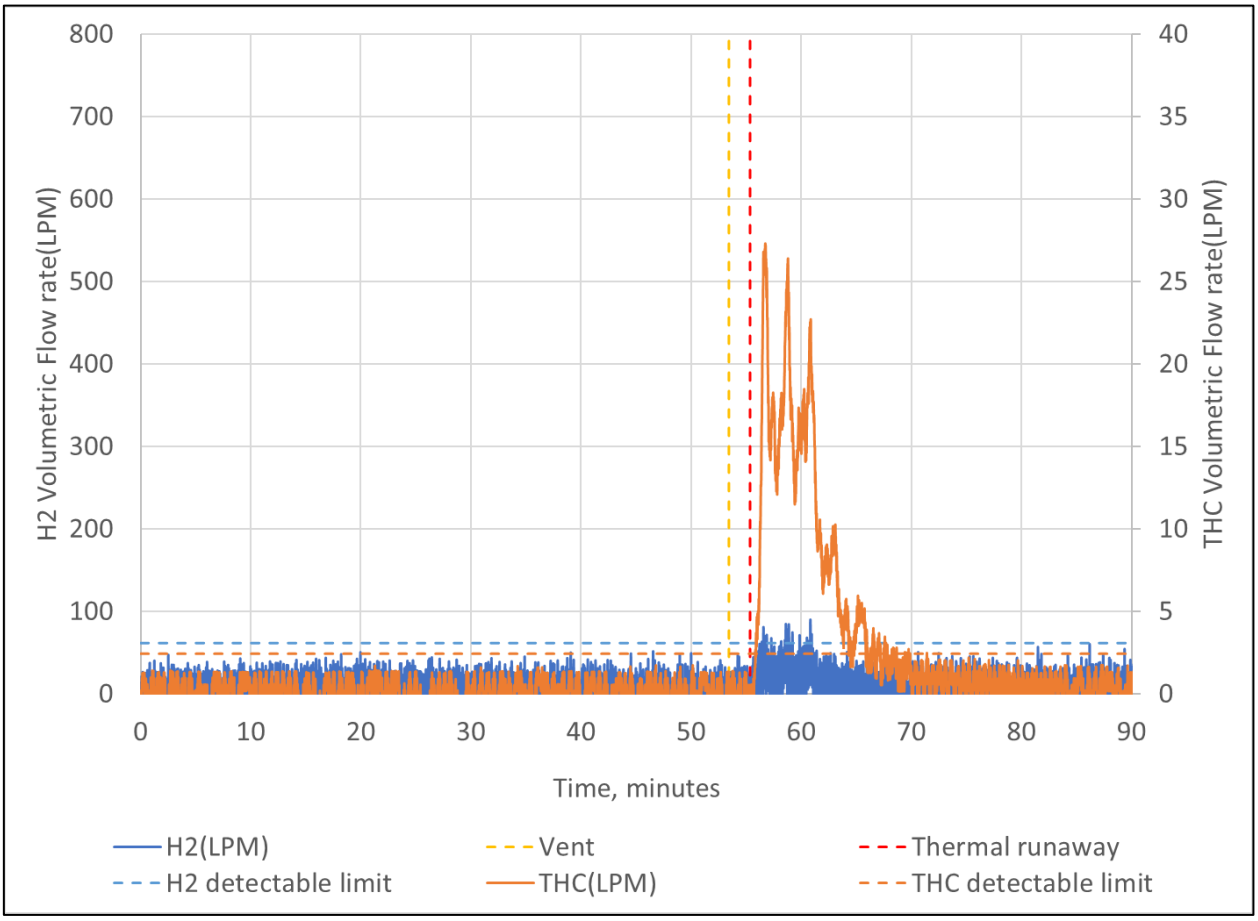


Figure 23: THC, H2 flow rates

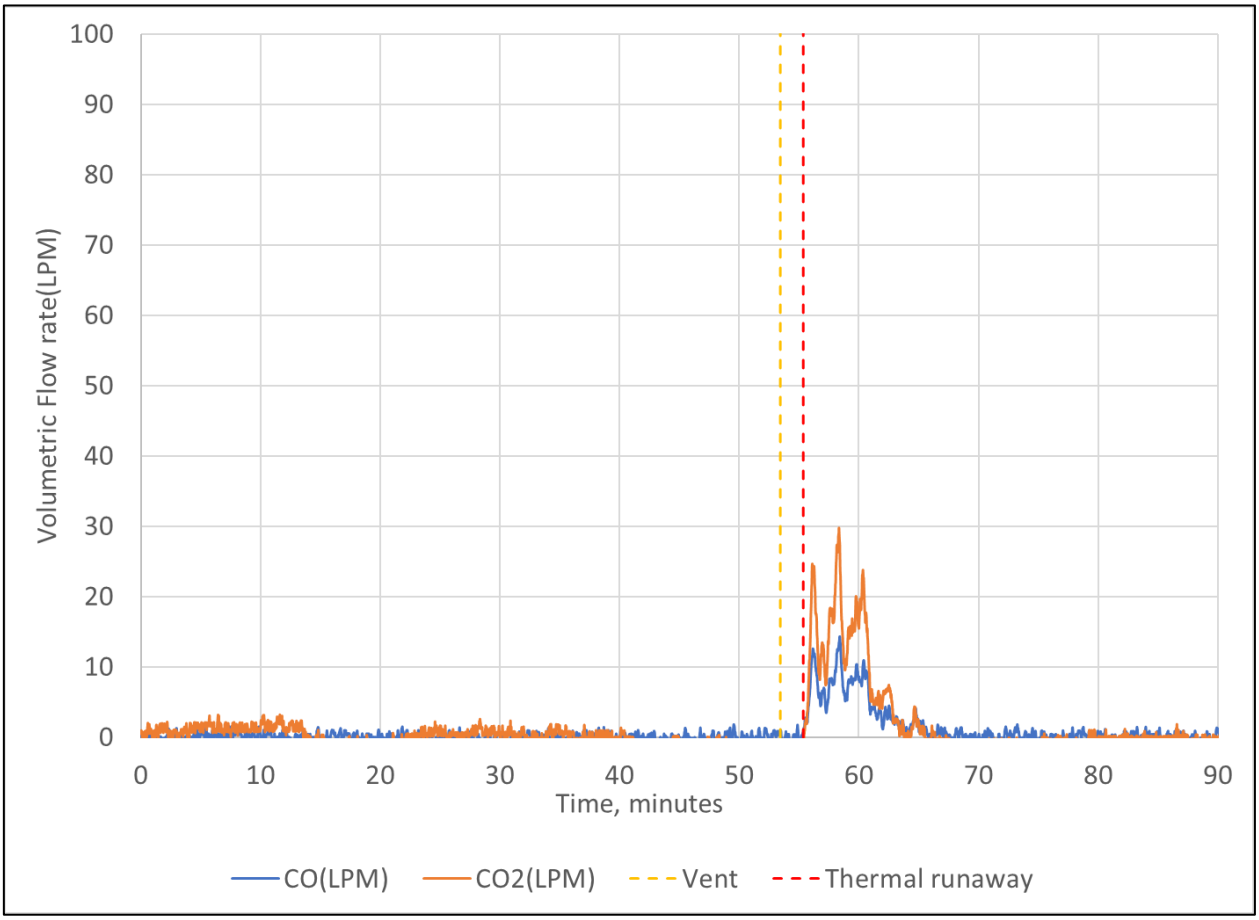


Figure 24: CO, CO2 flow rates

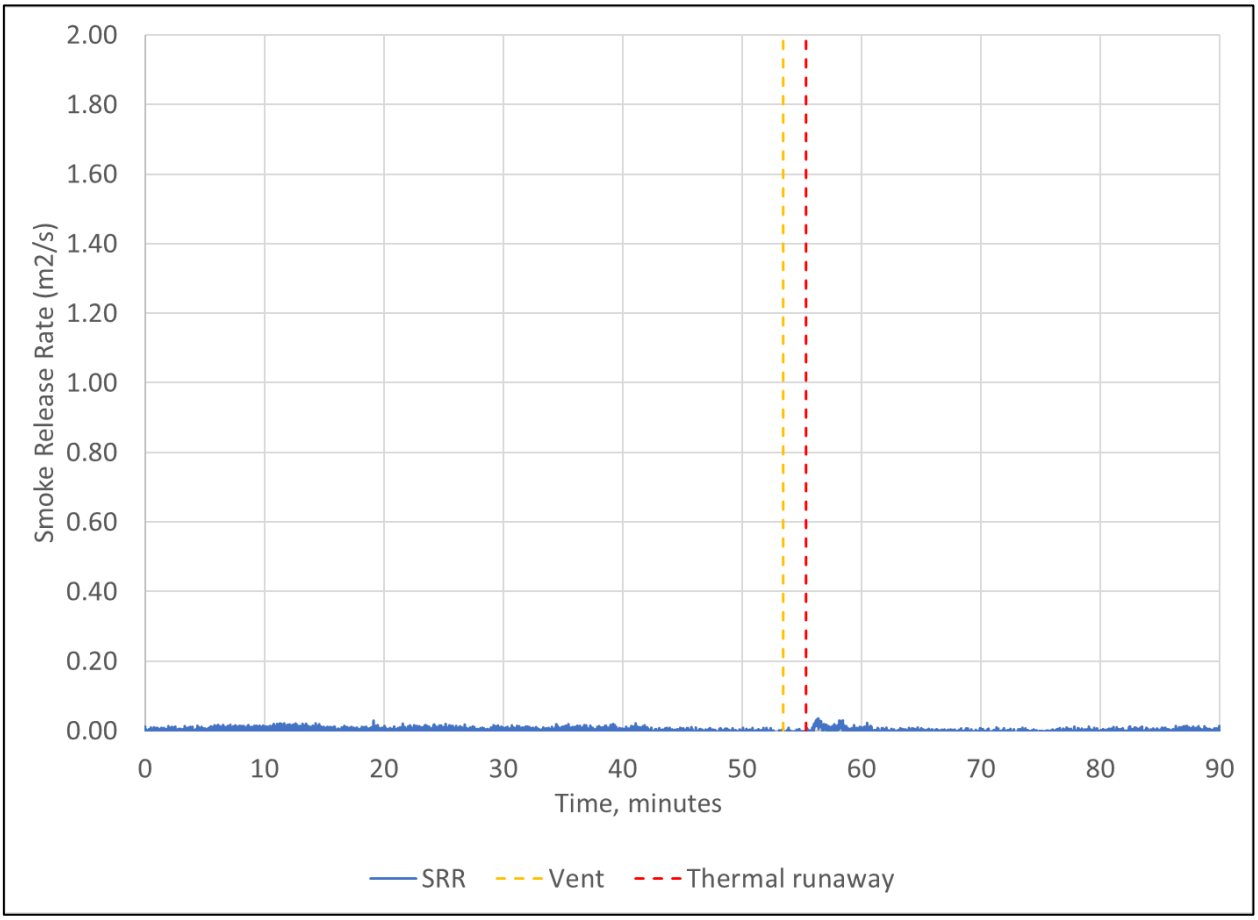


Figure 25: Smoke release rate

Appendix D

CATL EnerX-UL 9540 Certificate

Appendix D

ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

America

C E R T I F I C A T E

No. U14 004951 0251 Rev. 00

Holder of Certificate: **Contemporary Amperex Technology Co., Limited**
No.2 Xingang Road, Zhangwan Town, Jiaocheng District
352100 Ningde, Fujian
PEOPLE'S REPUBLIC OF CHINA

Certification Mark:

C US

Product: **Energy Storage System (Battery energy storage system)**

The product was tested on a voluntary basis and complies with the USA and Canadian standards stated on this certificate. It can be marked with the certification mark above. The certification mark shown above can be affixed on the product. It is not permitted to alter the certification mark in any way. In addition, the certification holder must not transfer the certificate to third parties.

Test report no.: 64290243024901

Date, 2024-09-18

(Billy Qiu)

TÜV SÜD America, Inc. • 401 Edgewater Place Suite #500 • Wakefield • MA 01880 • USA

ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

America

C E R T I F I C A T E

No. U14 004951 0251 Rev. 00

Model(s): **C06530P25L01**

Tested according to: CAN/UL 9540:2023
UL 9540:2023

Parameters:

Model:	C06530P25L01
Rated energy [kWh]:	5644.29
Rated capacity [Ah]:	4240
Rated voltage [V d.c.]:	1331.2
Voltage range [V d.c.]:	1040 ~ 1500
Maximum continuous charging power [kW]:	1411.07
Maximum continuous charging current [A d.c.]:	1060
Maximum continuous discharging power [kW]:	1411.07
Maximum continuous discharging current [A d.c.]:	1060
Battery String parameters:	
Battery String model:	C06530P25L01-R
Battery type:	LFP
Battery module model:	M02530P25L01
Rated Energy [kWh]:	1411.07
Rated capacity [Ah]:	1060
Rated voltage [V d.c.]:	1331.2
Voltage range [V d.c.]:	1040 ~ 1500
Maximum continuous charging power [kW]:	352.77
Maximum continuous charging current [A d.c.]:	265
Maximum continuous discharging power [kW]:	352.77
Maximum continuous discharging current [A d.c.]:	265
Auxiliary power supply parameters:	
Maximum input power for AUX1 terminal [kW]:	34.5
Rated input voltage for AUX1 terminal [V a.c.]:	480, 3P/N/PE (for other systems)
Maximum input power for AUX2 terminal [kW]:	0.5
Rated input voltage for AUX2 terminal [V a.c.]:	120, L/N/PE (for fire system and ventilation system)
Rated input frequency [Hz]:	60
General	
Protective class:	I
Ingress protection rating:	IP55(Battery Cabinet) IP55(Electrical Cabinet) IP67(Electrical Control Box of Chiller)
Ambient temperature range [°C]:	-35 ~ 55

TÜV SÜD America, Inc. • 401 Edgewater Place Suite #500 • Wakefield • MA 01880 • USA

Appendix E

CATL EnerX – UL 1973 Test Report

TEST REPORT

UL 1973:2022

TUV SUD Test Report for
Batteries for Use in Stationary and Motive Auxiliary Power Applications

Report No.:	64.280.24.60119.01
Date of issue:	2024-09-03
Project handler:	Liam Li
Testing laboratory:	TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch
Address:	5F&8F East, Communication Building, No.163 Pingyun Road, Huangpu Ave. West, Guangzhou, Guangdong 510656, P.R. China
Testing location:	See page 8
Client:	Contemporary Amperex Technology Co., Limited
Client number:	004951
Address:	No.2 Xingang Road, Zhangwan Town, Jiaocheng District, 352100 Ningde, Fujian, PEOPLE'S REPUBLIC OF CHINA
Contact person:	Shirley Chen
Standard:	This TUV SUD test report form is based on the following requirements: UL 1973:2022 Third Edtion (3Ed) CAN/UL 1973:2022 Third Edition (3Ed)
TRF number and revision:	TRF UL 1973:2022 Revision 0
eDoc_ID:	
TRF originated by:	TUV SUD New Energy Testing (Guangdong) Co., Ltd., Mr. Ryan Jin
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Scheme:	☐ TUV Mark ☐ cTUV Mark (SCC) ☒ TUVus Mark (NRTL) ☐ GS Mark ☐ without certification ☐ other: ☐ AoC/CoC for EU-Directive / EU-Regulation:

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Non-standard test method: National deviations:	☒ No N/A	☐ Yes, see details under *Summary of testing*	
Number of pages *(Report)*: Number of pages *(Attachments)*:	130 N/A		
Compiled by: (+ signature)	Liam Li Liam Li	Approved by: (+ signature)	Ryan Jin Ryan J

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Test sample:	Batteries
Type of test object:	Rechargeable Li-ion Battery System
Trademark:	CATL
Model and/ or type reference:	C06530P25L01
Rating(s):	1331.2Vd.c., 4240Ah

Manufacturer:	Contemporary Amperex Technology Co., Limited
Manufacturer number:	004951
Address:	No.2 Xingang Road, Zhangwan Town, Jiaocheng District, 352100 Ningde, Fujian, PEOPLE'S REPUBLIC OF CHINA
Name and address of factory(ies)	
Contemporary Amperex Technology Co., Limited No.2 Xingang Road, Zhangwan Town, Jiaocheng District, 352100 Ningde, Fujian, PEOPLE'S REPUBLIC OF CHINA	

Sub-contractors / tests (clause):	N/A
Name:	N/A
Order description:	☒ Complete test according to TRF
	☐ Partial test according to manufacturer's specifications
	☐ Preliminary test
	☐ Spot check
	☐ Others:
Date of order:	2024-02-19
Date of receipt of test item:	2023-12-07
Date(s) of performance of test:	2024-02-20 to 2024-09-02

Test item particulars:

According to UL 1973:2022 and CAN/UL 1973:2022

Purpose of the product (description of intended use):

The Rechargeable Li-ion Battery System, model: C06530P25L01, used in industrial applications, which consists of 4pcs battery racks (model no. C06530P25L01-R) connected in parallel.

Characteristic data (not shown on the marking plate):

1. Each battery rack consists of one main control box and 8pcs battery modules (model: M02530P25L01) connected in series.

2. Each battery module consists of 104pcs approved cells (model: CBLC0) connected in 2P52S.

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3. The detailed information of the battery system, module and the built-in cell are shown in following table.

Item	Specifications			
Product name	Rechargeable Li-ion Cell	Rechargeable Li-ion Battery Module	Rechargeable Li-ion Battery	Rechargeable Li-ion Battery System
Type/model	CBLC0	M02530P25L01	C06530P25L01-R	C06530P25L01
Nominal voltage	3.2Vd.c.	166.4Vd.c.	1331.2Vd.c.	1331.2Vd.c.
Rated capacity	530.0Ah	1060Ah	1060Ah	4240Ah
Charging voltage declared by manufacturer	3.65V	189.8V	1500V	1500V
Upper limit charging voltage	3.95V	-	-	-
Charging current declared by manufacturer	848.0W	44.1kW (constant power)	352.77kW (constant power)	1411.07kW (constant power)
Maximum Continuous Charging Current	265.0A	265A	265A	1060A
Discharging current declared by manufacturer	848.0W	44.1kW (constant power)	352.77kW (constant power)	1411.07kW (constant power)
Maximum Continuous Discharging Current	339.2A	265A	265A	1060A
Discharging cut off voltage	2.5V	130V or any cell voltage reaches 2.5V	1040V or any cell voltage reaches 2.5V	1040V or any cell voltage reaches 2.5V
Lower limit discharging voltage	2.0V	-	-	-
Standard temperature range for charging	0°C to 60°C	-	-	-
Standard temperature range for discharging	-30°C to 60°C	-	-	-
Ambient temperature range for operation	-	-	-35°C to 55°C	-35°C to 55°C

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Standard charging method by manufacturer	848.0W CP to 3.65V	Charge at constant power 44.1kW to 189.8V or any cell voltage reaches 3.65V	Charge at constant power 352.77kW to 1500V or any cell voltage reaches 3.65V	Charge at constant power 1411.07kW to 1500V or any cell voltage reaches 3.65V
Dimension	T*W*H: (73.1±1.0)mm* (274.6±1.0)mm* (212.8±1.0)mm	1193mm(W)* 2231.1mm(D)* 257mm(H)	-	2896mm(H)* 2438mm(D)* 6058mm(W)
Weight	(9380±500)g	Approx. 1100kg	-	Approx. 45000kg
Configuration	-	2P52S	(2P52S)8S	((2P52S)8S)4P
Max. short circuit current declared by manufacturer	-	-	15kA	55kA
Duration at max. short circuit current declared by manufacturer	-	-	2ms	2ms

Attachments:

Photo Documentation (24 pages) and CDF (14 pages)

If additional information is necessary, please provide

N/A

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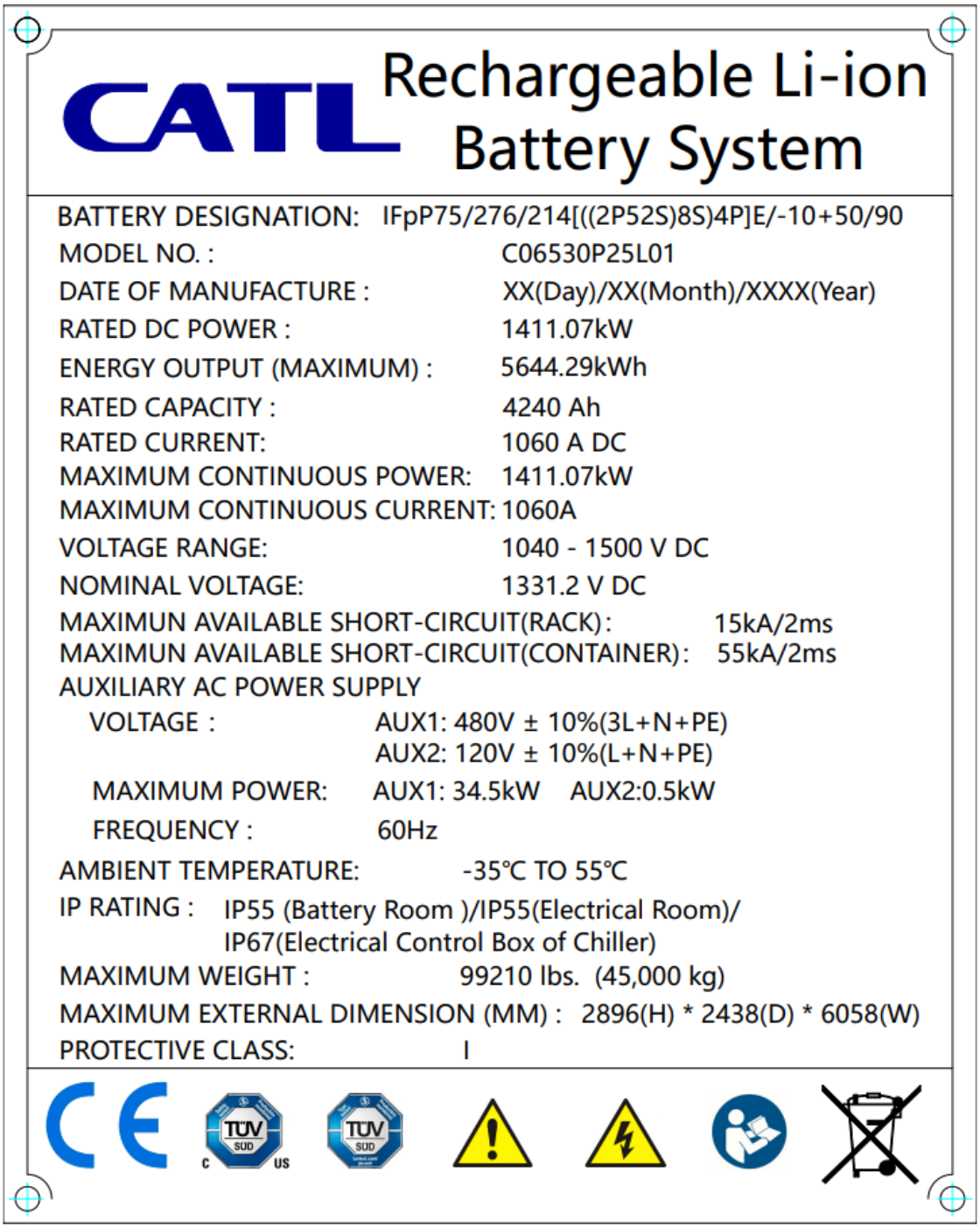
Copy of marking plate:



Remark:

1. Polarity is marked near the connector of the battery system.
2. “XXXX(Year)” represents the year of manufacture, “XX(Month)” represents the month of manufacture, “XX(Day)” represents the day of manufacture.

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Pictures of the product:

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Summary of testing:

Tests are made with the number of samples specified in Table 8.1 of UL 1973:2022 and CAN/UL 1973:2022.
Tests of section 15, 16, 19 were performed on one main control box and one module (model: M02530P25L01).
Test of section 17 was performed on one module (model: M02530P25L01) and one battery rack (model: C06530P25L01-R).
Tests of section 18, 20, 22, 23, 24, 25, 31, 32, 34 were performed on battery system (model: C06530P25L01).
Test of section 21 was performed on one main control box and two modules (model: M02530P25L01).
Tests of section 33 was performed on one module (model: M02530P25L01).

Electrical Tests

Section 15 Overcharge Test
Section 16 High Rate Charge
Section 17 Short Circuit Test
Section 18 Overload Under Discharge
Section 19 Overdischarge Protection Test
Section 20 Temperature and Operating Limits Check Test
Section 21 Imbalanced Charging Test
Section 22 Dielectric Voltage Withstand Test
Section 23 Continuity Test
Section 24 Failure of Cooling/Thermal Stability System
Section 25 Working Voltage Measurements

Mechanical Tests

Section 31 Static force Test
Section 32 Impact Test
Section 33 Drop Impact Test
Section 34 Wall Mount Fixture/Support Structure/Handle Test

The testing location / address for tests of section 15, 16, 19, 21 was TÜV SÜD New Energy Testing (Guangdong) Co., Ltd. / North-1/F, 2/F & Unit 301-3/F, TÜV SÜD Testing Center, D1, No. 63 Chuangqi Road, Shilou Town, Panyu District, Guangzhou 511447, China.

The testing location / address for tests of section 17, 18, 20, 22, 23, 24, 25, 31, 32, 33, 34 was Contemporary Amperex Technology Co., Limited / No.2 Xingang Road, Zhangwan Town, Jiaocheng District, 352100 Ningde, Fujian, PEOPLE'S REPUBLIC OF CHINA

The samples comply with the standard requirements.

☐ deviation(s) found
☒ no deviations found
The product fulfils the requirements of: ☒ UL 1973:2022 (as on page 1)
☒ CAN/UL 1973:2022 (as on page 1)

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Additional information on non-standard test method(s)	
Sub clause:	N/A
Page:	N/A
Rational:	N/A

Possible test case verdicts:	
test case does not apply to the test object:	N/A (not applicable / not included in the order)
test object does meet the requirement:	P (Pass)
test object does not meet the requirement:	F (Fail)

General remarks:

"(see remark #)" refers to a remark 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.*
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.

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Clause	Requirement + Test	Result – Remark	Verdict

INTRUDUCTION

1	**Scope**		—
2	**Components**		P
2.1	A component of a product covered by this standard shall comply with the requirements for that component. See Annex A for a list of standards covering components generally used in the products covered by this standard. A component shall comply with the CSA, UL, and/or ULC standards as appropriate for the country where the product is to be used.		P
3	**Units of Measure**		—
4	**Undated References**		—
5	**Normative References**		—
6	**Glossary**		—

CONSTRUCTIONS

7	**General**		P
7.1	**Non-metallic materials**		P
7.1.1	Polymeric materials employed for enclosures shall comply with the requirements as outlined in the Enclosure Requirements table, Table 4.1, Path III, of UL 746C except as modified by this standard.	Metal enclosure used	N/A
	Exception No. 1: Polymeric materials utilized for light electric rail (LER) enclosures for motive and VAP applications shall have a minimum flammability of V-1 or better, in accordance with UL 94 if intended for building into an enclosure or compartment within the train.		N/A
	Exception No. 2: LER enclosure parts for motive and VAP applications may alternatively be evaluated to the 20 mm end-product flame tests in accordance with UL 746C.		N/A
7.1.2	The factors taken into consideration when an enclosure is being judged are as follows. For a Non-metallic enclosure, all of these factors shall be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief distortion test. a) Resistance to impact; b) Crush resistance; c) Abnormal operations; d) Severe conditions; and e) Mold-stress relief distortion.	Metal enclosure used	N/A

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Clause	Requirement + Test	Result – Remark	Verdict
7.1.3	The polymeric materials employed as enclosures and insulation shall be suitable for anticipated temperatures encountered in the intended application.		P
	Pack enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application but no less than 80°C (176°F), as determined in accordance with UL 746B.	Metal enclosure used	N/A
7.1.4	The pack enclosure materials intended to be exposed to sunlight in the end use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with UL 746C.	Metal enclosure used	N/A
7.1.5	Polymeric materials used as direct support for live parts other than those circuits determined non-hazardous (i.e. limited power circuits) shall comply with the insulation requirements of UL 746C.		P
	Exception: Polymeric materials used as direct support for live parts that meet the requirements for "Safeguards Against Fire Under Normal Operating Conditions and Abnormal Operating Conditions," Clause 6.3, of UL 62368-1/CSA C22.2 No. 62368-1, or the requirements for "Safeguards Against Fire Under Single Fault Conditions," Clause 6.4, of UL 62368-1/CSA C22.2 No. 62368-1 are considered acceptable. Where specified in the reference document that components must meet the relevant IEC component standards, those components shall meet the applicable CSA or UL Standards.		N/A
7.1.6	Polymeric tanks, piping and housings containing only electrolyte and sensors in flow batteries shall have a flammability rating of HB or better in accordance with UL 94.		N/A
7.1.7	Printed wiring boards shall have a flammability rating of V-0 or V-1 in accordance with UL 94.		P
	Exception: This requirement does not apply to printed wiring boards connected only in low-voltage, limitedenergy circuits (LVLE) where the deterioration or breakage of the bond between a conductor and the base material does not result in a risk of fire or electric shock.		N/A
7.1.8	Gaskets and Seals relied upon for safety shall be determined suitable for the temperatures they are exposed to and other conditions of use. Compliance is determined by the applicable tests of UL 157.		P
7.2	**Metallic parts resistance to corrosion**		P
7.2.1	Metal pack enclosures shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection can be found in UL 50E/C22.2 No. 94.2.	A suitable coating can achieve corrosion resistance.	P
7.2.2	Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Table D.1 of Annex D shall be avoided unless there is an evaluation that demonstrates that the		P

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Clause	Requirement + Test	Result – Remark	Verdict
	potential for corrosion is negligible for the particular connection materials and design. See Annex D.		
7.3	**Enclosures**		P
7.3.1	The enclosure of a battery system shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its intended use, in order to reduce the risk of fire or injury to persons. Compliance is determined by the tests of this standard.		P
7.3.2	A tool providing the mechanical advantage of a pliers, screwdriver, hacksaw, or similar tool, shall be the minimum mechanical capability required to open the enclosure.		P
7.3.3	Openings in the enclosure shall be designed to prevent inadvertent access to hazardous parts. Compliance is determined by the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, Clause 12 of IEC 60529 or CAN/CSA-C22.2 No. 60529, for a minimum IP rating of IP2X or IPXXB, and C22.1, the Enclosure Selection Table for Nonhazardous Locations, Table 65. (Evaluation per IEC 60529 or CAN/CSA-C22.2 No. 60529, Clause 12, consists of the use of the IEC articulate probe applied with a force of 10 N ±10 %).	IP55 (Battery Room)	P
	Exception: For battery systems intended for location in restricted access locations only per 6.51, hazardous parts may be contacted with the articulate probe, but shall be located or guarded to prevent unintended contact by service or other trained personnel. Such equipment shall be provided with installation instructions in accordance with 45.3 and marked in accordance with 44.14.		N/A
7.3.4	Openings in the enclosure shall be constructed to prevent accumulation of flammable gases that could lead to a hazardous condition from concentrations of hydrogen gas due to electrolysis of aqueous electrolytes for applicable battery technologies, such as vented or valve regulated lead acid and nickel batteries and applicable electrochemical capacitor technologies, greater than 25% of the LFL of hydrogen (equivalent to 1% concentration in a volume of air). Ventilation openings shall have a minimum opening area of:		N/A
	A = 0.005NC$_5$ (cm^2) *Where:* *A = Total cross sectional area of ventilation holes required (cm^2)* *N = Number of cells in battery* *C$_5$ = Capacity of battery at the 5-h rate (Ah)*		—
	Exception: *The area of ventilation openings can be reduced if it can be demonstrated that there is sufficient ventilation within the battery to prevent hydrogen accumulations above 25% of the LFL of hydrogen.*		N/A
7.3.5	Packs intended for installation where they may be exposed to moisture either through rain, splashing	IP67	P

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Clause	Requirement + Test	Result – Remark	Verdict
	water or immersion shall be evaluated for their intended resistance to ingress of moisture in accordance with IEC 60529 or CAN/CSA-C22.2 No. 60529, or as outlined in NFPA 70, Article 110, or Section 2 of C22.1 for enclosure type designation and UL 50E/C22.2 No. 94.2, or NEMA 250. See also Section 39.		
7.4	**Wiring and terminals**		P
7.4.1	**General**		P
7.4.1.1	Wiring shall be insulated and acceptable for the purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected within the equipment.		P
7.4.1.2	A wiring splice or connection shall be mechanically secure and shall provide electrical contact without strain on connections and terminals.		P
	Wiring shall be secured and routed away from sharp edges or parts exceeding insulation.		P
	Openings in compartments through which insulated wiring is routed shall be smooth and well-rounded or provided with protective insulating bushings or grommet to prevent abrasion.		P
	Wiring connections between various parts of a battery module/pack and accessories shall be routed and secured to prevent the potential for short circuit conditions to occur.		P
7.4.1.3	An uninsulated live part, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so that it will be prevented from turning, shifting in position, or creating short circuit.		P
7.4.1.4	An external battery terminal shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when installed in its end use application.	Connector prevent inadvertent shorting, inadvertent misalignment or disconnection	P
7.4.1.5	External non-detachable cords and leads that are accessible in the end use installation shall be provided with strain relief that prevents strain to internal conductors under pull and push-back conditions. Compliance is determined by the tests of 26.4 and 26.5.		N/A
7.4.1.6	Plugs and receptacles shall be rated for the intended voltage, current, temperature, and if applicable, for disconnect under load conditions.		N/A
7.4.1.7	Battery system cables shall be rated for their anticipated service including voltage, current, temperature and environment. External cords for		P

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Clause	Requirement + Test	Result – Remark	Verdict
	hazardous voltage circuits shall be jacketed to prevent wear to internal conductors and rated and provided with insulation suitable for the intended applications.		
7.4.1.8	In multiway plugs and sockets, and wherever shorting could otherwise occur, means shall be provided to prevent contact between parts in SELV circuits or parts at hazardous voltage due to loosening of a terminal or breaking of a wire at a termination. Compliance is checked by inspection, by measurement and, where necessary, by the following test. A force of 10 N (2.25 lbf) is applied to the conductor near its termination point. The conductor shall not break away or pivot on its terminal to the extent that spacings are reduced below the values specified in 7.5.		N/A
7.4.1.9	Wiring compartments and wiring terminals provided for connection of the battery system to external circuits shall be constructed as outlined below:		N/A
	a) A field wiring compartment in which supply connections are to be made shall be located so that the connections will be accessible for inspection after the unit is installed as intended.		N/A
	b) A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure. The knockout shall be surrounded by a flat surface to accommodate seating of a conduit bushing or locknut of the appropriate size.		N/A
	c) An outlet box, terminal box, wiring compartment, in which field connections are made shall be free from any sharp edges including screw threads, a burr, a fin or moving part of the like that may abrade the insulation on conductor or otherwise damage wiring.		N/A
	d) A field wiring terminal or lead shall be rated for the connection of a conductor or conductors having a minimum ampacity rating of 125% of the rating of the unit.		N/A
	e) The distance between the end of the connection point of a field installed wire and the wall of the enclosure toward which the wire is to be directed, shall be in accordance with Table 312.6 (A) or (B) of NFPA 70.		N/A
7.4.2	**Beads and ceramic insulators**		N/A
7.4.2.1	Beads and similar ceramic insulators on conductors shall:		N/A
	a) Be so fixed or supported that they cannot change their position in such a way that a hazard would be created; and		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	b) Not rest on sharp edges or sharp corners.		N/A
7.4.2.2	If beads are located inside flexible metal conduits, they shall be contained within an insulating sleeve, unless the conduit is mounted or secured in such a way that movement in normal use would not create a hazard. Compliance is checked by inspection and, where necessary, by the following test. A force of 10 N (2.25 lbf) is applied to the insulators or to the conduit. The resulting movement, if any, shall not create a hazard in the meaning of this standard.		N/A
7.5	**Spacings and separation of circuits**		P
7.5.1	**General**		P
7.5.1.1	Electrical circuits within the pack at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits (i.e. electrical spacings on printed wiring boards, physical securing of un-insulated leads and parts, etc.). Insulation suitable for the anticipated temperatures and maximum voltages shall be used where spacings cannot be controlled by reliable physical separation.		P
7.5.1.2	Electrical spacings in circuits shall be based upon the grade of insulation required as outlined in the Insulation Materials and Requirements, Clause 5.4 of UL 62368-1/CSA C22.2 No. 62368-1, and shall comply with Clearances, Clause 5.4.2, and Creepage Distances, Clause 5.4.3, of UL 62368-1/CSA C22.2 No. 62368-1. For the appropriate pollution degree of the intended environment see 7.5.2 and 7.5.3.		N/A
	Exception No. 1: As an alternative to these spacing requirements, the spacing requirements in UL 840, may be used. For determination of clearances, a dc source such as a battery does not have an overvoltage category as outlined in the section for Components of UL 840 unless charged through an ac mains connected rectifier, then the overvoltage category should be the same as that required for the rectifier unless the rectifier uses galvanic isolation. If galvanic isolation is employed, then the overvoltage category can be reduced to the next lower overvoltage category. The anticipated pollution degree is determined by the design and application of the electrical energy storage system or subassembly under evaluation.		N/A
	Exception No. 2: As an alternative to the clearance values outlined in UL 62368-1/ CSA C22.2 No. 62368-1 the alternative method for determining minimum clearances in the Annex for Alternative Method for Determining Clearances for Insulation in Circuits Connected to an AC Mains not Exceeding 420 V peak (300 V RMS), Annex X, of UL 62368-1/CSA C22.2 No. 62368-1 may be applied.		N/A
	Exception No. 3: As an alternative to these spacing requirements, the spacing requirements of Table 7.1 may be applied instead. When using this table, maximum working voltages of circuits can be determined through the test of Section 23. See the note in Table 7.1 regarding adjustment for spacings where double or reinforced insulation is required.		N/A
	Exception No. 4: As an alternative, clearances and creepage distances per IEC 60664-1 can be applied instead.		P

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Clause	Requirement + Test	Result – Remark	Verdict
7.5.1.3	Conductors of circuits operating at different potentials shall be reliably separated from each other unless they are each provided with insulation acceptable for the highest potential involved.		P
7.5.1.4	An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different potential. Some examples include clamping or routing of conductors, use of separating barriers of insulating material or other means that provides permanent separation of the parts.		P
7.5.1.5	There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a compound or subassembly if the distance through the insulation, at voltages above SELV levels is a minimum of 0.4-mm (0.02-in) thick for supplementary or reinforced insulation, and passes the Dielectric Voltage Withstand Test. There is no minimum insulation thickness requirement for insulation of circuits at or below SELV levels for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation.		P
7.5.1.6	UL 840 shall not be used for clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable. UL 840 shall not be used for the clearance and creepage distance at field wiring terminals.		N/A
7.5.1.7	When determining the clearance for double or reinforced insulation in accordance with UL 840, the clearances of reinforced insulation shall be dimensioned corresponding to the rated impulse voltage, but choosing one step higher in the preferred series of values in the Minimum Clearances for Equipment table of UL 840 than that specified for basic insulation. If the impulse withstand voltage required for basic insulation, is other than a value taken from the preferred series, reinforced insulation shall be dimensioned to withstand 160 % of the impulse withstand voltage required for basic insulation.		N/A
7.5.1.8	When determining the creepage for double or reinforced insulation in accordance with UL 840, the creepage distances for reinforced insulation shall be twice the creepage distance required for the basic insulation as determined in UL 840.		N/A
7.5.1.9	When determining the electrical spacing according to 7.5.1.1, a battery circuit that has no direct connection to a primary circuit and derives its power from a transformer or converter shall be considered a secondary circuit. The phase-to-ground rated system voltage used in the determination of mains transient voltage in UL 62368-1/CSA C22.2 No. 62368-1 or the		P

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	rated impulse voltage in UL 840 shall be the rated supply voltage of the charging equipment for the battery.		
7.5.1.10	For batteries intended for installation at high altitudes (i.e. 2000 m and above), see the Multiplication Factors for Clearances and Test Voltages table of UL 62368-1/CSA C22.2 No. 62368-1 or the Altitude Correction Factors for Clearance Correction table of IEC 60664-1 for multiplication factors to be applied to clearance values.	4000 m	P
7.5.2	**Overvoltage categories applied for electrical creepage and clearance determination**		P
7.5.2.1	When determining the creepage and clearance requirements from 7.5.1.2, the overvoltage categories for the battery systems shall be determined based on how the batteries are connected to the supply mains. For equipment or circuits energized from the mains, four categories are considered:		P
	a) Category IV applies to equipment permanently connected at the origin of an installation (upstream of the main distribution board). Examples are electricity meters, primary overcurrent protection equipment and other equipment connected directly to outdoor open lines;		N/A
	b) Category III applies to equipment permanently connected in fixed installations (downstream of, and including, the main distribution board). Examples are switchgear and other equipment in an industrial installation;		N/A
	c) Category II applies to equipment not permanently connected to the fixed installation. Examples are appliances, portable tools and other plug-connected equipment; and		P
	d) Category I applies to equipment connected to a circuit where measures have been taken to reduce transient overvoltages to a low level.		N/A
7.5.2.2	For stationary battery systems, Overvoltage Category III is applied. Overvoltage Category II may be applied for a stationary battery system that is isolated from an Overvoltage category III supply source (such as from an Overvoltage category III PCS) through an isolated transformer or protected in a manner that prevents transient overvoltage conditions. For vehicle auxiliary power batteries and on board LER batteries, Overvoltage Category II shall be applied.		P
7.5.3	**Pollution degree for electrical creepage and clearance determination**		P
7.5.3.1	With reference to 7.5.1.2, the following are conditions for determining the pollution degree to utilize when		P

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	determining creepage and clearance distances. See also examples noted in Table 7.2.		
	a) Pollution Degree 1 – No pollution or only dry, non-conductive pollution. Normally, this is achieved by having components and subassemblies adequately enclosed by enveloping or hermetic sealing so as to exclude dust and moisture.		N/A
	b) Pollution Degree 2 – Only non-conductive pollution that might temporarily become conductive due to occasional condensation.		P
	c) Pollution Degree 3 – Subject to conductive pollution, or to dry non-conductive pollution which could become conductive due to expected condensation.		N/A
	d) Pollution Degree 4 – Pollution that generates persistent conductivity through conductive dust or rain and snow.		N/A
7.6	**Insulation levels and protective grounding and bonding**		P
7.6.1	Hazardous voltage circuits shall be insulated from accessible conductive parts and circuits as outlined in 7.6.2 through the following:		P
	a) Basic insulation and provided with a protective grounding system for protection in the event of a fault of the basic insulation; or		P
	b) A system of double or reinforced insulation; or		P
	c) A combination of (a) and (b).		P
7.6.2	Safety extra low voltage (SELV) circuits as defined in 6.54 that are insulated from accessible conductive parts through functional insulation only are considered accessible.		P
7.6.3	Batteries that rely upon protective grounding, shall comply with 7.6.4 – 7.6.9.		P
7.6.4	Accessible non-current carrying metal parts of a battery system with hazardous voltage circuits, that could become live in the event of an insulation fault, shall be bonded to the equipment ground terminal.		P
7.6.5	Parts of the protective grounding system shall be reliably secured in accordance with 7.4.1.2 and provided with good metal-to-metal contact. All connections shall be secured against accidental loosening and shall ensure a thoroughly good connection. The resistance between the protective conductive terminal of 7.6.8 and the accessible non-current carrying conductive parts outlined in 7.6.2 shall not exceed 0.1 Ω.		P
7.6.6	With reference to 7.6.5, when connecting conductive parts to be bonded, paint or coatings in areas of		P

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	contact shall be removed or paint piercing lock washers shall be used with securement bolts or screws to provide good metal to metal contact. Thread-locking sealants, epoxies, glues, or other similar compounds, and solder alone shall not be used as a securement means as these are not considered reliable. In addition, rivets, hinges (unless metal-to-metal piano type hinges), and parts that may be removed as a result of servicing shall not be relied upon as connections for ensuring continuity of the protective grounding and bonding system.		
7.6.7	With reference to 7.6.5, methods of securement considered reliable and ensuring good metal-to-metal contact can consist of the following methods:		P
	a) Terminal blocks;		P
	b) Pressure connectors, grounding lugs and similar grounding and bonding equipment connectors;		N/A
	c) Exothermic welding processes;		N/A
	d) Machine screw-type fasteners that engage not less than two threads or are secured with a nut; and		P
	e) Thread-forming machine screws that engage not less than two threads in the enclosure.		P
7.6.8	The main ground terminal of the protective grounding system shall be identified by one of the following:		P
	a) A green-colored, not readily removable terminal screw with a hexagonal head;		N/A
	b) A green-colored, hexagonal, not readily removable terminal nut;		N/A
	c) A green colored pressure wire connector; or		N/A
	d) The word ″Ground″ or the letters ″G″ or ″GR″ or the grounding symbol (IEC 60417, No. 5019) or otherwise identified by a distinctive green color.		P
7.6.9	Conductors, relied upon for the protective grounding and bonding system, shall be sized to handle intended fault currents and if insulated, the insulation shall be green or green and yellow striped in color. Grounding conductors shall be sized in accordance with Article 250.122 of NFPA 70 or Rule 10-810 of C22.1.		P
7.7	**Transformers**		P
7.7.1	Transformers shall be evaluated in accordance with UL 1562, UL 1310 or an equivalent standard for overload conditions, and shall have suitable insulation for the circuits they are connected to.		P
7.7.2	Transformers in low voltage circuits can alternatively be evaluated in accordance with 26.6.		N/A

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7.7.3	Transformers shall be provided with overcurrent protection on the primary side of the transformer and sized in accordance with Article 450 of NFPA 70 or Section 26 of C22.1.		N/A
7.8	**System safety analysis**		P
7.8.1	A safety analysis consisting of a hazard identification, risk analysis and risk evaluation shall be conducted on the device under test. This safety analysis shall determine which parts of the system are safety related through an existing methodology such as outlined 7.8.2. This approach should determine the hazard scenarios and define mitigation mechanisms. This safety analysis shall identify safety circuits or software that address each hazardous condition and consider the performance of each safety circuit or software.		P
	The following conditions in (a) – (c) shall be considered unless sufficient justification (e.g. additional safety analysis) is provided by the manufacturer that these conditions are not hazardous.		P
	The following conditions in (a) – (c) shall be considered at a minimum, but are not limited to: a) Battery cell over-voltage and under-voltage; b) Battery over-temperature and under-temperature; and c) Battery over-current during charge and discharge conditions.		P
7.8.2	Documents that can be used as guidance for the safety analysis include:		P
	a) IEC 60812;		P
	b) IEC 61025;		N/A
	c) MIL-STD-1629A; and		N/A
	d) IEC 61508, all parts.		N/A
7.8.3	The analysis of 7.8.1 is utilized to identify anticipated faults in the system which could lead to a hazardous condition and is validated by compliance with 7.9. The analysis shall consider the reliability of any monitoring components and systems and any communication systems providing information to the controls that can affect safety. The analysis shall consider single fault conditions in the protection circuit in addition to single faults elsewhere that could lead to a hazardous condition.		P
7.9	**Protective circuit and controls**		P
7.9.1	Active protective devices shall not be relied upon for critical safety and shall comply with one of the following in (a) – (c) and comply with 7.9.2 and 7.9.3		P

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	as applicable. Refer to 6.49 and 6.50 for definitions of active and passive protective devices.		
	a) They are provided with a redundant passive protective device; or		N/A
	b) They are provided with redundant active protection that remains functional and energized upon loss of power to, or failure of the first level of active protection; or		P
	c) They remain fully operational or fail safe upon loss of power to, or under a single fault condition of the active circuit.		P
	Exception : Active protective devices that comply with IEC 61508 (all parts), meeting minimum Safety Integrity Level (SIL) "2", ISO 13849 (all parts), meeting minimum performance level (PL) "c", or ISO 26262 (all parts), minimum of Automotive Safety Integrity Level (ASIL) "C" are permitted to be relied upon for critical safety. The SIL, PL, or ASIL for a safety function may be reduced if the manufacturer provides additional safety analysis, e.g. Layer of Protection Analysis (LOPA), showing that the required risk reduction level has been reduced by other measures used within the battery system.		N/A
7.9.2	Active protective devices relied upon for safety as noted in 7.9.1, shall be evaluated in accordance with:		P
	a) The Failure-Mode and Effect Analysis (FMEA) requirements in UL 991 (Section 7);		P
	b) The Protection Against Internal Faults to Ensure Functional Safety requirements in UL 60730-1 or CAN/CSA E60730-1 (Clause H.27.1.2); or		P
	c) The Protection Against Faults to Ensure Functional Safety requirements (Class B requirements) in CSA C22.2 No. 0.8 (Section 5.5) to determine compliance and identify tests necessary to verify single fault tolerance.		N/A
7.9.3	With reference to 7.9.1, software relied upon for safety shall comply with:		P
	a) Software Class 1 requirements of UL 1998;		N/A
	b) Software Class B requirements of CSA C22.2 No. 0.8; or		N/A
	c) The Controls Using Software requirements (Software Class B requirements) in UL 60730-1 (Clause H.11.12) or CAN/CSA E60730-1.		P
7.9.4	Software and its associated hardware determined critical to safety that can be updated remotely shall meet the requirements outlined in UL 5500.	Software and its associated hardware determined critical to safety could not be updated remotely.	N/A
7.9.5	Battery systems shall be protected against all hazards identified in the safety system safety analysis of 7.8.		P
7.9.6	With reference to 7.9.5, if relied upon for maintaining the cells within their safe operating limits, the battery		P

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	management system (BMS) shall maintain cells within the specified cell voltage and current limits to protect against overcharge and over-discharge. The BMS shall also maintain cells within the specified temperature limits providing protection from overheating and under temperature operation. When reviewing safety circuits to determine that cell operating region limits are maintained, tolerances of the protective circuit/component shall be considered in the evaluation. Components such as fuses, circuit breakers or other devices and parts determined necessary for safe operation of the battery system that are required to be provided in the end use installation, shall be identified in the installation instructions.		
7.9.7	With reference to 7.9.5 and 7.9.6, if safe operating limits are exceeded, a protective circuit shall limit or shut down the charging or discharging to prevent excursions beyond these limits. When a hazardous scenario occurs, as determined in 7.8.1, the system shall continue to provide the safety function or go to a safe state (SS) or risk addressed (RA) state. If the safety function has been damaged, the system shall remain in the safe state or risk addressed state until the safety function has been restored and the system has been deemed safe to operate.		P
7.9.8	Solid state circuits and software controls, relied upon as the primary safety protection, shall be evaluated and tested to verify electromagnetic immunity in accordance with Section 27.		P
	Exception: Solid state circuits and software need not comply if it can be demonstrated that the solid state circuits and software are not relied upon as the primary safety protection.		N/A
7.9.9	Battery systems with hazardous voltage circuits, including outputs of 60 V or greater, shall either be provided with a manual disconnect device or be provided with installation instructions for the disconnect device to be provided during installation of the system. The disconnect device shall be located as near as possible to the battery system terminals and it shall be rated for the application including disconnect under load if applicable. The disconnect device shall disconnect both poles of the circuit. The manual disconnect shall not require the use of a special tool or equipment to be operated. The disconnect device shall consist of either a manually operated switch or circuit breaker.		P
	Exception No. 1: A battery system having either a plug or receptacle or connector for connection to the output circuit may be provided without an additional disconnect means. The plug, receptacle and connectors used for this purpose shall be investigated in accordance with UL 1682 and rated for current interruption suitable for		N/A

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	the circuit. The required spacing to the hazardous voltage circuits shall be maintained when the plug or receptacle or connector is disconnected.		
	Exception No. 2: A flow battery that can be turned off such that no circuits remain at hazardous voltage are not required to have a manual disconnect device.		N/A
7.9.10	Fuses provided for battery overcurrent protection including short circuit protection shall be evaluated for both short circuit and overload conditions. Fuses that are evaluated for short circuit conditions only (type aR fuses), shall be provided with supplementary protection (e.g. the BMS) to ensure protection under overcurrent conditions in ranges below those covered by these types of fuses.		P
7.9.11	Protective components of battery modules intended for series connection in battery systems shall be rated for the maximum voltage of the intended battery system.		P
7.10	**Cooling/thermal management system**		P
7.10.1	Battery systems that rely upon integral thermal management systems to prevent overheating shall be designed to shutdown upon failure of the thermal management system unless is can be demonstrated, that the thermal management system failure does not result in a hazardous situation. Compliance is determined by the Failure of the Cooling/Thermal Stability System Test of Section 24.		P
7.10.2	Piping, hose, and tubing used to contain liquid shall be resistant to chemical degradation from the liquid it contains, as well as other liquids reasonably likely to contact such parts during expected life of the equipment. It shall have the strength and material characteristics necessary to withstand the anticipated mechanical and environmental stresses. Compliance is determined as outlined in 7.11.1.		P
7.10.3	With reference to 7.10.2, piping containing fluids in accordance with the scope of ASME B31.3, shall comply with the applicable requirements of that code. ASME B31.3 applies to piping that contains toxic fluids, flammable fluids, fluids damaging to human tissue, and nonhazardous fluids at pressures greater than 15 psi (105 kPa) or temperatures lower than −29°C (−20°F) or greater than 186°C (366°F).		P
7.10.4	Piping, hose, and tubing containing liquids, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard.		P
7.10.5	Fans or blowers utilized for air-cooling systems shall comply with the applicable requirements in UL 507.		P
	Exception: Fans located in SELV or ELV dc circuits need not be evaluated if shown to comply with the test of 26.1.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
7.10.6	Battery systems that rely on integral heaters to maintain operating temperatures of the battery system, shall be designed to shutdown upon failure of the heaters unless is can be demonstrated through fault analysis and if necessary an abnormal operation test, that the heater failure does not result in a hazardous situation.		P
7.10.7	Temperature controls for heaters used to maintain the operating temperature range of a battery system during cold ambient conditions shall be positioned such that they monitor the system temperature and are minimally affected by the outside ambient. For example, temperature controls or regulators should normally be located away from outside vents.		P
7.11	**Electrolyte containment parts and parts subject to pressure**		N/A
7.11.1	Parts that contain electrolyte, such as piping, hose, and tubing shall be resistant to chemical degradation from the electrolyte. Electrolyte containing parts shall have the strength and material characteristics necessary to withstand the anticipated mechanical and environmental stresses.		N/A
	Compliance is determined through review of material datasheets and where determined necessary, an immersion test (using the electrolyte as the test liquid) in accordance with the Volume Change Test after Immersion of UL 157 for elastomeric materials or the Test for Resistance of Polymeric Materials to Chemical Reagents in UL 746A for other than elastomeric materials, (same as ASMT D543, Test Method I), as applicable to the material and part being tested.		N/A
	Elastomeric parts in contact with electrolyte shall be subjected to the volume change and extraction test after 70-h immersion in the electrolyte in accordance with UL 157. The volume change shall be minus 1 to plus 25% and extraction (change in weight) no greater than 10%.		N/A
	Plastics other than elastomeric parts in contact with electrolyte shall be subjected to an immersion for 168 h at room temperature followed by a check for volume and weight change in accordance with ASTM D543, Procedure I method. The percentage of change of volume shall not be greater than 2% of the original and the change in weight shall be no not increase more than 25% or decrease more than 10% of the original value.		N/A
	Exception No. 1: See Appendix C for material requirements for flowing electrolyte systems.		N/A

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	Exception No. 2: Not applicable to individual cell or capacitor casings and materials that have been evaluated to appropriate component requirements per 7.12.		N/A
7.11.2	Piping, hose, and tubing containing electrolyte, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard.		N/A
7.11.3	Parts under pressure shall be acceptable for the maximum anticipated pressure as determined by the tests of Section 36.		N/A
	Exception: See Appendix C for material requirements for flowing electrolyte systems.		N/A
7.11.4	Relief valves or rupture members relied upon to relieve overpressure conditions in a battery system shall operate in accordance with their specifications for start to discharge (i.e. pressure at which the relief valve or rupture membrane starts to relieve pressure). Compliance is determined by the tests of Section 37. This requirement does not apply to relief valves or rupture members integral to a cell or monobloc battery such as a VRLA type battery.		N/A
	Exception: Relief valves and ruptures members stamped with the ASME approval mark for the particular device in accordance with the ASME Boiler and Pressure Vessel Code need not be subjected to the tests of Section 37.		N/A
7.11.5	A pressure-relief device shall have its discharge opening located and directed so that operation of the device will not deposit moisture on bare live parts or on insulation or components that could be detrimentally affected by the discharge. It shall have a start to discharge (i.e. pressure at which the relief valve or rupture membrane starts to relieve pressure) rating adequate to relieve the pressure.		N/A
7.11.6	The fill port of the electrolyte containment of a monobloc system shall be designed to prevent overfill and spillage of electrolyte during the electrolyte filling.		N/A
7.11.7	Flow batteries shall be provided with a means for spill control such as a spill containment system to prevent electrolyte spills. The spill containment shall be sufficient to handle electrolyte spills for the size of the system. See Spill Containment Systems, C6, for means to determine compliance.		N/A
7.11.8	Flowing electrolyte batteries shall be provided with a means of leak detection that shall identify when a leak occurs in the system and initiate controls to mitigate the leak condition.		N/A
7.12	**Cells (battery and electrochemical capacitor)**		P
7.12.1	Sealed nickel metal hydride cells shall comply with the cell tests of the Testing Required for Cells table of UL 2054 in addition to the requirements of this standard. Cells shall be provided with specifications for use (charging and discharging), installation, storage and disposal.		N/A

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	Exception No. 1: The overall dimensions of the projectile test aluminum test screen may be increased from those outlined in UL 2054 to accommodate large cells intended for stationary and LER applications, but the flat panels of the test screen shall not exceed a distance of 305 mm (12 in) from the cell in any direction.		N/A
	Exception No. 2: The overall external resistance for the short circuit test shall be less than or equal to 20 mΩ.		N/A
	Exception No. 3: The crush test shall be a bar crush test rather than a flat plate crush using a bar with a 15-cm (5.9-in) diameter if the flat plate crush test per UL 2054 is insufficient to create a crush condition in the cell as determined by (a) – (c) below. The force shall be applied until one of the following occurs: *a) A voltage (OCV) drop of one-third of the original cell voltage occurs;* *b) A deformation of 15 % or more of initial cell dimension occurs; or* *c) A force of 1,000 times the weight of cell is reached.*		N/A
	Exception No. 4: Nickel metal hydride or nickel cadmium cells that are sealed and formed as part of a monobloc battery, need only comply with the requirements of this standard as part of the assembled battery. If provided with a pressure release vent or flame arrester, the nickel battery shall comply with the requirements outlined in 7.12.8.		N/A
	Exception No. 5: Sample numbers tested for each test based upon UL 2054 test program may be reduced from 5 samples tested to 2 samples tested.		N/A
	Exception No. 6: During the heating test, the samples are held for 30 min at the maximum temperature rather than 10 min.		N/A
7.12.2	Secondary lithium cells shall comply with the requirements outlined in Annex E, and be marked as required in 44.15 and 44.16. Cells shall be provided with specifications as outlined in 45.7.		P
7.12.3	Secondary lithium cell design shall ensure sufficient safety measures to mitigate internal short circuits and other hazardous conditions during the life of the cells. Safety measures to maintain cell safety include, but are not limited to, the following:		P
	a) The appropriate choice and placement of insulation. IEEE 1625 and IEEE 1725 provide guidance on placement and application of insulation within cells and general cell design safety considerations;		P
	b) Sufficient sizing of the negative electrode active materials to cover the positive electrode active materials;		P
	c) Proper placement of insulation and separation of parts at opposite polarity including insulation and placement of tabs to prevent inadvertent short circuits during the life of the cell;		P
	d) The use of appropriate protection mechanisms such as separator shutdown, protective coatings and electrolyte additives, etc.; and		P
	e) The use of separators with sufficient strength, thermal properties and that are sized to prevent short		P

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	circuit between the positive and negative electrodes during charge and discharge over the life of the cells.		
7.12.4	With reference to 7.12.3, compliance to (a) – (e) is determined through a review of the cell construction as part of a tear down analysis, a review of documentation on the cell construction and components, and the cell tests of Annex E.	Cell certified by UL 1973, file number: MH 62898	P
7.12.5	Sodium-beta cells and batteries shall comply with the cell tests outlined in Annex B. Cells shall be provided with specifications for use (charging and discharging), installation, storage and disposal.		N/A
7.12.6	Flowing electrolyte cells and battery systems shall comply with the requirements outlined in Appendix C.		N/A
7.12.7	With reference to 7.12.6, flowing electrolyte battery systems shall be designed to mitigate shunt currents. Imbalance conditions and the potential for corrosion of the electrolyte containment parts may occur as a result of excessive shunt currents in a flowing electrolyte battery system. The flowing electrolyte battery manufacturer shall demonstrate through analysis and data that shunt currents have been mitigated as a result of the system design.		N/A
7.12.8	Batteries employing pressure release valves or flame arrestors shall comply with the pressure release test or the flame arrester test of UL 1989 in addition to the requirements of this standard. See Annex H for alternative criteria for vented or valve regulated lead acid or nickel cadmium batteries. Cells and multi-cell/monobloc batteries shall be provided with specifications for use (charging and discharging), installation, storage and disposal as outlined in Annex H.		N/A
7.12.9	Electrochemical capacitor cells and modules shall comply with the requirements outlined in UL 810A in addition to the requirements of this standard.		N/A
7.12.10	Sodium ion cells (e.g. Prussian Blue cells or transition metal layered oxide cells) shall comply with Annex E, and be marked as required in 44.15 and 44.16. Cells shall be provided with specifications as outlined in 45.7.		N/A
7.13	**Repurposed cells and batteries**		N/A
7.13.1	Batteries and battery systems using repurposed cells and batteries shall ensure that the repurposed parts have gone through an acceptable process for repurposing in accordance with UL 1974. See also 44.3.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
PERFORMANCE			
8	**General**		P
8.1	Unless indicated otherwise the device under test (DUT) shall be at the maximum operational state of charge (MOSOC), in accordance with the manufacturer's specifications, for conducting the tests in this standard. After charging and prior to testing, the samples shall be allowed to rest for a maximum period of 8 h at room ambient.		P
	Exception: For secondary lithium ion cells or batteries in which temperature is not a dependency on the test, the rest time may be extended to 36 h, but shall not be less than 90 % MOSOC.		N/A
8.2	Unless otherwise indicated, fresh samples (i.e. not more than 6 months old) representative of production shall be used for the system level tests described in Sections 15 – 42. The test program and number of samples to be used in each test is shown in Table 8.1.		P
	Exception No. 1: At the agreement of the manufacturer, DUT samples may be re-used for more than one test if not damaged in a manner that would affect test results. Minor repairs can be made to samples such as replacement of fuses, etc. in order to reuse samples for multiple tests.		N/A
	Exception No. 2: For repurposed batteries and battery systems, the "repurposing manufacturing date" is the date of manufacture used to determine the 6 month threshold.		N/A
8.3	All tests, unless noted otherwise, are conducted in a room ambient 25 ±5°C (77 ±9°F). Tests shall be conducted with the DUTs heated to normal operating temperatures unless indicated otherwise in the test. For those tests that require the DUT to reach thermal equilibrium, thermal equilibrium is considered to be achieved if after three consecutive temperature measurements taken at intervals of 10% of the previously elapsed duration of the test but not less than 15 min, indicate no change in temperature greater than ±2°C (3.6°F).		P
8.4	Thermocouples shall be attached to the central component cell or module during the system level tests in Sections 15 – 42. Temperatures shall also be measured on any components affected by temperature in the control circuit during the tests of 9.1 and 9.2. Temperature shall be measured using thermocouples consisting of wires not larger than 24 AWG (0.21 mm2) and not smaller than 30 AWG (0.05mm2) connected to a potentiometer-type instrument. Temperature measurements shall be made with the measuring junction of the thermocouple held tightly against the component/location being measured.		P

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8.5	Unless noted otherwise in the individual test methods, the tests shall be followed by a 1-h observation time prior to concluding the test and temperatures shall be monitored in accordance with 10.2.		P
9	**Determination of Potential for Fire Hazard**		P
9.1	In addition to visible signs of fire, non-compliant test results for fire shall also include an evaluation for combustible vapor concentrations during testing if there is the potential for combustible vapor concentrations based upon the technology and design of the battery system. For detection of potential combustible vapor concentrations that may be emitted during testing, a gas monitor suitable for detecting 25% of the lower flammability limit (LFL) of the evolved gases being measured. A minimum of two sampling locations where concentrations may occur such as at vent openings or vent ducts shall be used for taking measurements.		N/A
	Exception: *As an alternative to using gas detection measurement to determine if there are combustible vapor concentrations, non-compliant tests results for fire may include an evaluation for potential combustible vapor concentrations with the use of a minimum of two continuous spark sources. The continuous spark sources shall provide at least two sparks per second with sufficient energy to ignite natural gas and shall be located near anticipated sources of vapor such as vent openings or at the vent duct.*		P
9.2	Additional precautions shall be taken during tests requiring this analysis due to the potential for combustible vapor concentrations that may occur within the test room or chamber.		P
10	**Important Test Considerations**		P
10.1	The tests contained in this standard may result in explosions, fire and emissions of combustible and/or toxic vapors , leakage of hazardous chemicals as well as electric shock. It is important that personnel use extreme caution when conducting any of these tests and that they be protected from flying fragments, leaked electrolyte, explosive force, toxic vapors and chemicals and sudden release of heat and noise that could result from testing. To prevent injury, protective equipment and clothing should be utilized when handling batteries and when conducting testing. Short-circuiting can lead to very hazardous currents, and large format batteries may still be hazardous even in an uncharged condition. The test area shall be well ventilated to protect personnel from possible harmful vapors or gases and care should be taken to prevent exposure to leaked electrolyte. Test facilities shall be equipped to contain, mitigate, and		P

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	exhaust toxic vapors and particulate matter, leaked electrolyte and other hazardous substances that may be generated during the tests of this standard including the External Fire Exposure Test of Section 41. See also 9.2.		
10.2	As an additional precaution, the temperatures on surfaces of the DUT shall be monitored during the tests per 8.5. All personnel involved in the testing of battery systems shall be instructed to never approach the DUT until temperatures are falling and are at safe levels.		P
11	**Single Fault Conditions**		P
11.1	Where there is a specific reference to a single fault condition in the individual test methods, the single fault shall consist of a single failure (i.e. open, short or other failure means) of any component in the electrical energy storage system that could occur as identified in the system safety analysis of 7.8 and that could affect the results of the test.		P
12	**Test Results**		P
12.1	Tests that result in one or more of the following conditions as noted in Table 12.1 and as defined in Section 6, shall be considered as non-compliant for the test. Additional details of passing results criteria are provided in the individual test methods.		P
12.2	For the following tests, if the DUT is still operational after the test (a user replaceable fuse may be replaced or user resettable device such as an accessible circuit breaker, etc. reset), it shall be subjected to a minimum single charge/discharge cycle in accordance with the manufacturer's specifications. No non-compliant results as outlined in Table 12.1 shall occur during the charge/discharge cycle of a still operational DUT.		P
	a) Overcharge;		P
	b) Short Circuit;		N/A
	c) Overdischarge Protection;		P
	d) Imbalanced Charging;		P
	e) Failure of Cooling/Thermal Stability System;		P
	f) Electrostatic Discharge;		N/A
	g) Radio-Frequency Electromagnetic Field;		N/A
	h) Fast Transient/Burst Immunity;		N/A
	i) Surge Immunity;		N/A
	j) Radio-Frequency Common Mode;		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	k) Power Frequency Magnetic Field;		N/A
	l) Operational Verification;		N/A
	m) Vibration;		N/A
	n) Shock;		N/A
	o) Impact or Drop Impact;		P
	p) Static Force;		P
	q) Thermal Cycling;		N/A
	r) Salt Fog; and		N/A
	s) Resistance to Moisture.		N/A
	NOTE: If the tests of (f) – (l) may be done on the battery management system only and not the whole battery system.		—
13	**Determination of Toxic Emissions**		P
13.1	For those systems for which venting from cells or capacitors could result in the emission of toxic gases as determined by an analysis of the outgassed substances, the concentration of toxic gases during the destructive testing noted in Table 12.1 shall be monitored using one of the sampling methods noted below and as outlined in 13.2. Analysis of the outgassed substances can be obtained through review of MSDS sheets and/or analysis of the outgassed substances. If it can be determined through examination of the cells after testing that they did not vent as a result of the test, the system is in compliance with these criteria.	No vent as a result of the test.	P
	a) ASTM D4490;		N/A
	b) ASTM D4599;		N/A
	c) OSHA Evaluation Guidelines for Air Sampling Methods Utilizing Spectroscopic Analysis; or		N/A
	d) NIOSH Manual of Analytic Methods.		N/A
13.2	To determine the concentration of toxic emissions, testing shall be conducted in a closed test chamber of known volume large enough to contain the DUT. Results obtained from continuous sampling the emissions during testing shall be scaled to estimate the anticipated exposure and concentration of toxic materials within either the passenger compartment of a light electric rail (LER) or the anticipated smallest room in which the system can be installed. For walk-in units, continuous monitoring shall also be conducted in the interior of the system enclosure. The results for stationary applications shall be further scaled to consider a 0.5 air changes per hour (ACH) ventilation rate. The 0.5 ACH represents allowable low ventilation rated for construction.		N/A

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	Exception: *Stationary systems intended for installation outdoors only and that are not walk-in units are exempted from this monitoring. Stationary systems and systems for LER applications are also exempted from these requirements if provided with a ventilation system or otherwise designed to prevent exposure to toxic vapor releases and vents vapors to a safe location.*		N/A
14	**Measurement Equipment Accuracy**		P
14.1	Unless noted otherwise in the test methods, the overall accuracy of measured values of test specifications or results when conducting testing in accordance with this standard, shall be within the following values of the measurement range:		P
	a) ±1% for voltage;		P
	b) ±3% for current;		P
	c) ±4% for watts;		P
	d) ±2°C (±3.6°F) for temperatures at or below 200°C (392°F), and ±3% for temperatures above 200°C (392°F);		P
	e) ±0.1% for time;		P
	f) ±1% for dimension;		P
	g) ±3% for Ah;		P
	h) ±4% for Wh.		P

ELECTRICAL TESTS

15	**Overcharge Test**		P
15.1	The purpose of this test is to evaluate a battery system's ability to withstand an overcharge condition.		P
15.2	A fully discharged DUT (i.e. discharged to the manufacturer's specified EODV) shall be subjected to an overcharge resulting from a single fault condition in the charging protection/control circuit of the system that could lead to an overcharge condition. See Section 11 for a description of a single fault condition.		P
	Single fault conditions can be applied to both passive and active protective devices. The test supply equipment used for charging the DUT shall be sufficient to create an overcharge of the DUT to at least 110% of the maximum specified charging voltage. The charging rate used shall be the manufacturer's specified maximum charging rate.		N/A
	Exception No. 1: Overcharge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.		P

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Clause	Requirement + Test	Result – Remark	Verdict
	Exception No. 2: Components in circuits evaluated for reliability (i.e. evaluated for functional safety in accordance with 7.9) need not be subjected to single fault conditions.		P
15.3	The test shall continue until ultimate results occur followed by an observation period per 8.5. Ultimate results are considered to have occurred when one of the following occurs:		P
	a) The sample charging is terminated by the protective circuitry whether it is due to voltage or temperature controls or if the DUT reaches 110% of its maximum specified charging voltage limit. Exceeding the manufacturer's specified charging limit is considered a non-compliant result. The DUT is monitored per 8.5 and 10.2; or		P
	b) Battery system failure occurs as evidenced by explosion, fire or other identifiable non-compliant results per Table 12.1.		N/A
15.4	During the test, detection methods as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary.		P
	If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
15.5	If the DUT is operational after the overcharge test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
15.6	At the conclusion of the observation period, the samples shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
15.7	As a result of the overcharge test, the maximum charging voltage measured on the cells or modules shall not exceed their normal operating region. Also, the following in (a) – (h) are considered noncompliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L– Leakage (external to enclosure of DUT);	No Leakage	P

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Clause	Requirement + Test	Result – Remark	Verdict
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
16	**High Rate Charge**		P
16.1	The purpose of this test is to evaluate a battery system's ability to protect against a high rate charge condition at currents over the battery maximum charging current specification.		P
16.2	A fully discharged DUT (i.e. discharged to the manufacturer's specified EODV) shall be subjected to a high rate charge. There shall be a single fault condition on overcurrent charge protection devices or controls unless they have been evaluated for reliability (i.e. evaluated for functional safety in accordance with 7.9). During the test, the current and voltage of the cells shall be measured. The test supply equipment used for charging the DUT shall be sufficient to provide a current that is 20 % greater than the maximum specified charging rate for the batteries.		P
	Exception: High rate charge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.		P
16.3	The high rate charging of the DUT shall continue until ultimate results occur followed by an observation period per 8.5. Ultimate results are considered to have occurred when one of the following occurs:		P
	a) The sample charging is terminated by the protective circuitry whether it is due to current, voltage or temperature controls. The DUT is monitored per 8.5 and 10.2; or		P
	b) Battery system failure occurs as evidenced by explosion, fire or other identifiable non-compliant results per Table 12.1.		N/A
16.4	During the test, detection methods as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
16.5	If the DUT is operational after the high rate charge test, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user		P

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	resettable devices. An observation period per 8.5 is then conducted.		
16.6	At the conclusion of the observation period, the samples shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
16.7	As a result of the high rate charge test, the battery protection circuit (e.g. BMS) shall detect the overcharging current and shall prevent the battery from being charged over the maximum battery charging current. The following in (a) – (h) are considered non-compliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L– Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
17	**Short Circuit Test**		P
17.1	This test shall be conducted on a fully charged DUT (MOSOC per 8.1) with parallel connected cells or modules to determine its ability to withstand an external short circuit. DUTs with only series connections (i.e. no parallel connections of cells or modules) are tested at the cell level if determined to be equivalent to testing at the system level.		P
	Exception: Short circuit testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.		P
17.2	The sample shall be short-circuited by connecting the positive and negative terminals of the sample with a shorting device having resistance as low as practicable. In all cases the resistive circuit load shall have a maximum total resistance of 20 mΩ, as measured from the DUT terminals. For battery systems, the short circuit discharge profile at the terminals for current and time shall be recorded and compared with the manufacturer's specified value in 44.4.		P

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17.3	The direct short circuit test shall also be conducted on the battery module if it is intended to be installed or replaced in the field. The output of the battery module sample shall be short-circuited with a shorting device having resistance as low as practicable with a maximum total resistance of 20mΩ.		P
17.4	Tests shall be conducted at room ambient. The samples shall reach thermal equilibrium temperature as outlined in 8.3 before the terminals are connected.		P
17.5	The sample shall be completely discharged (i.e. discharged until near zero state of charge/its energy is depleted), or protection in the circuit has operated and the temperature on the center module has peaked or reached a steady state condition and 7 h has elapsed, or a fire or explosion has occurred.		P
17.6	During the test, samples supplied with protective devices shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices.		N/A
	Exception: Components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.9) need not be subjected to single fault conditions.		P
17.7	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
17.8	If the DUT is operational after the short circuit test it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		N/A
17.9	At the conclusion of the observation period , the samples shall be subjected to the "as received" dielectric voltage withstand test in accordance with Section 20. The DUT shall be examined for signs of rupture and evidence of leakage.		P
17.10	As a result of the short circuit test, the following in (a) – (h) are considered non-compliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P

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Clause	Requirement + Test	Result – Remark	Verdict
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
	Exception: For modules that do not have integral short circuit protection controls, the compliance criteria is (a) and (b) above only.		N/A
17.11	For battery systems, the measured maximum short circuit current and duration at that maximum value shall not be greater than the specified value of 44.4.		P
18	**Overload Under Discharge**		P
18.1	This test shall be conducted on a fully charged DUT (MOSOC per 8.1) with parallel connected cells or modules to determine its ability to withstand an overload discharge condition. DUTs with only series connections (i.e. no parallel connections of cells or modules) may be tested at the cell or module level if determined to be equivalent to testing at the system level.		P
	Exception: Overload under discharge testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.		P
18.2	Condition 1 is the overload above the specified maximum discharge current of the battery, but below the BMS overcurrent protection (secondary protection) in accordance with 18.3 – 18.5.		N/A
18.3	With reference to 18.2, the positive and negative terminals of the DUT is to be connected to the external discharging equipment. The fully charged DUT shall then be discharged at a current equal to 90 % of the rated overcurrent protection value of the BMS (secondary protection).		N/A
18.4	With reference to 18.2, the test shall be continued until:		N/A
	a) The DUT has been completely discharged (i.e. discharged until near zero state of charge/its energy is depleted);		N/A
	b) The protection in the circuit has operated and the temperature on the center cell/module has peaked or reached a steady state condition and 7 h has elapsed; or		N/A

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	c) A fire or explosion has occurred.		N/A
	Exception: The overload condition 1 can be waived if the maximum discharge current of the battery is equal to or higher than 90 % of the overcurrent protection value of the BMS (secondary protection).		P
18.5	With reference to 18.2, during the test, samples supplied with protective devices in the discharge circuit shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices.		N/A
	Exception: Overcurrent protection components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.9) need not be subjected to single fault conditions.		N/A
18.6	Condition 2 is the overload above the BMS overcurrent protection, but below the primary overcurrent protection in accordance with 18.7 – 18.9.		P
18.7	With reference to 18.6, the positive and negative terminals of the DUT shall be connected to the external discharging equipment. The DUT shall then be discharged at a current equal to 135 % of the main fuse rating.	Main fuse rating 450A	P
	Exception No. 1: If the secondary overcurrent protection is a contactor, switch or similar disconnecting device, which has been investigated for an overload current higher than 135 % of the primary overcurrent protector rating, then the test shall be conducted at a discharge current of 150 % of the primary overcurrent protector rating.		N/A
	Exception No. 2: If the secondary overcurrent protection has be investigated for an overload current higher than 150 % of the primary overcurrent protector rating, then the condition 2 test can be waived.		N/A
18.8	With reference to 18.6, the test shall be continued until:		P
	a) The DUT has been completely discharged (i.e. discharged until near zero state of charge/its energy is depleted);		N/A
	b) The protection in the circuit has operated and the temperature on the center cell/module has peaked or reached a steady state condition and 7 h has elapsed; or		P
	c) A fire or explosion has occurred.		N/A
18.9	With reference to 18.6, during the test, samples supplied with protective devices in the discharge circuit shall be subjected to a single component fault using any single fault condition that may be determined to occur during discharge conditions. See Section 11 for details regarding single fault conditions. Single fault conditions can be applied to both passive and active protective devices.		N/A

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	Exception: Overcurrent protection components in circuits evaluated for reliability (i.e. evaluated for functional safety criteria considering single fault conditions in accordance with 7.9) need not be subjected to single fault conditions.		P
18.10	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
18.11	If the DUT is operational after the short circuit test, it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 shall then be conducted.		P
18.12	At the conclusion of the observation period, the samples shall be subjected to the "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
18.13	As a result of the overload test, the following in (a) – (h) are considered non-compliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
19	**Overdischarge Protection Test**		P
19.1	This test shall be conducted on a fully charged sample (MOSOC per 8.1) to determine the DUTs ability to withstand an over-discharge condition and is conducted with all discharge protection circuitry for both temperature and minimum voltage connected to prevent irreparable cell damage. During the test, active protective devices shall be subjected to single fault conditions, unless the protection circuit has been		P

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Clause	Requirement + Test	Result – Remark	Verdict
	tested for functionality in accordance with 7.9. During test, the voltage of the cells shall be measured.		
	Exception: *Over-discharge protection testing on a subassembly may be conducted instead of the complete battery system if determined to be representative of the battery system.*		P
19.2	The DUT shall be subjected to a constant discharging current/power that will discharge a battery at the manufacturer's specified maximum discharge rate.		P
	The test will continue until the passive protection device(s) are activated, or the minimum cell voltage/maximum temperature protection is activated, or the DUT has been discharged for an additional 30 min after it has reached its specified normal discharge limit, whichever comes first.		P
19.3	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations as determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
19.4	If the DUT is operational after the overdischarge protection test it shall be subjected to a charge and discharge cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
19.5	At the conclusion of the observation period, the samples shall be subjected to the ″as received″ dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
19.6	As a result of the overdischarge protection test, the minimum discharge voltage measured on the cells shall not exceed their normal operating range. Also, the following in (a) – (h) are considered noncompliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P

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Clause	Requirement + Test	Result – Remark	Verdict
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
20	**Temperature and Operating Limits Check Test**		P
20.1	This test is conducted to determine whether or not the cells/modules of the DUT are being maintained within their specified operating limits (including voltage and current at specified temperature) during maximum charge and discharge conditions. During this test, it shall also be determined as to whether or not temperature sensitive safety critical components are being maintained within their temperature ratings based upon the maximum operating temperature specifications of the DUT as well as a determination that temperatures on accessible surfaces are not exceeding safe limits.		P
	Exception: *Temperature and operating limits check test on a subassembly may be conducted instead of a complete battery system if determined to be representative of the battery system.*		N/A
20.2	A fully discharged DUT (i.e. discharged to EODV) shall be conditioned within a chamber set to the upper limit charging temperature specifications of the DUT. After being stabilized at that temperature (refer to 8.3), the DUT shall be connected to a charging circuit input representative of anticipated maximum charging parameters. The DUT shall then be subjected to maximum normal charging while monitoring voltages and currents on modules until it reaches the manufacturer's specified fully charged condition. Temperatures shall be monitored on temperature sensitive components including cells.		P
	Exception No. 1: *If the DUT is unable to be tested in a chamber, it can be tested at an ambient temperature of 25 ±5°C (77 ±9°F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed:* $T \leq T_{max} - (T_{ma} - T_{amb})$ *Where:* *T is the temperature of the given part measured under the prescribed test.* T_{max} *is the maximum temperature specified for compliance with the test.* T_{amb} *is the ambient temperature during the test.* T_{ma} *is the maximum ambient temperature permitted by the manufacturer's specified or 25°C (77°F), whichever is greater.*		N/A
	Exception No. 2: *If the design of the DUT and its controls result in worse case normal charging conditions when testing at ambient (i.e. due to thermostats or other controls lowering the charge levels at elevated ambient), the test shall be conducted at ambient temperature of 25 ±5°C (77 ±9°F). Temperatures on temperature sensitive components shall not exceed Tmax.*		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
20.3	While still in the conditioning chamber, the chamber temperature shall be set to the upper limitdischarging temperature specifications of the DUT if different from the charging temperature. The fullycharged DUT (MOSOC per 6.1) shall then be discharged in accordance with the manufacturer's maximum rate of discharge down to the manufacturer's specified end of discharge condition while monitoring voltage and current on modules. Temperatures shall be monitored on temperature sensitive safety criticalcomponents including cells. Temperatures on accessible surfaces are also monitored.		P
	Exception No. 1: *If the DUT is unable to be tested in a chamber, it can be tested at an ambient temperature of 25 ±5°C (77 ±9°F). If tested at ambient temperatures during the test, the temperature measurement T shall not exceed:* $T \leq T_{max} - (T_{ma} - T_{amb})$ *Where:* *T is the temperature of the given part measured under the prescribed test.* T_{max} *is the maximum temperature specified for compliance with the test.* T_{amb} *is the ambient temperature during the test.* T_{ma} *is the maximum ambient temperature permitted by the manufacturer's specified or 25°C (77°F), whichever is greater.*		N/A
	Exception No. 2: *If the design of the DUT and its controls result in worse case normal discharging conditions when testing at ambient (i.e. due to thermostats or other controls lowering the discharge rate at elevated ambient), the test shall be conducted at ambient temperature of 25 ±5°C (77 ±9°F). Temperatures on temperature sensitive components shall not exceed Tmax.*		N/A
20.4	The charge and discharge cycles are then repeated for a minimum of two complete cycles of charge and discharge. The DUT is then subjected to an observation period per 8.5.		P
20.5	At the conclusion of the observation period, the samples shall be subjected to the "as received" dielectric voltage withstand test in accordance with Section 22 if it anticipated that there has been deterioration of the insulation during the temperature test. The DUT shall be examined for signs of rupture and evidence of leakage.		P
20.6	The manufacturer's specified operating limits for cells/modules (voltage, current at specified temperatures) shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications. Temperatures measured on accessible surfaces shall not exceed allowed limits. See Table 20.1 and Table 20.2 for temperature limit tables. Additional non-compliant results during the temperature test are as noted below in (a) – (e).		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P

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Clause	Requirement + Test	Result – Remark	Verdict
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
21	**Imbalanced Charging Test**		P
21.1	This test is to determine whether or not a battery system with series connected cells/modules can maintain the cells/modules within their specified operating parameters if it becomes imbalanced.		P
	Exception No. 1: Testing may be conducted at a subassembly level if that is representative of the battery system.		P
	Exception No. 2: Testing may be conducted on an alternate configuration if it can be shown to be representative for the battery system.		N/A
21.2	A fully charged DUT (MOSOC per 8.1) shall have all of its modules/cells with the exception of one discharged to its specified fully discharged condition. The undischarged module/cell shall be discharged to approximately 50% of its specified state of charge (SOC) to create an imbalanced condition prior to charging.		P
21.3	The sample shall then be charged in accordance with the manufacturer's maximum normal charging specifications. Charging shall continue until end of charge conditions and the DUT reaches thermal equilibrium. The voltage of the partially charged module/cell shall be monitored during the charging to determine if its voltage limits are being exceeded.		P
	During the test, active protective devices shall be subjected to single fault conditions, unless the protective circuit has been tested for functionality in accordance with 7.9.		P
21.4	During the test, a detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations as determined necessary. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P

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Clause	Requirement + Test	Result – Remark	Verdict
21.5	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
21.6	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
21.7	The maximum voltage limit of the module/cell shall not be exceeded when charging an imbalanced DUT.		P
	Also, the following in (a) – (h) are considered non-compliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
22	**Dielectric Voltage Withstand Test**		P
22.1	This test is an evaluation of the electrical spacings and insulation at hazardous voltage circuits within the battery system.		P
22.2	Circuits exceeding 42.4 V peak or 60 Vdc shall be subjected to an electric strength test in accordance with UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.9.		P
	Exception: Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.		N/A
22.3	The test voltage shall be applied between the hazardous voltage circuits of the DUT and noncurrent carrying conductive parts that may be accessible and low voltage circuits separated from hazardous voltage circuits by reinforced or double insulation.		P

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Clause	Requirement + Test	Result – Remark	Verdict
22.4	The test voltage is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the DUT.		P
22.5	If the accessible parts of the DUT are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts.		P
22.6	The test voltages shall be applied for a minimum of 1 min with the cells/modules disconnected to prevent charging during application of the voltage. Technologies that are required to be at an elevated operating temperature in order to be active, such as sodium-beta chemistries, shall be in a hot state prior to disconnection and applying the test potential.		P
22.7	There shall be no evidence of a dielectric breakdown (breakdown of insulation resulting in a short through insulation/arcing over electrical spacings) as evidenced by an appropriate signal from the dielectric withstand test equipment as a result of the applied test voltage. Corona discharge or a single momentary discharge is not regarded as an dielectric breakdown (i.e. insulation breakdown).		P
22.8	If the battery system contains hygroscopic materials that may affect spacings, this test is repeated with the DUT or with the subassembly of the DUT containing the hygroscopic materials subjected to humidity conditioning of UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.8. As a result of this testing, there shall be no dielectric breakdown as outlined in 22.7.		N/A
23	**Continuity Test**		P
23.1	This test evaluates the continuity of the protective grounding and bonding system of the battery system that is intended to provide an electrically conductive path from the point of a ground fault on a battery system or its representative parts or components through normally non-current-carrying conductors, equipment, or the earth to the electrical supply source.		P
23.2	An alternate test method outlined in 23.7 may be used if the construction of the protective grounding and bonding system adheres to the construction methods outlined in 7.6.5 – 7.6.7. If the connections means vary from that outlined in 7.6.6 and 7.6.7, the fault current method outlined in 23.3 – 23.6 is the default method for evaluating the suitability of the protective grounding system.		P

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Clause	Requirement + Test	Result – Remark	Verdict
23.3	The grounding system of an battery system shall have no more than 0.1-Ω resistance between any two parts of the system that are measured in accordance with the continuity test of 23.4 and 23.5.		N/A
23.4	The voltage drop in a protective grounding system is measured after applying a test current of 200% of the rating of the overcurrent protection device rating, for a duration corresponding to 200% of the time-current characteristic of the overcurrent protection device. If the duration for 200% is not given, a point closest on the time-current characteristic shall be used. The overcurrent protective device limits the fault current in the protective grounding system, and is either provided in the battery system or external to the battery system and specified in the installation instructions. The supply used to provide the test current shall have a no load voltage not exceeding 60 Vdc.		N/A
23.5	The voltage drop measurement is made between any two conductive parts of the grounding system.		N/A
23.6	The resistance shall be calculated from the measured voltage drop and current. The determined resistance shall be less than or equal to 0.1 Ω.		N/A
23.7	To check the continuity of the bonding connections, the resistance can be measured between two points on the bonding connections using a milli-ohmmeter. The measured resistance between any two bonding connections shall be less than or equal to 0.1 Ω.		P
24	**Failure of Cooling/Thermal Stability System**		P
24.1	The purpose of this test is to determine if the battery system can safely withstand a failure in the cooling/thermal stability system.		P
	Exception: Testing may be conducted at a subassembly level if that is representative of the energy storage system.		N/A
24.2	The DUT shall be fully discharged to the manufacturer's end of discharge condition EODV and then conditioned at maximum specified operating ambient for a period of 7 h or until thermally stable per 8.3, whichever is shorter. While still in the conditioning chamber, the DUT, with its cooling/thermal stability system disabled shall then be charged at its maximum specified charge rate until completely charged or until operation of a protective device.		P
24.3	The DUT shall be fully charged (MOSOC per 8.1) and then conditioned at maximum specified operating ambient for a period of 7 h or until thermally stable per 8.3, whichever is shorter. While still in the conditioning chamber, the DUT, with its		P

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Clause	Requirement + Test	Result – Remark	Verdict
	cooling/thermal stability system disabled shall then be discharged at the maximum discharge rate until it reaches its specified end of discharge condition or until operation of a protective device.		
24.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
24.5	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		P
24.6	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test per Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
24.7	The test method of 24.2 – 24.6 shall be repeated with the DUT conditioned at the minimum specified operating ambient.		P
24.8	As a result of the failure of cooling/thermal stability test, the following in (a) – (h) are considered non-compliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
25	**Working Voltage Measurements**		P
25.1	This test is to measure the working voltage of a battery system.		P
25.2	The working voltage between live parts of opposite polarity, live and dead metal parts, live parts and a		P

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Clause	Requirement + Test	Result – Remark	Verdict
	metal enclosure, and live and ground connections under both normal charging and discharging conditions as specified by the manufacture is measured.		
25.3	The dead metal parts and metal enclosure shall be assumed to be connected to the negative terminal of the system for testing purpose.		P
25.4	The values obtained during the measurements outlined in 25.2 shall be used to verify electrical spacings criteria per 7.5.		P
26	**Tests on Electrical Components**		N/A
26.1	**Locked-rotor test for low voltage dc fans/motors in secondary circuits**		N/A
26.1.1	The purpose of this test is to determine if a low voltage dc fan or motor does not present a hazard in a locked rotor condition. Fans complying with UL 507 are considered to comply with this requirement without test.		N/A
26.1.2	A sample of the fan or motor is placed on a wooden board, which is covered with a single layer of tissue paper, and the sample in turn is covered with a single layer of bleached cotton cheesecloth of approximately 40 g/m2.		N/A
26.1.3	The sample is then operated at the voltage used in its application and with its rotor locked for 7 h or until steady conditions are established per 8.3, whichever is the longer.		N/A
26.1.4	There shall be no ignition of the tissue paper or cheesecloth.		N/A
26.2	**Input**		N/A
26.2.1	The input current draw of a control or accessory separate from the pack such as a mains supplied control or an accessory control evaluated independent from a system, shall be subjected to the input test of 26.2.2.		N/A
26.2.2	The current or watts input to an ac mains supplied unit, when connected to an ac supply adjusted to the test voltage specified in Table 26.1 shall not be more than 110% of the rated/specified value. The current or watts input draw of a dc supplied unit, when connected to a dc supply, shall not exceed the rated/specified value of the device.		N/A
26.3	**Leakage current**		N/A
26.3.1	For separate controls or other accessories of the system that are cord connected and supplied by ac mains circuits, the controls shall comply with the Protective Touch Voltage, Touch Current and		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	Protective Conductor Current test of UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.7.		
26.4	**Strain relief test**		N/A
26.4.1	The purpose of this test is to determine if the strain relief means for a non-detachable accessible cord prevents damage or displacement upon being pulled.		N/A
26.4.2	The battery system or accessory provided with a strain relief shall withstand without damage to the cord or conductors and without displacement, a direct pull of 156 N (35 lbf) applied to the cord for 1 min.		N/A
	Supply connections within the equipment shall be disconnected from terminals or splices during the test when applicable. If the strain relief is mounted in a polymeric enclosure or part, the test is conducted after the mold stress test after the part has cooled to room temperature.		N/A
26.4.3	As a result of the pull force, there was no damage or displacement of internal connectors. Inner conductors may not elongate more than 2 mm (0.08 in) from the pre-test position.		N/A
26.5	**Push-back relief test**		N/A
26.5.1	The purpose of this test is to determine if the strain relief of a non-detachable accessible cord provides adequate protection to connections and prevent hazardous displacement of internal wiring and connections as a result of push back.		N/A
26.5.2	A product shall be tested in accordance with 26.5.3 and 26.5.4 without occurrence of any of the following conditions:		N/A
	a) Subjecting the supply cord to mechanical damage;		N/A
	b) Exposing the supply cord to a temperature higher than that for which it is rated;		N/A
	c) Reducing spacings (such as to a metal strain-relief clamp) below the minimum required values; or		N/A
	d) Damaging internal connections or components.		N/A
26.5.3	The supply cord shall be held 25.4 mm (1 in) from the point where the cord or lead emerges from the product and is then to be pushed back into the product. When a removable bushing, which extends further than 25.4 mm (1 in) is present, the bushing shall be removed prior to the test.		N/A
26.5.4	When the bushing is an integral part of the cord, then the test shall be carried out by holding the bushing. The cord shall be pushed back into the product in 25.4-mm (1-in) increments until the cord buckles or the force to push the cord into the product exceeds 26.7 N (6 lbf).		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
26.5.5	The supply cord shall be manipulated to determine compliance with 26.5.1.		N/A
26.5.6	If the strain relief is mounted in a polymeric enclosure or part, the test is conducted after the mold stress test after the part has cooled to room temperature.		N/A
26.6	**Low voltage transformer evaluation**		N/A
26.6.1	The purpose of this test is to determine that transformers located in low voltage circuits (i.e. ≤ 60 Vdc) do not present a fire hazard under overload conditions. Transformers complying with UL 1310 or equivalent standard and evaluated under overload conditions are considered to comply with these requirements without further testing.		N/A
26.6.2	If the tests in this section are conducted under simulated conditions on the bench, these conditions shall include any protection device that would protect the transformer in the complete equipment. Tests shall be conducted under ambient laboratory conditions. A sample of the transformer is placed on a wooden board, which is covered with a single layer of tissue paper, and the sample in turn is covered with a single layer of bleached cotton cheesecloth of approximately 40 g/m2 (1.18 oz/yd2).		N/A
26.6.3	If a transformer has more than one secondary winding or a tapped secondary winding, separate tests shall be conducted for each winding, or each section of a tapped winding, with the other windings loaded or unloaded as may occur in service unless it can be determined that one condition will produce the most unfavorable results.		N/A
26.6.4	resistive load that will draw three times the normal input current or maximum obtainable output current, whichever is less, shall be connected directly to the transformer secondary winding with the transformer connected to the voltage of the circuit the transformer will be installed in. The transformer shall be operated continuously:		N/A
	a) Until ultimate conditions are observed, including opening of a thermal cutoff or a similar device;		N/A
	b) For 7 h if temperatures stabilize or cycling of an automatically reset protector occurs; or		N/A
	c) For 50 cycles of resetting a manually reset protector.		N/A
26.6.5	As a result of the overload test, there shall be no emission of molten metal or fire as evidenced by burning or charring of the cheesecloth indicator or tissue paper.		N/A
27	**Electromagnetic Immunity Tests**		P

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Clause	Requirement + Test	Result – Remark	Verdict
27.1	**General**		P
27.1.1	Active protective devices (e.g. battery management systems, solid state circuits, software controls, etc.) relied upon as the primary safety protection in 7.8 – 7.9 shall demonstrate sufficient immunity to electromagnetic interference by complying with the tests specified in 27.2 – 27.7. Alternate test procedures and levels specified in other standards may be used, but only if they are equivalent or more severe than the test procedures and levels specified below.	See EMC report: 64.772.24.30223.01	P
27.1.2	Each test shall begin with an operational DUT. The DUT may consist of only the battery management system, if that is the only part of the battery system that will be impacted.		P
27.1.3	During specific tests as indicated in 27.2 – 27.7, the DUT shall be subjected to a charge/discharge cycle in accordance with the manufacturer's specification. No non-compliant results as outlined in Table 12.1 shall occur during the charge/discharge cycle.		P
	Exception: It is acceptable if the charge/discharge cycle is not completed at the conclusion of the test.		N/A
27.1.4	After each test in 27.2 – 27.7, the DUT shall be inspected to verify that it is still operational and in compliance with Table 12.1. This may require Operational Verification (27.8) of the DUT if it is not possible to determine that it is fully operational by inspection. If the DUT is no longer operational, a failure analysis shall be conducted to determine the reason for the failure and to verify that the DUT has failed safely in accordance with Table 12.1. A DUT that is no longer operational shall not be used on any remaining test.		P
27.1.5	In addition, after all tests in this section have been completed, all samples used during the tests specified in 27.2 – 27.7 shall comply with the Operational Verification in 27.8.		P
27.2	**Electrostatic discharge**		P
27.2.1	The DUT shall demonstrate immunity to electrostatic discharges in accordance with the test procedure specified in IEC 61000-4-2.		P
27.2.2	The following test levels shall be used: a) ±6 kV contact discharge; and b) ±8 kV air discharge.		P
27.2.3	After the test, the DUT shall comply with 27.1.4.	Performed on protected condition of voltage, current, temperature.	P
27.3	**Radio-frequency electromagnetic field**		P

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Clause	Requirement + Test	Result – Remark	Verdict
27.3.1	The DUT shall demonstrate immunity to radio-frequency electromagnetic fields in accordance with the test procedure specified in IEC 61000-4-3.		P
27.3.2	The following test levels shall be used: a) 10 V/m from 80 MHz to 1 GHz, 1 kHz (80 % AM); and b) 3 V/m from 1.4 GHz to 6.0 GHz, 1 kHz (80 %AM).		P
27.3.3	During the test, the DUT shall comply with 27.1.3.		P
27.3.4	After the test, the DUT shall comply with 27.1.4.	Performed on protected condition of voltage, current, temperature.	P
27.4	**Fast transient/burst immunity**		P
27.4.1	The DUT shall demonstrate immunity to electrical fast transients/bursts in accordance with the test procedure specified in IEC 61000-4-4.		P
27.4.2	The following test levels in (a) – (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b).		P
	a) On signal/control ports intended to be connected to cables longer than 3 m (118 in), ±1 kV (5/50 ns, 5 kHz); capacitive clamp shall be used; b) On input and output DC ports, ±1 kV (5/50 ns, 5 kHz); and c) On input and output AC ports, ±2 kV (5/50 ns, 5 kHz).	c)	P
27.4.3	After the test, the DUT shall comply with 27.1.4.	Performed on protected condition of voltage, current, temperature.	P
27.5	**Surge immunity**		P
27.5.1	The DUT shall demonstrate immunity to surges in accordance with the test procedure specified in IEC 61000-4-5.		P
27.5.2	The following test levels in (a) – (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b).		P

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Clause	Requirement + Test	Result – Remark	Verdict
	a) For I/O signal/control ports intended to be connected to long-distance cables longer than 30 m (98.4 ft), which leave the building, and/or are for outdoor use, ±1 kV line-to-ground; b) For input and output DC ports, ±0.5 kV line-to-line, and ±1 kV line-to-ground; and c) For input and output AC ports, ±1 kV line-to-line, and ±2 kV line-to-ground.	c)	P
27.5.3	After the test, the DUT shall comply with 27.1.4.	Performed on protected condition of voltage, current, temperature.	P
27.6	**Radio-frequency common mode**		P
27.6.1	The DUT shall demonstrate immunity to radio-frequency conducted disturbances in accordance with the test procedure specified in IEC 61000-4-6.		P
27.6.2	The following test levels in (a) – (c) shall be used. If the DUT has a DC power input port connected to an AC/DC converter such as a power supply or charger that is an integral part of the battery pack, the test shall be conducted on the AC input of the AC/DC converter using the test level specified in (c). Otherwise, the test shall be conducted on the DC power input port of the DUT using the test level specified in (b).		P
	a) For I/O signal/control ports intended to be connected to cables longer than 3 m (118 in), 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM); b) For input and output DC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM); and c) For input and output AC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM).	c)	P
27.6.3	During the test, the DUT shall comply with 27.1.3.		P
27.6.4	After the test, the DUT shall comply with 27.1.4.	Performed on protected condition of voltage, current, temperature.	P
27.7	**Power-frequency magnetic field**		P
27.7.1	The DUT shall demonstrate immunity to power-frequency magnetic fields in accordance with the test procedure specified in IEC 61000-4-8.		P
27.7.2	The test level of 10 A/m shall be used.		P
27.7.3	During the test, the DUT shall comply with 27.1.3.		P
27.7.4	After the test, the DUT shall comply with 27.1.4.	Performed on protected condition of voltage, current, temperature.	P
27.8	**Operational verification**		P

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Clause	Requirement + Test	Result – Remark	Verdict
27.8.1	After the tests in 27.2 – 27.7 have been completed, all samples used during these tests shall comply with the following.		P
27.8.2	The manufacturer shall declare the anticipated performance of all safety functions performed by active protective devices.		P
27.8.3	The manufacturer shall provide test procedures to verify that each of the safety functions performed by active protective devices is working correctly. This may include, for example, execution of a full charge/discharge cycle, or verification of correct safety function performance by simulation.		P
27.8.4	The test procedures specified in 27.8.3 shall be performed with each DUT in the following conditions: a) Fully-charged; and b) Fully-discharged.		P
27.8.5	During the test procedures specified in 27.8.3 – 27.8.4, each DUT shall exhibit one of the following behaviors:		P
	a) No loss of safety functions; or		P
	b) Transition to an appropriate state to ensure safe operation of the DUT. This could include a DUT that has lost its ability to charge or discharge as long as safety is maintained.		P
27.8.6	If redundant methods of protection are provided for a safety function to comply with 7.9.1, each method of protection shall be evaluated to determine if it functions as intended.		P

MACHANICAL TESTS

28	**Vibration Test (LER Motive and VAP Applications)**		N/A
28.1	The purpose of this test is to determine the battery system's resistance to anticipated vibration in LER motive and VAP installations and applies only to those systems intended for installation in these applications.	Not be used in LER Motive and VAP Applications	N/A
28.2	The sample shall be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample.		N/A
	Exception: *The sample may be mounted within a mounting fixture representative of the intended end use application.*		N/A
28.3	The fully charged sample (MOSOC per 8.1) shall be subjected to a vibration test in accordance with the Simulated Long Life Testing at Increased Random		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	Vibration Levels Tests of IEC 61373, for the appropriate Category and Class of equipment as determined by the intended rail installation. (Category and Class of equipment is defined in IEC 61373.)		
	Exception: Batteries intended for VAP applications shall be subjected to the Vibration Endurance Test of UL/ULC 2271 or UL/ULC 2580.		N/A
28.4	The DUT shall be subjected to vibration in 3 mutually perpendicular directions. During the test the OCV of the DUT and temperatures on the center cell/module shall be monitored for information purposes.		N/A
28.5	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N/A
28.6	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. See 12.2 for details regarding user resettable devices. An observation period per 8.5 is then conducted.		N/A
28.7	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
28.8	As a result of the vibration test, the following in (a) – (h) are considered non-compliant results.		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L – Leakage (external to enclosure of DUT);		N/A
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
	h) P – Loss of protection controls.		N/A
	For additional information on non-complying results refer to Table 12.1.		N/A
29	**Shock Test (LER Motive and VAP Applications)**		N/A
29.1	The purpose of this test is to determine the battery system's resistance to anticipated shock in LER	Not be used in LER Motive and VAP Applications	N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	motive and VAP installations and applies only to those systems intended for installation in these applications.		
29.2	The sample shall be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample. During the test, temperatures on the center module are monitored for information purposes.		N/A
	Exception No. 1: This sample may be mounted within a mounting fixture representative of the intended end-use rail application.		N/A
	Exception No. 2: Batteries intended for VAP applications shall be subjected to the Shock Test of UL/ULC 2271 or UL/ULC 2580.		N/A
29.3	A fully charged sample (MOSOC per 8.1) shall be subjected to a shock test in accordance with IEC 61373 for the appropriate Category and Class of equipment as determined by the intended rail installation. (Category and Class of equipment is defined in IEC 61373.)		N/A
	Exception: This test may be conducted at the module level if it can be shown that testing shall be representative of the battery system.		N/A
29.4	Both positive and negative direction shocks shall be applied in each of 3 mutually perpendicular directions for a total of 18 shocks.		N/A
29.5	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N/A
29.6	If the DUT is operational after the test it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		N/A
29.7	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
29.8	As a result of the shock test, the following in (a) – (h) are considered non-compliant results.		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L – Leakage (external to enclosure of DUT);		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
	h) P – Loss of protection controls.		N/A
	For additional information on non-complying results refer to Table 12.1.		N/A
30	**Crush Test (LER Motive and VAP Applications)**		N/A
30.1	This test is conducted on a fully charged battery system intended for LER motive and VAP applications to determine its ability to withstand a crush that could occur during an accident and applies only to those systems intended for installation in these applications.	Not be used in LER Motive and VAP Applications	N/A
30.2	A sample shall be crushed between a fixed surface and a ribbed test platen in accordance with the test fixture described in SAE J2464, with the following exceptions as noted below. Packs with 3 axes of symmetry, are subjected to 3 mutually perpendicular directions of press. A different sample of the DUT may be used for each crush.		N/A
	Exception No. 1: The maximum force applied to the DUT shall be 100 ±6 kN.		N/A
	Exception No. 2: Battery systems with only 2 axes of symmetry, such as cylindrical designs are subjected to 2 mutually perpendicular directions of press.		N/A
	Exception No. 3: The DUT may be installed in a protective framework representative of what is provided in the end use application.		N/A
	Exception No. 4: A subassembly may be tested instead of a complete battery system if it can be demonstrated to be equivalent to testing a complete battery system.		N/A
30.3	A detection method as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations within the sample. Venting of gases may occur, but shall not exceed ERPG-2 levels using the measurement methods outlined in Section 13. The sample shall be subjected to an observation period and the examined.		N/A
30.4	As a result of the crush test, the following in (a) – (d) are considered non-compliant results.		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	For additional information on non-complying results refer to Table 12.1.		N/A
31	**Static Force Test**		P

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Clause	Requirement + Test	Result – Remark	Verdict
31.1	The purpose of this test is to determine if the enclosure has sufficient strength to safely withstand a static force that may be applied to it.		P
31.2	The enclosure of a fully charged DUT (MOSOC per 8.1) shall withstand a steady force of 250 N ±10 N for a period of 5 s, applied in turn to the top, bottom and sides of the enclosure fitted to the DUT, by means of a suitable test tool providing contact over a circular plane surface 30 mm (1.2 inch) in diameter. However, this test is not applied to the bottom of an enclosure having a mass of more than 18 kg (39.7 lbs).		P
	If the DUT is operational after completion of the application of the static force, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
31.3	If deemed necessary (i.e. due to design of system and anticipation of venting of cells), one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
31.4	After the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
31.5	As a result of the static force test, the following in (a) – (h) are considered non-compliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
32	**Impact Test**		P

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Clause	Requirement + Test	Result – Remark	Verdict
32.1	The purpose of this test is to evaluate the mechanical integrity of the enclosure and its ability to provide mechanical protection to the battery system contents.		P
32.2	A fully charged sample (MOSOC per 8.1) shall be subjected to a minimum of three impacts of 6.8 J (5 ft-lb) on any surface that can be exposed to a blow during intended use. The impact shall be produced by dropping a steel sphere, 50.8 mm (2 inches) in diameter, and weighing 535 g (1.18 lb) from a height, H, of 1.29 m (50.8 in). For surfaces other than the top of an enclosure, the steel sphere shall be suspended by a cord and swung as a pendulum, dropping through the vertical height of 1.29 m (50.8 in), with the product being impacted placed against a restraining vertical wall. See Figure 32.1. A different sample may be used for each impact.		P
32.3	If the DUT is operational after the impacts it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
32.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		P
32.5	After the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
32.6	As a result of the impact test, the following in (a) – (h) are considered non-compliant results.		P
	a) E – Explosion;	No Explosion	P
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P

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Clause	Requirement + Test	Result – Remark	Verdict
33	**Drop Impact Test**		P
33.1	Modules that are intended for field installation into rack mount or similar equipment are subjected to a drop impact test to determine that no hazard exists as a result of an inadvertent drop during installation or removal.		P
33.2	After being equilibrated at room temperature per 8.3, a fully charged module/component pack shall be dropped from a minimum height of 100 cm (39.4 in) for products weighing 7 kg (15.4 lbs) or less, 10 cm (3.9 in) for products weighing >7 kg (15.4 lbs), but less than 100 kg (220.5 lbs), and 2.5 cm (0.98 in) for products weighing > 100 kg (220.5 lbs), to strike a concrete or metal surface in the position most likely to produce adverse results and in a manner most representative of what would occur during maintenance and handling/removal of the battery system during installation and servicing. The orientation of the drop shall be determined by the testing personnel from an analysis of the installation and servicing instructions. If using a metal test surface, it should be provided with some manner of insulation such as insulating film that will prevent inadvertent short circuiting to the surface but will not affect test results.		P
33.3	The sample shall be dropped a minimum of one time. However, if only one drop test is performed, it shall not be a flat drop. If one drop test is a flat drop, then at least one other test shall be performed that is not a flat drop.		P
33.4	The concrete surface shall be at least 76-mm (3-in) thick and the concrete or metal drop surface shall be large enough in area to cover the DUT.		P
33.5	After the drop, if the DUT is operational it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		P
33.6	At the conclusion of the observation period, an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		P
33.7	A spark ignition source or gas monitoring as outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations within the sample immediately after the drop and repeated in the instance of increasing temperatures.		P
33.8	As a result of the drop impact test, the following in (a) – (f) are considered non-compliant results.		P
	a) E – Explosion;	No Explosion	P

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Clause	Requirement + Test	Result – Remark	Verdict
	b) F – Fire;	No Fire	P
	c) C – Combustible vapor concentrations;	No Combustible vapor concentrations	P
	d) V – Toxic vapor release;	No Toxic vapor release	P
	e) S – Electric shock hazard (dielectric breakdown);	No Electric shock hazard	P
	f) L – Leakage (external to enclosure of DUT);	No Leakage	P
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);	No Rupture	P
	h) P – Loss of protection controls.	No Loss of protection controls	P
	For additional information on non-complying results refer to Table 12.1.		P
34	**Wall Mount Fixture/Support Structure/Handle Test**		P
34.1	A wall mounting apparatus of a wall mounted battery system, a battery support structure such as a stationary battery system rack, the support structure for a flow batteries stack(s), or a handle(s) provided for handling of a field/rack installed module/pack, shall have sufficient strength to support the battery system or allow for carrying of module/pack. Compliance is determined by the test below.		P
	Exception: This test can be waived for a battery rack complying with UL 2416 and rated for the intended weight of the batteries to be supported.		N/A
34.2	The wall mounting apparatus or other support structure and battery system shall be installed in accordance with the manufacturer's specifications. A force equal to three times the weight of the battery system is additionally applied to the center of the mounting apparatus or support structure in a downward direction. The force shall be held for 1 min.		P
	For modules/packs with a carrying handle(s), the DUT shall be supported by the carrying handles and a force equal to three times the weight of the DUT is additionally applied in a downward direction. If more than one carrying handle is provided, the added weight shall be distributed between the handles.		N/A
34.3	As a result of the applied force, there shall be no damage to the mounting apparatus or support structure and the securement means when testing the wall mounting fixture or supporting structure. As a result of the applied force, there shall be no damage to handles or the handle mounting/securement means of the DUT.		P
35	**Mold Stress Test**		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
35.1	The purpose of this test is to determine if an enclosure made from molded polymeric material can withstand an accelerated aging test without compromising the safety of the enclosure.	Metal enclosure	N/A
35.2	One complete fully discharged sample (discharged to the manufacturer's specified EODV) shall be placed in a full-draft circulating-air oven maintained at a uniform temperature of at least 10°C (18°F) higher than the maximum temperature of the enclosure measured during the Temperature and Operating Limits Check Test in Section 20, but not less than 70°C (158°F). The sample shall remain in the oven for 7 h.		N/A
35.3	After removal from the oven the DUT shall be subjected to an observation period per 8.5. After the observation period, the sample shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
35.4	As a result of the mold stress conditioning, the sample shall show no evidence of mechanical damage, such as cracking of the enclosure exposing hazardous parts or reducing electrical spacings or leakage of electrolyte from the enclosure.		N/A
36	**Pressure Release Test**		N/A
36.1	The purpose of this test is to ensure that the resettable pressure relief valve operates to prevent damage to the battery system and its electrolyte containment. This test is applicable to valve regulated technologies such as valve regulated lead acid batteries and for nickel systems with resettable relief valves.	No resettable pressure relief valve	N/A
36.2	A sample of the battery/cell shall be submerged in a container of mineral oil. For large batteries only the pressure relief valve needs to be submerged.		N/A
36.3	A charging current shall be caused to flow at an increased rate (to be specified by the manufacturer) until bubbles are observed to rise from the pressure relief valve.		N/A
36.4	Results are acceptable if gas is released normally and the electrolyte containment system does not rupture or leak and the DUT's casing is not ruptured.		N/A
37	**Start-To-Discharge Test**		N/A
37.1	The purpose of this test is to determine the average start to discharge pressure of a resettable pressure	No resettable pressure relief valve	N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	relief valve not provided with an ASME stamp and rating.		
37.2	A calibrated pressure gauge having a range of at least 150% of the anticipated maximum working pressure of the pressure relief valve shall be installed to indicate pressures developed within the battery system during test.		N/A
37.3	To determine the start-to-discharge pressure setting of a pressure-relief valve, each of three samples of the valve shall be subjected three times to a gradually increasing air pressure. The pressure at which the valve begins to open shall be recorded. The start-to-discharge pressure setting of each sample is considered to be the average value of the three trials.		N/A
37.4	The start-to-discharge value mentioned in 37.3 is the highest average value for the three samples tested.		N/A
37.5	The start-to-discharge pressure shall be in the range of 90 – 100% of its assigned start-to-discharge pressure setting.		N/A

ENVIRONMENTAL TESTS

38	**Thermal Cycling Test (LER Motive and VAP Applications)**		N/A
38.1	This test determines the electrical energy storage system's ability to withstand temperature fluctuations that may be anticipated during the end-use application. This test is only applicable to LER motive and VAP applications.	Not be used in LER Motive and VAP Applications	N/A
38.2	A fully charged battery system (MOSOC per 8.1) shall be placed in a test chamber and subjected to the following cycles in (a) – (e). At the conclusion of the cycling, the samples shall remain at room temperature, 25 ±5°C (77 ±9°F) for 24 h.		N/A
	a) Raising the chamber-temperature to 75 ±2°C (167 ±3.6°F) within 30 min and maintaining this temperature for 6 h.		N/A
	b) Reducing the chamber temperature to 20 ±2°C (68 ±3.6°F) within 30 min and maintaining this temperature for 2 h.		N/A
	c) Reducing the chamber temperature to minus 40 ±2°C (minus 40 ±3.6°F) within 30 min and maintaining this temperature for 6 h.		N/A
	d) Raising the chamber temperature to 20 ±2°C (68 ±3.6°F) within 30 min.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	e) Repeating the sequence for a further 9 cycles.		N/A
	Exception No. 1: Temperatures may need to be held for longer periods for those larger systems where temperature stabilization may take longer. The time required in this case for systems that require longer exposures should be based upon the time it takes for the temperature on internal cells within the DUT to reach thermal equilibrium per 8.3 plus 1 additional hour. This time shall never be less than the exposure times noted in (a) – (d) above.		N/A
	Exception No. 2: Testing may be conducted at a subassembly level if that is representative of the energy storage system.		N/A
38.3	If the DUT is operational after the test, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		N/A
38.4	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N/A
38.5	At the conclusion of the observation period, the sample is then subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
38.6	As a result of the thermal cycling test, the following in (a) – (h) are considered non-compliant results.		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L – Leakage (external to enclosure of DUT);		N/A
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
	h) P – Loss of protection controls.		N/A
	For additional information on non-complying results refer to Table 12.1.		N/A
39	**Resistance to Moisture Test**		N/A
39.1	The purpose of this test is to determine that the battery system can safely withstand exposure to moisture anticipated in the end use.	Not be used to exposure to moisture anticipated	N/A
39.2	With the DUT in its normal operating orientation, it shall be subjected to a moisture resistance test based upon its IP rating in accordance with IEC 60529 or CAN/CSA-C22.2 No. 60529. The battery system shall be installed and connected as intended		N/A

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	for this test for the end use application. For batteries located where they may be subjected to flooding conditions, the IP rating will need to minimally cover immersion.		
	If the DUT is operational after the conditioning, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications. An observation period per 8.5 is then conducted.		N/A
	Exception No. 1: Enclosures with Enclosure Type Ratings as identified in NFPA 70, Article 110, or Section 2 of C22.1, are subjected to the environmental testing outlined in UL 50E/C22.2 No. 94.2, rather than the IP Code.		N/A
	Exception No. 2: Testing may be conducted at a subassembly level if that is representative of the energy storage system.		P
39.3	During the test, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if venting of cells is anticipated. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the testing per Section 13.		N/A
39.4	At the conclusion of the observation period, the DUT shall be subjected to an "as received" dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
39.5	As a result of the resistance to moisture test, the following in (a) – (h) are considered non-compliant results.		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L – Leakage (external to enclosure of DUT);		N/A
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
	h) P – Loss of protection controls.		N/A
	For additional information on non-complying results refer to Table 12.1.		N/A
40	**Salt Fog Test**		N/A
40.1	This test determines the electrical energy storage system's ability to safely withstand anticipated exposure to a salt fog conditions due to use near marine environments, and would apply to those stationary systems installed near sea environments	Not be used near marine environments	N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	whose internal components may be exposed to deterioration from salt fog through openings in the enclosure. This test would not apply to those systems not intended to be installed near marine environments as indicated in the installation instructions or whose enclosure is designed to prevent ingress of moisture with protection against corrosion (e.g. UL/NEMA 4X).		
40.2	A fully charged electrical energy storage system (MOSOC per 8.1) shall be subjected to the test method per IEC 60068-2-52, with a severity level of 1 or 2 depending upon the application and location of installation.		N/A
	Exception: A sample at the subassembly level that would be representative of the battery system may be used for this test.		N/A
40.3	If the DUT is operational after the conditioning, it shall be subjected to a discharge and charging cycle in accordance with the manufacturer's specifications.		N/A
40.4	During the cycling, one of the detection methods outlined in Section 9 shall be used to detect the presence of combustible vapor concentrations if venting of cells is anticipated. If required based upon system design or installation, venting of toxic releases shall be continuously monitored during the cycling per Section 13. An observation period per 8.5 is then conducted.		N/A
40.5	At the conclusion of the observation period, the DUT shall be subjected to an ″as received″ dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
40.6	As a result of the salt fog test, the following in (a) – (h) are considered non-compliant results.		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L – Leakage (external to enclosure of DUT);		N/A
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
	h) P – Loss of protection controls.		N/A
	For additional information on non-complying results refer to Table 12.1.		N/A

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41	**External Fire Exposure for Projectile Hazards Test**		N/A
41.1	The purpose of this test is to determine that a battery system will not explode as evidenced by projectiles breaking through the test cage as a result of being exposed to a hydrocarbon pool/brush fire.		N/A
	Exception No. 1: The battery system may be subjected to the External Fire Exposure Test in UL/ULC 2580 instead of the method outlined in 41.3.		N/A
	Exception No. 2: Testing may be conducted on a representative subassembly rather than a complete battery system if determined that equivalent results to testing a battery system can be obtained.		N/A
	Exception No. 3: If the secondary lithium cells employed in the system comply with the projectile test of Section E9, the system is exempted from this test. This test is not applicable to systems employing lead acid or similar monobloc aqueous electrolyte batteries.		P
	Exception No. 4: This test does not apply to systems intended for outdoor use only that are mounted on a non-combustible surface such as a concrete pad that extends a minimum of 91.4 cm (3 ft) beyond the perimeter of the battery system.		N/A
41.2	This test shall be conducted in a controlled setting free from the effects of wind or other environmental factors that may affect the test. The ambient temperature during the testing is to be within the range of 0 °C to 46 °C (32 °F to 114.8 °F).		N/A
41.3	A fully charged DUT at normal operating temperature is subjected to a hydrocarbon pool fire for 20 min. The fuel used shall be heptane or similar hydrocarbon fuel.		N/A
41.4	The pan, which provides the fire containment, shall be constructed of steel of sufficient thickness to prevent warping during the course of the 20-min test. The pan shall be sized in relation to the DUT and to accommodate the fuel and water levels. The walls of the pan shall not project more than 8 cm (3.1 in) above the level of the fuel at the start of the test. The pan dimensions shall be sized to ensure that the sides of the tested-device are exposed to the flame. The pan shall exceed the horizontal projection of the DUT by 20 to 50 cm (7.9 to 19.7 in).		N/A
41.5	There should be approximately 15.24 cm (6 in) of water in the pan prior to adding the hydrocarbon fuel to protect the fuel pan and to provide for consistent flame output during the test. The fuel shall be added as needed during the test to provide sufficient fuel for the test duration. The fire shall cover the whole area of the pan during whole fire exposure.		N/A
41.6	A suitable means to extinguish the fire in the fuel pan within 15 s, or remove the battery from above the fire, shall be provided. This may be accomplished by drawing a cover over the pan, or by moving the DUT from over the pan or removing the pan as putting the		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	fire out may be difficult and should not be underestimated.		
41.7	The DUT shall be fully supported and centered above the fire containment pan above the surface of the heptane. The DUT support structure shall be robust enough to withstand the weight of the DUT for the duration of the test without allowing the DUT to lean or topple. The pan shall be sized large enough to cover the dimension of the DUT, and shall be of a sufficient height so that the bottom surface of the DUT is approximately 50 cm (19.7 in) from the top fuel surface in the pan. See Figure 41.1 for details of set up.		N/A
41.8	During the test, the temperature of the cells or modules within the DUT may be monitored for information purposes.		N/A
41.9	After the 20-min fire exposure the fire shall be extinguished, and the DUT shall be subjected to a hose down in accordance with 41.10 to represent fire fighter response the system may be exposed to during a fire. At the conclusion of the hose down, there shall be a one hour observation period in accordance with 8.5.		N/A
41.10	The battery shall be subjected to a low impact hose stream delivered through a 38 mm (1-1/2 in) fog nozzle set at a discharge angle of 30° with a nozzle pressure of 517 kPa (75 psi) and a minimum discharge of 4.7 L/s (75 gpm). The tip of the nozzle shall be a maximum of 1.5 m (5 ft) from the center of the exposed surface of the DUT. The minimum duration of the low impact hose stream test shall be 6.5 s/m2 (0.60 s/ft2). The outer surface of the DUT shall be identified as the exposed area, as the hose stream must traverse this area during its application. To prevent potential for exposure to projectiles, the technician conducting the hose down portion of the test shall do so behind a protective barrier.		N/A
41.11	To determine that an explosion hazard has resulted, the DUT with pan fire test set up shall be centered within a circular inner perimeter marked on the floor with paint or a similar marking material. The marking shall be no wider than 12 mm (0.47 in) and the size of the circular inner perimeter area marking shall be no greater than 1.0 m (3.3 ft) from the outer edge of the longest side of the DUT.		N/A
41.12	For protection from projectiles during the test, the DUT, test set up, and inner perimeter marking shall be enclosed within a protective test chamber that can contain the projectiles or within an outer perimeter consisting of a protective barrier wall of a noncombustible material such as masonry or concrete and wall thickness suitable for containing		N/A

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	projectiles during the test. The walls of the test chamber or the outer perimeter shall be located a minimum of 1.5 m (4.95 ft) from the inner perimeter marking to prevent the possibility of projectiles bouncing off the walls and back into the inner perimeter.		
41.13	As a result of this test, there shall be no explosion of the DUT that results in projectiles falling outside of the circular inner perimeter described in 41.11. See Table 12.1 for additional details.		N/A

TOLERANCE TO INTERNAL CELL FAILURE TESTS

42	**Single Cell Failure Design Tolerance**		P
42.1	**General**		P
42.1.1	There have been field incidents with various battery technologies that have been attributed to a cell failure, which led to a hazardous event. The cell failures in these incidents were the result of either manufacturing defects or insufficient cell or battery design or a combination of both. Since there is a possibility that a cell may fail within a battery system, the battery system shall be designed to prevent a single cell failure from propagating to the extent that there is fire external to the DUT or an explosion.	See UL 9540A report: 4791072766	P
42.1.2	The cell failure mechanism used for this testing shall reflect what is known or anticipated to occur in the field for a given technology. If the cell failure mechanism cannot be exactly replicated, a close simulation of what is known to occur in the field through the use of an external stress such as applied heating or mechanical force shall be utilized for the test. Examples of methods to simulate a single cell failure are outlined in Appendix F. Multiple tests and possible multiple failure methods may need to be conducted as part of the analysis before a final methodology for testing is determined.		P
42.2	**Single cell failure design tolerance (lithium ion)**		P
42.2.1	A lithium ion battery system shall be designed to mitigate a single cell failure leading to a thermal runaway of that cell. With lithium ion batteries, it is often the effects of propagation to surrounding cells due to the heating effect of the initial cell failure that leads to hazardous events. The DUT (e.g. battery pack or module) shall be designed to prevent a single cell thermal runaway failure from creating a significant hazard as evidenced by fire propagation outside of the DUT and/or an explosion.		P

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42.2.2	Any number of methods can be used to produce a single cell thermal runaway failure. For example, thermal runaway in cells can be achieved through the use of heaters, nail penetration, overcharge, etc. The testing agency is responsible for selecting and demonstrating an appropriate method for inducing thermal runaway. It is recommended to evaluate a candidate method first using a small subassembly of cells to evaluate the cell failure and effects to surrounding cells. During an effort to establish a suitable failure method, temperatures should be taken on the cell casings, and voltages measured for information purposes. See Appendix F for guidance on several methods of inducing cell failure. The method chosen shall be agreed upon by the testing agency.		P
42.2.3	The details of the method used when analyzing the cell's reaction that can impact the results are to be documented. For example, if heating the cell to achieve failure: e.g. the type of heater and its dimensions, location on the cell where the heater is placed and how it is placed, maximum temperature attained including temperature ramp rate, length of time until reaction, temperatures on cell and voltage, state of charge of the cell at the beginning of the heating phase, etc. The test article shall be representative of the actual battery configuration and any modifications should not significantly impact the test results. For example, if overcharge is to be carried out, the heat conduction path between tabs shall not be hindered as that may reduce the severity of the test.		P
42.2.4	Once a suitable method of cell failure has been determined, the fully charged DUT (MOSOC per 8.1) shall be subjected to the single cell failure tolerance test, which consists of inducing a fault in one internal cell that is within the DUT, until cell failure resulting in thermal runaway as defined in 6.58 occurs, and determining whether or not that failure produces a significant external hazard or whether or not that failure does not cause the failure of neighboring cells. If cascading occurs, the cascading shall not propagate beyond the DUT. Prior to choosing the specific cell to fail, an analysis of the DUT design to determine the cell location considered to have the greatest potential to lead to a significant external hazard shall be conducted, taking into consideration the cell's proximity to other cells and materials that may lead to potential for propagation. If it can impact the results, the sample shall be at the maximum specified temperature during charging and operation with some tolerance as necessary for movement of the sample outside of the chamber during testing, but within ±10 °C (±18 °F) for cells just before inducing		P

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	the mechanism to create thermal runaway. Once the thermal runaway is initiated, the mechanism used to create thermal runaway is shut off or stopped and the DUT is subjected to a 24-h observation period.		
	Exception No. 1: Testing may be repeated on another sample with a cell in a different location within the DUT if it is not clear which location represents the worst case scenario. The location of the failed cell shall be documented for each test.		N/A
	Exception No. 2: Testing may be conducted on a representative subassembly consisting of one or more modules and surrounding representative environment, if it can be demonstrated that there is no propagation beyond the subassembly. When testing at the module or subassembly level, consideration needs to be made of the vulnerability to combustion of those components surrounding the module in the final assembly. Temperatures on DUT external surfaces and surfaces of parts in contact with or near the DUT in the final assembly, shall be monitored to determine if excessive temperature on these adjacent parts could result in a potential for propagation within the full battery system. If there are excessive temperatures on the surfaces that may lead to potential for propagation, testing shall be repeated with all adjacent components in place of a complete battery system.		P
42.2.5	Temperatures on the failed cell and surrounding cells, external enclosure surfaces of the DUT and the supporting surface are to be monitored and reported for information purposes.		P
42.2.6	As a result of the testing of 42.2, there shall be no fire propagating from the DUT or explosion of the DUT.		P
42.3	**Single cell failure design tolerance (other technologies)**		N/A
42.3.1	Other technologies such as lithium metal, sodium sulfur, sodium nickel chloride, and lead acid where there may not be enough field data regarding their tolerance to single cell failure events, are to be subjected to a single cell failure test method similar to 42.2, except as modified as noted below. The failure mechanism for these technologies may be different than that of lithium ion and thermal runaway may or may not result from the cell failure. Similar to lithium ion, when choosing a cell failure technique, it should be representative of what can occur in the field for the particular technology. The failure mechanism chosen shall consider failures due to potential cell manufacturing defects for that technology and/or cell and battery design deficiencies that could lead to latent failures of the cell, and that would not be evident under the individual cell safety testing.		N/A
42.3.2	For other technologies, similarly as with lithium ion, it is recommended to evaluate a candidate method first using a small subassembly of cells to evaluate the cell failure and effects to surrounding cells. During an effort to establish a suitable failure method, temperatures should be taken on the cell casings, and voltages measured for information purposes. See Appendix F for guidance on several methods of		N/A

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	inducing cell failure. The method chosen shall be agreed upon by the testing agency.		
42.3.3	When a suitable worse case representative method for cell failure has been determined, the DUT is to be subjected to the internal cell failure occurring in the location within the DUT considered most vulnerable to the potential for propagation. The DUT shall be in a condition that reflects its operating parameters at the worst moment such a failure could occur. For example, the DUT shall be at its nominal operating temperature. During the test, temperatures shall be monitored in critical locations such as adjoining cells during the test to record the rise in temperature due to the internal failure. Temperatures on the external enclosure surfaces of the DUT and the supporting surface shall also be recorded for information purposes. If no thermal runaway occurs as a result of the single cell failure, the test is stopped when the DUT temperature has stabilized or reaches ambient room temperature, and the DUT is subjected to a 24-h observation period. If a thermal runaway is initiated, the mechanism used to create thermal runaway is shut off or stopped and the DUT is subjected to a 24-h observation period.		N/A
	Exception No. 1: Testing may be repeated on another sample with a cell in a different location within the DUT if it is not clear which location tested represented the worst case scenario. The location of the failed cell is to be documented for each test.		N/A
	Exception No. 2: Testing may be conducted on a representative subassembly consisting of one or more modules and surrounding representative environment, if it can be demonstrated that there is no propagation beyond the subassembly. When testing at the module or subassembly level, consideration needs to be made of the vulnerability to combustion of those components surrounding the modules in the final assembly.		N/A
42.3.4	As a result of the testing per 42.3.3, there shall be no fire propagating from the DUT or explosion of the DUT.		N/A
42.3.5	Temperatures on the failed cell and surrounding cells, external enclosure surfaces of the DUT and the supporting surface are to be monitored and reported for information purposes. The number of cells that fail due to propagation from the triggering cell shall be documented.		N/A

MANUFACTURING AND PRODUCTION LINE TESTS

43	**General**		P
43.1	Manufacturers of battery systems shall have documented production process controls in place that continually monitor the following key elements of the manufacturing process that can affect safety, and		P

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	shall include corrective/preventative action to address defects found affecting these key elements:		
	a) Supply chain control; and		P
	b) Assembly processes.		P
43.2	Battery systems shall be subjected to 100% production screening to determine that any active controls utilized for safety are functioning.		N/A
	Exception: This check of the safety controls can be conducted on subassemblies or components of the system before final assembly.		P
43.3	An "as received" dielectric voltage withstand test as outlined in the Dielectric Voltage Withstand Test, Section 22 shall be conducted on 100% production of Assemblies/packs with circuits exceeding 60 Vdc or 42.4 V peak as outlined in Section 22.		P
	Exception: The time for the test may be reduced to 1 s if the test voltage values are increase by 2.4 times the values in Section 22 or as outlined in the routine test criteria of the Electric Strength Test of UL 62368-1/CSA C22.2 No. 62368-1, Clause 5.4.9.		N/A
43.4	A continuity check of the grounding system using a milliohmmeter or other method, shall be conducted on 100% production employing protective grounding. The continuity check shall determine that measurements made on any two points of the grounding system do not exceed 0.1 Ω.		P
43.5	Each resettable non-ASME coded pressure-relief valve shall be tested by the manufacturer for the start-to-discharge pressure by subjecting the pressure-relief valve to a gradually increasing air pressure until the valve begins to open. The start-to-discharge pressure shall be in the range of 90 – 100% of its rated start-to-discharge pressure rating.		N/A

MARKINGS

44	**General**		P
	Advisory Note: *In Canada, there are two official languages. Therefore, it is necessary to have CAUTION, WARNING, and DANGER instructions and markings in both English and French. Appendix G lists acceptable French translations of the CAUTION, WARNING, and DANGER instructions and markings specified in this Standard. When a product is not intended for use in Canada, instructions and markings may be provided in English only.*		—
44.1	Required markings shall be permanent. Examples of permanent marking are ink stamping, engraving and if adhesive labels, compliance to UL 969 or CSA C22.2 No. 0.15 for the surface adhered and conditions of use. Markings required by this standard including nameplate markings per 44.2 and any cautionary markings shall be legible, provided in text		P

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	color that contrasts with the background color and visible upon installation of the battery system.		
44.2	Batteries shall be marked with the manufacturer's name, trade name, trademark or other descriptive marking which may identify the organization responsible for the product, part number or Model number, and electrical ratings in volts dc and capacity in Ampere-hours or Watt-hours and chemistry. The battery system terminals shall be marked to indicate whether they are positive (+) or negative (-). The battery shall also be marked with its IP rating.		P
44.3	Batteries and Battery systems using repurposed batteries in accordance with 7.13, shall be marked "Repurposed" or "Second Life" and "UL 1974".		N/A
44.4	Battery systems shall be marked with the maximum short circuit current and duration (at maximum short circuit current) at the system output terminals.		P
44.5	Battery systems shall also be marked with the date of manufacture, which may be in the form of a code that does not repeat within 20 years.		P
44.6	A battery system intended for use with specific chargers shall be marked with the following or equivalent: ″Use Only ( ) Charger″.		N/A
44.7	A battery system evaluated for protection against ingress of moisture per 7.3.5, shall be provided with the appropriate IP Code rating.		P
44.8	Systems shall be marked with a cautionary marking indicating to read all instructions before installation, operation and maintenance of the system. This marking may be in the form of the symbol(s) for example: ISO 7000, ″caution″ Symbol No. 434 (exclamation point inside triangle) followed by the ″read instruction manual″ Symbol No. 790 (open book). If using symbols, their meaning shall be explained in the instruction manual.		P
44.9	Systems that must be operated in a certain orientation for safe operation, shall be provided with markings indicating the correction orientation of the system.		P
44.10	Systems shall be marked with a warning marking indicating risk of electrocution near hazardous voltage battery terminals.		P
44.11	Systems with replaceable fuses, shall be marked with rating and type of fuse for replacement. The marking shall be located near the fuseholder.		N/A
44.12	Separable accessories and controls which are intended for connection to the mains supply shall be provided with markings that include the manufacturer's name, part number of the accessory		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	and electrical ratings in voltage, frequency, phase if applicable, and current or watts.		
44.13	A ground terminal shall be marked as outlined in 7.6.8.		P
44.14	Additional warning markings for battery systems located in restricted access locations such as warnings regarding hazardous moving or electrical parts, hot surfaces, etc., to alert service or other trained personnel and prevent hazards, shall be provided on the battery systems in locations where they will be visible those persons having access to the location.		N/A
44.15	With reference to 7.12.2, a secondary lithium cell shall be legibly and permanently marked with:		P
	a) The manufacturer's name, trade name, or trademark or other descriptive marking by which the organization responsible for the product may be identified;		P
	b) A distinctive catalog, model or designation number or the equivalent; and		P
	c) The date or other dating period of manufacture not exceeding any three consecutive months.		P
	Exception No. 1: The manufacturer's identification may be in a traceable code if the product is identified by the brand or trademark owned by a private labeler.		N/A
	Exception No. 2: The date of manufacture may be abbreviated; or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer, provided that the code: *a) Does not repeat in less than 10 years; and* *b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.*		N/A
44.16	With reference to 44.15, if a manufacturer produces a cell at more than one factory, each cell shall have a distinctive marking to identify it as the product of a particular factory.		N/A
44.17	Required markings for single cells and multi-cell/monobloc vented and valve regulated lead acid and nickel cadmium batteries shall be legibly and permanently marked in accordance with 44.1 with the following included:		N/A
	a) The manufacturer's name, trade name or trademark, model designation, and month and year of manufacture;		N/A
	Exception: The date of manufacture may be in the form of a code that does not repeat in 10 years.		N/A
	b) The statement "Warning: Risk of fire, explosion, or burns. Do not disassemble, heat above XX °C (or °F), or incinerate." (Where XX is the cell or battery's maximum temperature specification.)		N/A

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	Exception: This statement may be included in the instructions provided with the cell or battery, rather than be marked on the battery.		N/A
	c) Battery type (e.g. valve regulated lead-acid battery) and rated nominal voltage and capacity; and		N/A
	d) Positive and negative leads or terminals indicated by (+) and (−).		N/A

INSTRUCTIONS

45	**General**		P
45.1	Components of a battery system shall be provided with a complete set of instructions for proper installation and use in a battery system. These instructions shall include normal operating specifications.		P
45.2	Systems shall be provided with complete instructions for installation in the end use application. Installation instructions shall include the following along with any other instructions necessary for the safe and correct installation of the system and its accessories in the intended end use:		P
	a) Insulated tools, insulated gloves, personal protective equipment, and clothing and other measures necessary for safe installation of the battery system;		P
	b) The necessary housing requirements for protection against ingress of moisture and debris or access by persons;		P
	c) Ventilation requirements to prevent accumulation of hydrogen greater than 25% of hydrogen LFL;		P
	d) Protective components and devices required in the end use installation such as fuses, circuit breakers, wiring, and other devices such as disconnect devices in accordance with NFPA 70 or C22.1. See 7.9.9;		P
	e) Circuit diagrams and instructions for proper connection of the system and any ancillary devices such as separate controllers, monitoring devices, etc.;		P
	f) Warnings and instructions regarding the battery electrolyte;		P
	g) Instructions regarding any commissioning tests and checks necessary before placing system into service;		P
	h) Table or list, etc. of symbols used and their meanings;		P

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	i) The necessary information to complete an arc flash/blast analysis, including bolted fault current (IBF), 1/2 bolted fault current (1/2 IBF), protective device clearing time, and protective device current interrupt capability at a minimum, if applicable to the system; and		P
	j) If applicable, the manufacturer shall provide information on design considerations for maximum and minimum system configurations, such as number of modules installed in series, maximum resistance, and maximum inductance to prevent arc flash incident energy from exceeding the requirements of Personal Protective Equipment Category 4 per NFPA 70E or CSA Z462-15.		P
45.3	Battery systems intended for installation in a restricted access location per 6.51 shall have installation instructions indicating this with instructions defining the type of location required, its restrictions, signage and other information to be provided.		P
45.4	A system shall be provided with instructions for the proper use including charging and discharging, storage, recycling and disposal. These instructions shall include temperature limits, charging and discharging limits as well as instructions regarding the use of any controls or monitoring systems.		P
45.5	A system shall include the following statements or equivalent:		P
	a) An attention word, such as ″DANGER,″″WARNING,″ or ″CAUTION.″		P
	b) A brief description of possible hazards.		P
	c) A list of actions to take to avoid possible hazards regarding disposal of the system such as do not crush, disassemble, dispose of in fire, or similar actions.		P
45.6	The system shall be provided with a maintenance manual that includes a schedule for maintenance of the system and accessories including a check of wiring and connections, etc. The maintenance manual shall include necessary safety precautions regarding handling or conducting maintenance on the system and its connections and accessories.		P
45.7	Cells shall be provided with a complete set of instructions that include operating region specifications for charging and discharging including current temperature range and voltages, installation instructions, storage of batteries and disposal instructions. Guidance on cell specification information that should be provided on cells can be		P

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	found in the Cell Specification Sheet, Annex E of IEEE 1625.		
45.8	The installation instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that the batteries and components of the battery systems shall be installed in accordance with Article 480 or 706 of NFPA 70 or Section 64 of CSA C22.1.		N/A
45.9	Installation instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that the charging system for these batteries shall prevent charging outside of the battery specifications through the use of voltage (and temperature for VRLA) monitoring and controls, or both current and temperature monitoring and controls. The system may also use current monitoring to prevent out of condition specifications. The instructions shall indicate that chargers shall comply with UL 1012, UL 1741, UL 60335-2-29/CSA C22.2 No. 60335-2-29, CAN/CSA C22.2 No. 107.2, or UL 62368-1/CSA C22.2 No. 62368-1. Instructions for the battery system shall provide information on a specific charger to be used with the battery system if the charger is relied upon to maintain the battery system safety.		N/A
45.10	The instructions for vented and valve regulated lead acid and nickel cadmium batteries shall indicate that battery systems exceeding 60 Vdc shall be provided with a disconnecting means for all ungrounded conductors in accordance with Article 480 of NFPA 70 or Section 64 of CSA C22.1.		N/A
45.11	Installation instructions for single cells and multi-cell/monobloc vented and valve regulated lead acid and nickel cadmium batteries shall be provided with instructions indicating that service disconnects shall be provided as applicable to the end product battery system in accordance with Article 480 of NFPA 70 or Section 64 of CSA C22.1.		N/A
45.12	Installation instructions for vented and valve regulated lead acid and nickel cadmium multibattery/ cell systems shall include the short circuit current output from the battery system rather than the marking of 44.4.		N/A
45.13	Vented lead acid or nickel cadmium cell and battery installation instructions shall indicate the need for spill control in accordance with the building, fire and installation codes.		N/A
45.14	The instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall indicate that ventilation to address any hydrogen off		N/A

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	gassing shall be in accordance with the local fire and installation codes.		
45.15	The instructions for open rack vented and valve regulated lead acid and nickel cadmium battery systems shall indicate that these racks shall be installed in restricted access locations or be installed within a protective enclosure that prevents access in accordance with the end use application.		N/A
45.16	Instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall indicate recommended wiring for battery connections, the minimum clearance between cells and batteries on the racks and any type of protection device.		N/A
45.17	Instructions for vented and valve regulated lead acid and nickel cadmium cells and batteries shall include maintenance instructions for maintaining the cells and batteries in safe operating condition through the life of the cell and battery including electrolyte maintenance if applicable, examination of terminals and casings for damage, etc.		N/A
45.18	If lead acid and nickel cadmium cells and batteries are intended for installation in an end use that utilizes protective grounding, the installation instructions shall recommend that the grounding and bonding system be checked after the completion of the assembly to ensure that the resistance is less than or equal to 0.1 Ω.		N/A
45.19	The instructions provided with lead acid and nickel cadmium cells and batteries shall indicate the maximum voltage of the end use system they can be installed in. If the voltage in the end use is exceeded, then the instructions shall recommend a repeat of the dielectric voltage withstand test of the assembly for the higher voltage.		N/A

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APPENDIXES

A	**APPENDIX A** (normative)		P
A1	**Standards for components**		P
A1.1	The CSA Group and UL standards listed below are used for evaluation of components and features of products covered by this standard. Components shall comply with all the applicable CSA Group and UL component standards. These standards shall be considered to refer to the latest edition and all revisions published to that edition.		P

B	**APPENDIX B – Test program for sodium-beta battery cells** (normative)		N/A
B1	**General**		N/A
B1.1	Battery systems that employ sodium-beta cells and batteries shall comply with the applicable construction and test requirements outlined in this standard. They shall additionally be subjected to the requirements of this Appendix.		N/A
B1.2	Table B.1outlines the tests and sample number of cells for the tests of this Appendix. Refer to Table 8.1 for the sample numbers of batteries used in battery tests.		N/A
B2	**Cell Tests**		N/A
B2.1	**Electrical**		N/A
B2.1.1	**Cell short circuit**		N/A
B2.1.1.1	Two as received fully charged cells and two fully charged cells previously subjected to charge/discharge cycling outlined in B2.1.1.2 shall comply with the short circuit test of B2.1.1.3.		N/A
B2.1.1.2	The cycled cells shall be cycled continuously in accordance with the manufacturer's specifications. The specifications shall be such that the full capacity of the cell is utilized and the number of cycles accumulated shall be at least equal to 25% of the advertised cycle life of the cell or cycled continuously for 90 days, whichever is shorter. Cycling shall be done either individually or in groups. The cell is then recharged prior to testing.		N/A
B2.1.1.3	Each test sample shall be short-circuited by connecting the positive and negative terminals to a resistance load of less than or equal to 20 mΩ. The testing is conducted at room ambient 25 ±5°C (77 ±9°F) with the cell heated to its normal operating temperature. Testing is continued until the cell is fully discharged and the temperature returns to operating		N/A

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	ambient. The test is repeated with the short circuit condition applied first and then the cell heated to its normal operating temperature.		
B2.1.1.4	As a result of the short circuit, the cell shall not explode or catch fire.		N/A
B2.1.2	**Cell abnormal charging**		N/A
B2.1.2.1	Two as received fully charged cells and two fully charged cells previously subjected to charge/discharge cycling outlined in B2.1.1.2 shall comply with the abnormal charging test of B2.1.2.2 – B2.1.2.4.		N/A
B2.1.2.2	Cells shall be discharged to the manufacturer's specified end of discharge conditions. Each test sample, at its specified operating temperature, shall be subjected to a constant current charging at the specified maximum charging current Ic until the maximum (abnormal) charging voltage as specified by the manufacturer is reached. Then the charging is continued using constant voltage charging at the maximum (abnormal) charging voltage for 7 h.		N/A
B2.1.2.3	When an overcurrent device operates during the test, the test is repeated on samples with a charging inputs below the trip point of the protective device.		N/A
B2.1.2.4	As a result of the abnormal charging, there shall be no fire or explosion.		N/A
B2.2	**Mechanical**		N/A
B2.2.1	**Cell shock test**		N/A
B2.2.1.1	A fresh sample of cell or fully charged small battery module (per MOSOC of 8.1) shall comply with the shock test as outlined below.		N/A
B2.2.1.2	The sample shall be secured to the testing machine by means of a rigid mount, which supports all mounting surfaces of the sample. Each sample shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular directions for a total of 18 shocks unless the sample has only two axes of symmetry, in which case only two directions are tested for a total of 9. The parameters of the shock applied are as noted in the Table B.2 below. The shocks shall be applied with the sample at room temperature of 25 ±5°C (77 ±9°F). At the conclusion of the shock testing the sample is operated (i.e. charged/discharged) at its normal operating temperature for 1 cycle to determine if is has been made hazardous as a result of the shock conditioning.		N/A
B2.2.1.3	The samples shall not explode or catch fire. The maximum mass percent loss of the cell shall be		N/A

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	0.1%. For sodium sulfur type cells, the cell casing temperature shall be equal or less than that of a fresh cell when cycled.		
B2.2.2	**Cell vibration**		N/A
B2.2.2.1	One fresh sample of the cell shall be subjected to simple harmonic motion with an amplitude of 0.8 mm (1.6 mm total maximum excursion).		N/A
B2.2.2.2	The frequency shall be varied at a rate of 1 Hz/min between 10 and 55 Hz, and return in not less than 90 min or more than 100 min. The cell is tested in three mutually perpendicular directions unless it has only two axes of symmetry, in which case it is only to be tested perpendicular to each axis. The vibration conditioning shall be at an ambient of 25 ±5°C (68 ±9°F). At the conclusion of the testing, the cell shall be operated (i.e. charged/discharged) for 1 cycle at it normal operating temperature to determine if it is hazardous after being subjected to the vibration conditioning.		N/A
B2.2.2.3	The cells shall not explode or catch fire. The maximum mass percent loss of the cell shall be 0.1%. For sodium sulfur type cells, the cell casing temperature shall be equal or less than that of a fresh cell when cycled.		N/A
B2.3	**Environmental**		N/A
B2.3.1	**Cell heating**		N/A
B2.3.1.1	Two fresh cells and two cells previously subjected to the charge discharge cycling of B2.1.1.2 were subjected to the cell heating test of B2.3.1.2.		N/A
B2.3.1.2	The cells shall be placed in an air circulating oven or gravity convection oven. The temperature shall be raised from an ambient of 25 ±5°C (68 ±9°F) at a rate of 5 ±2°C/min (7.5 ±3.6°F/min) to a temperature of 25 ±2°C (77 ±3.6°F) above the maximum operating temperature of the cell and held for 30 min. The test is then discontinued.		N/A
B2.3.1.3	As a result of the heating, there shall be no fire or explosion.		N/A
B2.3.2	**Cell temperature cycling**		N/A
B2.3.2.1	One fresh cell shall be subject to the temperature cycling test of B2.3.2.2.		N/A
B2.3.2.2	The sample shall be placed in a test chamber and subjected to the following cycles:		N/A
	a) Raising the chamber temperature to 85 ±2°C (185 ±3.6°F) within 30 min and maintaining this temperature for 4 h.		N/A

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	b) Reducing the chamber temperature to 20 ±2°C (68 ±3.6°F) within 30 min and maintaining this temperature for 2 h.		N/A
	c) Reducing the chamber temperature to minus 40 ±2°C (minus 40 ±3.6°F) within 30 min and maintaining this temperature for 4 h.		N/A
	d) Raising the chamber temperature to 20 ±2°C (68 ±3.6°F) within 30 min.		N/A
	e) Repeating the sequence for 9 additional cycles for a total of 10 cycles.		N/A
B2.3.2.3	After the tenth cycle the cell shall be operated (i.e. charged/discharged) for one cycle at its normal operating temperature.		N/A
B2.3.2.4	The cell shall not explode or catch fire. The maximum percent mass loss of the cell shall be 0.1%. For sodium sulfur type cells, the cell casing temperature shall be equal or less than that of a fresh cell when cycled.		N/A

C	**APPENDIX C – Test Program for flowing electrolyte batteries** (normative)		N/A
C1	**General**		N/A
C1.1	Battery systems consisting of flowing electrolyte batteries shall comply with the applicable construction and test requirements of this standard. They shall additionally be subjected to the requirements outlined in this Appendix.		N/A
	Exception: The Overdischarge Protection Test, Imbalanced Charging Test, and Drop Impact Test are not conducted on flowing electrolyte systems.		N/A
C1.2	The sample criteria for the cell stack tests is outlined in Table C1.1.		N/A
C2	**Materials Containing Electrolyte – Resistance to Deterioration from Fluids**		N/A
C2.1	Parts containing electrolyte shall be resistant to deteriorations from the fluids they contain. Compliance is determined by the testing outlined in C2.2 and C2.3. As a result of the testing, the tensile strength of tested materials shall not be less than 80% of the tensile strength of the material in the as received condition.		N/A
C2.2	Three as-received samples of materials conditioned as described in C2.3 shall be tested in accordance with ASTM D638. Prior to tensile strength testing, the samples shall be conditioned at a standard lab		N/A

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	temperature of 23 °C (73.4 °F), 50 % humidity for 40 h. The tensile strength of the materials under test shall be recorded.		
C2.3	Nine samples shall be immersed in the test liquid representative of the electrolyte contained. Three samples shall be conditioned for 7 days, three for 30 days and three for 60 days at a temperature of 50 °C (122 °F) in a full-draft air-circulating explosion-proof oven. Following the exposure tests the samples shall be removed from the oven and from the test liquid then conditioned at a standard lab temperature of 23 °C (73.4 °F), 50 % humidity for 40 h prior to tensile testing. Samples are evaluated from each of the exposure times for tensile strength and compared with as-received samples. The 60 day exposure test may be waived depending upon the results of samples subjected to the 30 day exposure.		N/A
C2.4	Gaskets and seals which contain the electrolyte shall be subjected to the volume change and extraction, tensile strength and elongation after 70 h immersion in the electrolyte at a temperature of 50 °C (122 °F) in accordance with UL 157. Prior to mechanical testing, the samples shall be cooled by use of a container of the electrolyte at 23 °C (73.4 °F) for 30 min. The tensile strength and elongation shall be a minimum of 60 % of the as received values and the volume change of minus 1 to +25 % of the as received values and extraction (change in weight) no greater than 10 %.		N/A
C3	**Materials Containing Electrolyte – Temperature Exposure**		N/A
C3.1	Parts containing electrolyte shall be suitable for intended temperature use. Compliance is determined by the testing of C3.2 and C3.3. As a result of the oven aging, the part shall not show signs of deterioration such as cracking or embrittlement. The tensile strength of the conditioned part shall not be less than 80% of the tensile strength of the as received part.		N/A
C3.2	Three as-received samples of materials conditioned as described in C3.3 shall be tested in accordance with ASTM D638. Prior to tensile strength testing, the samples shall be conditioned at a standard lab temperature of 23 °C (73.4 °F), 50 % humidity for 40 h. The tensile strength of the materials under test shall be recorded.		N/A
C3.3	Six samples of materials shall be conditioned in a full-draft air-circulating oven, three for 45 days and three for 90 days at a temperature of 70 °C (158 °F). Following the oven conditioning the samples shall be		N/A

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	removed from the oven and then conditioned at a standard lab temperature of 23 °C (73.4 °F), 50 % humidity for 40 h prior to tensile testing. The samples are evaluated from each of the conditioning times for tensile strength and compared with as-received samples.		
	Exception No. 1: As an alternative test method, the part shall be conditioned for 30 and 60 days at a temperature of 80 °C (176 °F) in a full-draft air-circulating oven.		N/A
	Exception No. 2: As an alternative test method, the parts shall be conditioned for 15 and 30 days at a temperature of 90 °C (194 °F) in a full-draft air-circulating oven.		N/A
C3.4	Gaskets and seals which contain the electrolyte shall be subjected to the air oven aging test of UL 157. The test temperature shall be in accordance with Table 4.3 of UL 157 and based upon the anticipated exposure temperatures in the end use application. Following oven conditioning, the samples shall be conditioned at a standard lab temperature of 23 °C (73.4 °F), 50 % humidity for 16 h prior to tensile and elongation testing. The tensile strength and elongation after oven aging shall be a minimum of 60 % of the as received values.		N/A
C3.5	Gasket and seals used in electrolyte containment systems shall be subjected to the lower temperature test of UL 157 for minus 40 °C (minus 40 °F), or the lowest ambient temperature specified by the manufacturer, but not higher than 0 °C (32 °F), with no visible evidence of cracking in accordance with the test criteria of UL 157.		N/A
C4	**Flowing Electrolyte Cell Stack Tests**		N/A
C4.1	**Vibration of cell stack**		N/A
C4.1.1	One sample of a flowing electrolyte cell stack shall be subjected to vibration in accordance with C4.1.2 and C4.1.3. As a result of the vibration conditioning, the cell stack shall not be damaged to the extent that results in leaks. See Table C1.1.		N/A
C4.1.2	The DUT shall mounted to a vibration text fixture and subjected to a simple harmonic motion with an amplitude of 0.76 mm, and a total maximum excursion of 1.52 mm. The frequency is varied at the rate of 1 Hz/min between the limits of 10 Hz and 55 Hz. The entire range of frequencies (10 Hz to 55 Hz) and return (55 Hz to 10 Hz), is traversed in 90 ±5 min for each mounting position (direction of vibration). The vibration is applied in each of three mutually perpendicular directions.		N/A
	Exception: Another method of vibration representative of the transport conditions of the cell stack such as ISO 13355, or IEC 60068-2-64, etc. may be used if determined to be more suitable for the size and design of the stack.		N/A

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C4.1.3	At the conclusion of the vibration conditioning, the DUT shall be checked for leaks by subjecting it to the leakage test C5.2		N/A
C4.2	**Shock test on cell stack**		N/A
C4.2.1	One sample of a flowing electrolyte cell stack shall be subjected to the shock test in accordance with C4.2.2 and C4.2.3. As a result of the shock conditioning, the cell stack shall not be damaged to the extent that results in leaks. See Table C1.1.		N/A
C4.2.2	The DUT shall be secured to a test machine by means of a rigid mounts supporting all surfaces of the cell stack. Each DUT shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular directions. For each shock the DUT shall be accelerated in such a manner that during the initial 3 ms, the minimum average acceleration is 75 g (where g is the local acceleration due to gravity). The peak acceleration shall be between 125 and 175 g.		N/A
	Exception: Where it is not practical to conduct a shock test on the DUT due to its size or configuration, it may be subjected to a drop impact test in accordance with Section 31 instead.		N/A
C4.2.3	At the conclusion of the shock conditioning or impact test, the DUT shall be checked for leaks by subjecting it to the leakage test C5.2.		N/A
C4.3	**High temperature test on cell stack**		N/A
C4.3.1	One sample of the flowing electrolyte cell stack shall be subjected to the high temperature test in accordance with C4.3.2 and C4.3.3. As a result of the high temperature conditioning, the cell stack shall not be damaged to the extent that results in leaks. See Table C1.1.		N/A
C4.3.2	The DUT shall be conditioned for 7 h in an air circulating temperature chamber at a temperature of 10 ±2°C (50 ±3.6°F) plus the maximum temperature rating of the cell stack or 70 ±2°C (158 ±3.6°F), whichever is greater.		N/A
C4.3.3	At the conclusion of the high temperature conditioning, the DUT shall be allowed to cool to room ambient and then it shall be checked for leaks by subjecting it to the leakage test of C5.2.		N/A
C4.4	**Short circuit test on cell stack**		N/A
C4.4.1	A cell stack shall be subjected to a short circuit test to a total external resistance of less than or equal to 20 mΩ until the cell stack is completely discharged, or the operation of an integral protective device or other results. See Table C1.1.		N/A
C4.4.2	As a result of the short circuit test, there shall be no fire or explosion.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
C5	**Flowing Electrolyte Battery System Tests**		N/A
C5.1	**Hydraulic pressure test**		N/A
C5.1.1	Electrolyte containment vessels where there is the potential for gas pressure build up having a pressure-times-volume value greater than 200 kPa-L (7.67 psi-gal), and pressure greater than 50 kPa (7.25 psi), shall be subjected to a hydraulic pressure test as described in C5.1.2. As a result of the test, the vessel shall not burst, leak, rupture, fracture, or permanently (plastic) deform.		N/A
	Exception No. 1: Where unmarked pressure vessels are not able to be hydraulically tested, compliance shall be verified by other applicable tests, such as an air pneumatic test at the same test pressure as for the hydraulic test.		N/A
	Exception No. 2: Piping systems under the scope of ASME B31.3, shall be subjected to ultimate strength and leakage testing in accordance with that code.		N/A
C5.1.2	The test pressure shall be the maximum pressure specified by the manufacturer multiplied by five or 1.5 times the operating pressure of a pressure relief device, whichever is greater. A pressure-relief device which is used to limit the maximum pressure shall be inactive during the test. The pressure shall be raised gradually to the specified test value and held at that value for 1 min.		N/A
C5.2	**Leakage test**		N/A
C5.2.1	Leakage from fluid-containing parts shall not result in the risk of fire, electric shock, or injury to persons. As a result of the leakage test, the following in (a) – (h) are considered non-compliant results:		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L – Leakage (external to enclosure of DUT);		N/A
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
	h) P – Loss of protection controls.		N/A
C5.2.2	Compliance is determined by subjecting the parts to a fluid pressure of 1.5 times the maximum pressure (if testing with liquid) or 1.1 times the maximum pressure (if air pneumatic testing) of intended use during operation of the system. There shall be no leaks as a result.		N/A
C5.3	**Electrolyte blockage tests**		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
C5.3.1	**Pump failure/blockage during charging**		N/A
C5.3.1.1	A pump failure or potential electrolyte blockage from another cause during charging may lead to an overcharge condition in a flowing electrolyte battery system.		N/A
C5.3.1.2	The Overcharge test of Section 15 shall additionally consider, for flowing electrolyte type battery systems, an overcharge condition that can result from an electrolyte pump failure or other cause leading to electrolyte line blockage.		N/A
C5.3.2	**Pump failure/blockage during discharging**		N/A
C5.3.2.1	A pump failure or potential electrolyte blockage from another cause during discharge may lead to an overdischarge condition in an flowing electrolyte battery system.		N/A
C5.3.2.2	A test shall be conducted to evaluate any hazards resulting from an electrolyte pump failure or electrolyte blockage during a maximum constant current discharge.		N/A
C5.3.2.3	As a result of the pump failure/blockage during discharging test, the following in (a) – (h) are considered non-compliant results.		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L – Leakage (external to enclosure of DUT);		N/A
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
	h) P – Loss of protection controls.		N/A
	For additional information on non-complying results refer to Table 12.1.		N/A
C5.4	**Short circuit test**		N/A
C5.4.1	When conducting the short circuit test of Section 17 on the system, the electrolyte flow rate shall be maintained at a constant rate during the test, until the protection operates, the system is discharged or other ultimate results occur to end the test.		N/A
C5.5	**Insulation resistance**		N/A
C5.5.1	Systems shall have sufficient insulation resistance to prevent hazards associated with energized electrolyte fluids traveling through the system.		N/A
C5.5.2	The resistance of insulation used on hazardous voltage circuits within the flowing electrolyte battery		N/A

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	shall be greater than or equal to 1 MΩ when conducting the test of C5.5.3.		
C5.5.3	The insulation resistance shall be measured using high impedance measuring equipment (e.g. mega ohmmeter) after applying a voltage of 500 Vdc between the live parts of the circuit under test and accessible conducting parts including the equipment grounding circuit, for 1 min.		N/A
	Exception: The insulation resistance test of IEC 60364-6, Low voltage electrical installations – Part 6: Verification, can be conducted instead. Compliance criteria is in accordance with the IEC 60364-6 when using this method.		N/A
C5.6	**Failure of the cooling/thermal stability system test**		N/A
C5.6.1	When conducting the failure of the cooling/thermal stability system test of Section 24, the battery system shall be tested at ambient temperature rather than tested in a test chamber.		N/A
C6	**Spill Containment Systems**		N/A
C6.1	If spill containment systems such as containment vessels and/or absorption pillows are used for containment, absorption or neutralization of electrolyte spills from a flowing electrolyte battery, the materials and parts of the system shall be subjected to the applicable tests of UL 2436.		N/A
	Exception: Tests involving exposure to or use of electrolyte other than sulfuric acid shall be modified from those of UL 2436 based upon the electrolyte, utilized in the flowing electrolyte system under test.		N/A

D	**APPENDIX D – Metal compatibility table** (normative)		P
D1	**General**		P
D1.1	For combinations that fall above the line in Table D.1, an evaluation on the parts can be conducted to determine suitability. Protection methods such as coatings can be used, but will need to be evaluated.		P
D1.2	The evaluation method shall consist of a comparison of the part to evaluate with a similar part using construction that is below the line of Table D.1, after corrosion conditioning such as a salt fog conditioning in accordance with ASTM B117, ISO 9227 or similar method. Measurements of the properties of the connection parts (design under consideration as well as comparison design) under test shall be made before and after conditioning with a comparison of the results. Properties to measure will depend upon the part being evaluated, but could include		P

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	resistance, temperatures on the part during operation, or bond/mechanical strength as applicable to the type of connection.		
D1.3	The deterioration of the devices under evaluation shall not result in unacceptable properties (i.e. reduced performance that would result in malfunction of the connection) nor shall the deterioration be greater than that of the comparison design.		P
D1.4	As another approach, a coating with known properties, such as one evaluated to UL 546, along with sealing the area to prevent moisture exposure can be used to establish acceptable protection against galvanic corrosion without additional evaluation.		P

E	**APPENDIX E – Cell Test Program** (normative)		N/A
E1	**General**		N/A
E1.1	The following shall be used to evaluate lithium ion cells or other secondary lithium cells.		N/A
E1.2	Samples used for testing shall be representative of production. The number of samples used for each test and the pass/fail criteria for testing is outlined in Table E.1. As an alternate, the lithium ion cell test program outlined in Sections E10 – E11 may be used.		N/A
E1.3	Prior to conditioning in E1.4, two samples from the total set of samples as representative samples shall be subjected to the capacity check per E2.2 to confirm the capacity of the samples is correct.		N/A
E1.4	Prior to testing, the samples shall be conditioned by first discharging them down to the manufacturer's specified end point voltage and then charging them to the manufacturer's specified upper limit charging voltage using the manufacturer's specified maximum charging current. Samples shall be charged at the upper temperature limit of the charging operating region and the lower limit of the charging operating region for those tests as identified in Table E.1. During charging, a minimum of one temperature is measured on the surface of the cell centered on the cell. For prismatic cells, this would be on the largest flat surface.		N/A
E1.5	Some lithium cells are capable of exploding when the tests described in this Annex are conducted. It is important that personnel be protected from the flying fragments, explosive force, sudden release of heat, and noise that results from such explosions. The test		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	area shall be well ventilated to protect personnel from possible harmful fumes or gases.		
E1.6	As an additional precaution, the temperatures on the surface of the cell casings shall be monitored in accordance with E1.7 during the tests described in this Annex. All personnel involved in the testing of lithium cells shall be instructed never to approach a lithium cell while the surface temperature exceeds 90 °C (194 °F) and not to touch the lithium cell while the surface temperature exceeds 45 °C (113 °F).		N/A
E1.7	In accordance with E1.6, the surface temperatures of the cell casing shall be measured as follows:		N/A
	a) By thermocouples consisting of wires not larger than 0.21 mm2 (24 AWG) and not smaller than 0.05 mm2 (30 AWG) and a potentiometer-type instrument; and		N/A
	b) The temperature measurements on the cells shall be made with the measuring junction of the thermocouple held tightly against the metal casing of the cell.		N/A
	Exception: Placing the thermocouple on a thin piece of paper or label is an acceptable practice.		N/A
E1.8	For protection, the Projectile Test in E9 shall be conducted in a room separate from the observer or within an appropriate containment chamber.		N/A
E2	**Preconditioning and Capacity Check**		N/A
E2.1	**Preconditioning**		N/A
E2.1.1	The charge/discharge cycling preconditioning in E2.1.2 shall be done before testing and conducted on secondary lithium metal (i.e. lithium metal anode) cells. Lithium ion cells need not be subjected to charge/discharge cycle preconditioning.		N/A
E2.1.2	Secondary lithium metal (i.e. lithium metal anode) cells shall be conditioned at 25 °C ±5 °C (77 °F ±9 °F). The cells shall be continuously cycled as specified by the manufacturer. The specification shall be such that the full rated capacity of the cell is utilized and the number of cycles accumulated shall be at least equal to 25 % of the advertised cycle life of the cell or cycled continuously for 90 days, whichever is shorter. Cycling shall be done either individually or in groups. Cells shall be recharged prior to testing.		N/A
E2.2	**Capacity check**		N/A
E2.2.1	Prior to conducting testing, the capacity of the lithium ion and lithium metal cells to be tested shall be		N/A

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	checked in accordance with E2.2.2 – E2.2.5 by selecting two samples from the total set of samples.		
E2.2.2	For secondary lithium metal (i.e. lithium metal anode) cells, this capacity check shall be conducted on preconditioned secondary lithium metal cells per E2.1.		N/A
	Exception : For secondary lithium metal cells subjected to preconditioning per E2.1, the capacity check may be conducted during the preconditioning of these secondary lithium metal cells by checking the discharged capacity during the first few cycles. This capacity confirmation may be done in the manufacturer shipping inspection by checking the capacity discharge curve shipped with the samples.		N/A
E2.2.3	The cell shall be discharged at 25 °C ±5 °C (77 °F ±9 °F) at a constant current of 0.2C rate, down to a specified end of discharge voltage. The cell shall then be charged in a room ambient temperature, 25 °C ±5 °C (77 °F ±9 °F), at charging parameters specified by the manufacturer until fully charged. The cell shall then be allowed to stabilize at room ambient per 6.52.		N/A
E2.2.4	With the cell in the fully charged condition, the cell shall be discharged at a constant current discharge in accordance with the cell manufacturer's specifications down to the end of discharge voltage. The duration of the discharge shall be monitored and the measured capacity of the cell shall be calculated to three significant figures.		N/A
E2.2.5	For cells to be used for the test program outlined in this Annex, their measured capacity shall equal or exceed the rated specifications. All samples shall be subjected to the capacity check test if any representative sample does not meet this criteria. The cells not meeting this criteria shall be excluded from testing.		N/A
E3	**Short Circuit**		N/A
E3.1	Fully charged, conditioned cells are stored in an ambient temperature of 25°C ±5°C (77°C ±9°F) until their casing reaches ambient temperature, and then subjected to a short circuit condition using an external resistance of ≤ 20 mΩ.		N/A
E3.2	The external resistance shall be applied to the cell terminals for 7 h or until temperatures on the cell cool to within ±10°C (18°F) of ambient conditions.		N/A
E3.3	The sample and compliance criteria shall be in accordance with Table E.1.		N/A
E4	**Cell Impact**		N/A
E4.1	Fully charged, conditioned cells shall be subjected to an impact test as outlined in E11.4. The cells shall be		N/A

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	at an ambient temperature of 25 °C ±5 °C (77 °F ±9 °F) prior to testing.		
E4.2	The sample and compliance criteria shall be in accordance with Table E.1.		N/A
E5	**Drop Impact**		N/A
E5.1	Fully charged cells shall be dropped three times from a height of 1 m (3.3 ft) onto a flat concrete or metal surface. The cells shall be at an ambient temperature of 25°C ±5°C (77°C ±9°F) prior to testing.		N/A
E5.2	The cells shall be dropped in a manner that the impacts occur in random orientations.		N/A
E5.3	After completion of the impacts, the cells shall be subjected to a minimum one hour observation period before being examined.		N/A
E5.4	The sample and compliance criteria shall be in accordance with Table E.1.		N/A
E6	**Heating**		N/A
E6.1	Fully charged, conditioned cells shall be subjected to a heating test as outlined in E11.7.		N/A
E6.2	The sample and compliance criteria shall be in accordance with Table E.1.		N/A
E7	**Overcharge**		N/A
E7.1	Fully charged conditioned cells shall be discharged in accordance to manufacturer's specifications down to the specified end point voltage. The test is conducted in an ambient of 25°C ±5°C (77°C ±9°F) and with the cell casing at an ambient of 25°C ±5°C (77°C ±9°F) at the start of the test. The voltage and temperature of the cell shall be monitored during the test.		N/A
E7.2	The cells are charged with a constant current at the maximum specified charge current until the voltage of the cell reaches 120% of the maximum specified charge voltage value or 130% State of Charge (SOC), whichever is reached first. The charge is then terminated while the cell temperature continues to be monitored. The test is concluded when the cell temperature drops and returns to ±10°C (18°F) of the test ambient.		N/A
E7.3	The sample and compliance criteria shall be in accordance with Table E.1.		N/A
E8	**Forced Discharge**		N/A

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E8.1	Fully charged cells shall be discharged in accordance to manufacturer's specifications down to the specified end point voltage. The test is conducted in an ambient of 25°C ±5°C (77°C ±9°F).		N/A
E8.2	The discharged cells are subjected to a forced discharge at a constant current 1.0 It A for 90 min with the discharge voltage limit not to exceed the numerical value of the upper limit charging voltage specified for the cell. If the discharge voltage limit is reached before the 90 min, the cell shall be discharged at a constant voltage discharge equal to the manufacturer's determined low voltage cutoff, with the current decreasing as necessary until the 90 min time period is reached.		N/A
E8.3	The sample and compliance criteria shall be in accordance with Table E.1.		N/A
E9	**Projectile**		N/A
E9.1	Two fully charged cells shall be subjected to the projectile test criteria as outlined in E11.10.		N/A
E9.2	As a result of the projectile test, the cells there shall not be an explosion of the cells resulting in projectiles with sufficient force to penetrate the test cage screen.		N/A
ALTERNATIVE TEST PROGRAM FOR SECONDARY LITHIUM CELLS			
E10	**General**		N/A
E10.1	This cell test program may be used to evaluate secondary lithium cells for use in battery systems that comply with this standard instead of the test program outlined in Sections E1 – E9. Samples used for testing shall be representative of production. The number of samples used for each test and the pass/fail criteria for testing shall be as outlined in Table E.2.		N/A
E10.2	Some lithium cells are capable of exploding when the tests described below are conducted. It is important that personnel be protected from the flying fragments, explosive force, sudden release of heat, and noise that results from such explosions. The test area shall be well ventilated to protect personnel from possible harmful fumes or gases.		N/A
E10.3	As an additional precaution, the temperatures on the surface of the cell casings shall be monitored in accordance with E10.4 during the tests described below. All personnel involved in the testing of lithium cells shall be instructed never to approach a lithium cell while the surface temperature exceeds 90 °C		N/A

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	(194 °F) and not to touch the lithium cell while the surface temperature exceeds 45 °C (113 °F).		
E10.4	In accordance with E10.3, the surface temperatures of the cell casing shall be measured as follows:		N/A
	a) By thermocouples consisting of wires not larger than 0.21 mm2 (24 AWG) and not smaller than 0.05 mm2 (30 AWG) and a potentiometer-type instrument; and		N/A
	b) With the measuring junction of the thermocouple held tightly against the metal casing of the cell.		N/A
	Exception: Placing the thermocouple on a thin piece of paper or label is an acceptable practice.		N/A
E10.5	For protection, the Projectile Test in E11.10 shall be conducted in a room separate from the observer or within an appropriate containment chamber.		N/A
E10.6	Secondary lithium metal (i.e. lithium metal anode) cells shall be conditioned in accordance with E2.1 prior to the testing.		N/A
E10.7	The capacity of the samples for all lithium chemistries shall be confirmed in accordance with E2.2 prior to testing.		N/A
E11	**Tests**		N/A
E11.1	**Short-circuit test**		N/A
E11.1.1	Each test cell shall be short-circuited by connecting the positive and negative terminals with a resistance load of less than or equal to 20 mΩ. The temperature of the cell case shall be recorded during the test. The short circuit shall be applied until the cell case temperature has returned to ±10 °C (±18 °F) of ambient temperature.		N/A
E11.1.2	Tests shall be conducted at 55 ±5 °C (131 ±9 °F). The samples shall reach equilibrium at 55 ±5 °C (131 ±9 °F), as applicable, before the terminals are connected.		N/A
E11.3	The sample and compliance criteria shall be as noted in Table E.2.		N/A
E11.2	**Overcharge test**		N/A
E11.2.1	The cell shall be subjected to the overcharge test as outlined in E11.2.2.		N/A
E11.2.2	A cell shall be subjected to a constant current charge at the maximum specified charging current until the cell reaches 120 % of its maximum specified charge voltage limit or it reaches 130 % SOC, whichever comes first.		N/A

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E11.2.3	The sample and compliance criteria shall be in accordance with Table E.2.		N/A
E11.3	**Crush test**		N/A
E11.3.1	A cell shall be subjected to a bar crush using a bar with a 15-cm (5.9-in) diameter. The force for the crushing shall be applied by a hydraulic ram or similar force mechanism. The force shall be applied until one of the following in (a) – (c) occurs. Once the maximum force has been obtained, the force shall be released.		N/A
	a) A voltage (OCV) drop of one-third of the original cell voltage occurs;		N/A
	b) A deformation of 15 % or more (in the direction of the crush) of initial cell dimension occurs; or		N/A
	c) A force of 1000 times the weight of cell is reached.		N/A
E11.3.2	A cylindrical, pouch or prismatic cell shall be crushed with its longitudinal axis parallel to the crushing apparatus. Each sample shall be subjected to a crushing force in only one direction and the crush shall be conducted only on the wide side of a pouch or prismatic cell. Separate samples shall be used for each test. See also, E11.3.3 and E11.3.4.		N/A
E11.3.3	With reference to E11.3.2, for other than pouch cells, the crush shall be applied in the center of the cells.		N/A
E11.3.4	With reference to E11.3.2, for pouch type cells, the crushing force shall be applied on the casing near where the cell tabs exit. If the positive and negative tabs are on opposite sides, the crush force shall be applied on the casing near where the negative tab exits.		N/A
E11.3.5	sample and compliance criteria shall be in accordance with Table E.2.		N/A
E11.4	**Impact test**		N/A
E11.4.1	A cell shall be placed on a flat surface. A 15.8 ±0.1-mm (5/8 ±0.004-in) diameter bar shall be placed across the center of the sample. A 9.1 ±0.46-kg (20 ±1-lb) weight shall be dropped from a height of 610 ±25 mm (24 ±1 in) onto the sample. See Figure E.1.		N/A
E11.4.2	The cell shall be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the 15.8-mm (5/8-in) diameter curved surface lying across the center of the test sample. For prismatic and pouch cells, only the wide side shall be impacted. Each sample shall be subjected to only a single impact. Separate samples shall be used for each test.		N/A
E11.4.3	The sample and compliance criteria shall be in accordance with Table E.2.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
E11.5	**Shock test**		N/A
E11.5.1	The cell shall be secured to the testing machine by means of a rigid mount which supports all mounting surfaces of the cell. Each cell shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular directions unless it has only two axes of symmetry in which case only two directions shall be tested. Each shock shall be applied in a direction normal to the face of the cell.		N/A
E11.5.2	For each shock, the cell shall be accelerated in such a manner that during the initial 3 ms the minimum average acceleration is 75 g (where g is the local acceleration due to gravity). The peak acceleration shall be between 125 and 175 g. Cells shall be tested at a temperature of 25 ±5 °C (77 ±9 °F).		N/A
E11.5.3	The sample and compliance criteria shall be in accordance with Table E.2.		N/A
E11.6	**Vibration test**		N/A
E11.6.1	A cell shall be subjected to simple harmonic motion with an amplitude of 0.8 mm (0.03 in) [1.6 mm (0.06 in) total maximum excursion].		N/A
E11.6.2	The frequency shall be varied at the rate of 1 Hz/min between 10 and 55 Hz, and return in not less than 90 nor more than 100 min. The cell shall be tested in three mutually perpendicular directions. For a cell that has only two axes of symmetry, the cell shall be tested perpendicular to each axis.		N/A
E11.6.3	At the end of the vibration conditioning, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.		N/A
E11.6.4	The sample and compliance criteria shall be in accordance with Table E.2.		N/A
E11.7	**Heating test**		N/A
E11.7.1	A cell shall be heated in a gravity convection or circulating air oven with an initial temperature of 25 ±5 °C (77 ±9 °F). The temperature of the oven shall be raised at a rate of 5 ±2 °C (9 ±3.6 °F) per minute to a temperature of 130 ±2 °C (266 ±3.6 °F) and remain for 10 min. For cells specified for temperatures above 100 °C (212 °F), the conditioning temperature shall be increased from 130 ±2 °C (266 ±3.6 °F), to 30 ±2 °C (86 ±3.6 °F) above the manufacturers maximum specified temperature.		N/A
	Exception: For cells whose weight is greater than 500 g (1.1 lbs), the maximum temperature of the heating test shall be held for 30 min rather than 10 min.		N/A

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E11.7.2	The sample shall return to room temperature, 25 ±5 °C (77 ±9 °F), and then be examined.		N/A
E11.7.3	The sample and compliance criteria shall be in accordance with Table E.2.		N/A
E11.8	**Temperature cycling test**		N/A
E11.8.1	The cells shall be placed in a test chamber and subjected to the following cycles:		N/A
	a) Raising the chamber-temperature to 85 ±2 °C (185 ±3.6 °F) or Tmax + 10 °C (Tmax is the manufacturer's maximum specified temperature) within 30 min and maintaining this temperature for 4 h;		N/A
	b) Reducing the chamber temperature to 25 ±5 °C (77 ±9 °F) within 30 min and maintaining this temperature for 2 h;		N/A
	c) Reducing the chamber temperature to minus 40 ±2 °C (minus 40 ±3.6 °F) within 30 min and maintaining this temperature for 4 h;		N/A
	d) Raising the chamber temperature to 25 ±5 °C (77 ±9 °F) within 30 min;		N/A
	e) Repeating the sequence for a further 9 cycles; and		N/A
	f) After the 10th cycle, storing the cells for a minimum of 24 h, at a temperature of 25 ±5 °C (77 ±9 °F) prior to examination.		N/A
E11.8.2	At the end of the cycling, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.		N/A
E11.8.3	The sample and compliance criteria shall be in accordance with Table E.2.		N/A
E11.9	**Low pressure (altitude simulation) test**		N/A
E11.9.1	Sample cells shall be stored for 6 h at an absolute pressure of 11.6 kPa (1.68 psi) and a temperature of 25 ±5 °C (77 ±9 °F).		N/A
E11.9.2	At the end of the conditioning, the open circuit voltage (OCV) of the cell is measured and compared with the pre-test value.		N/A
E11.9.3	The sample and compliance criteria shall be in accordance with Table E.2.		N/A
E11.10	**Projectile test**		N/A
E11.10.1	Each test sample cell shall be placed on a flat screen that covers a 102-mm (4-in) diameter hole in the center of a platform table. The flat screen cover shall be constructed of steel wire mesh having 20 openings per square 25.4 mm (1 in) area and a wire diameter of 0.43 mm (0.017 in).		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
E11.10.2	The screen shall be mounted 38 mm (1-1/2 in) above a Meker type burner. The fuel and air flow rates shall be set to provide a bright blue flame that causes the supporting screen to glow a bright red.		N/A
E11.10.3	An eight-sided covered wire cage, 610-mm (24-in) across and 305-mm (12-in) high, made from metal screening shall be placed over the test sample. See Figure E.2. The metal screening shall be constructed from 0.25-mm (0.010-in) diameter aluminum wire with 16 – 18 wires per square 25.4 mm (1 in) in each direction.		N/A
	Exception No. 1: The overall dimensions of the projectile test aluminum test screen may be increased from those outlined above to accommodate large cells intended for EV applications but the flat panels of the test screen shall not exceed a distance of 305 mm (12 in) from the cell in any direction.		N/A
	Exception No. 2: The projectile test cage may be replaced by a visible circular perimeter marking on the supporting surface located 0.5 m (19.7 in) from the longest side of the cell. The marking shall be no greater than 5-mm (0.2-in) thick. The test set-up shall be located within a protective enclosure/room with noncombustible surfaces located a distance from the test perimeter marking where any projectiles that fall beyond the test perimeter marking can be safely contained.		N/A
E11.10.3	The sample shall be heated and shall remain on the screen until it explodes or the cell has ignited and burned out. It is not required to secure the sample in place unless the sample is at risk of falling off the screen before the test is completed. When required, the sample shall be secured to the screen with a single wire tied around the sample.		N/A
E11.10.3	The sample and compliance criteria shall be in accordance with Table E.2.		N/A
E12	**Test Samples and Results Criteria**		N/A
E12.1	**General**		N/A
E12.1.1	The test samples and results criteria for the tests in this annex shall be in accordance with Table E.2.		N/A
E12.2	**Test results compliance criteria**		N/A
E12.2.1	Venting is determined by evidence of mass loss as noted in Table E.3 below.		N/A
E12.2.2	Leakage is determined by evidence of visible liquid electrolyte on the external case of the cell or mass loss criteria as outlined in Table E.3.		N/A
E12.2.3	Rupture is determined by a tear in the cell case at a location other than at the designed vent.		N/A
E12.2.4	Fire is determine by evidence visible flames or of charging and burning of the cell and its contents.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
E12.2.5	Explosion is determined by evidence of disassembly of the cell and its contents beyond a rupture of the case.		N/A

F	**APPENDIX F – Cell Failure Methods** (Informative)		—

G	**APPENDIX G – Safety marking translations** (informative)		—

H	**APPENDIX H – Alternative Approach for Evaluating Valve Regulated or Vented Lead Acid or Nickel Cadmium Batteries** (normative)		N/A
H1	**General**		N/A
H1.1	This Annex is provided as the evaluation program for valve regulated or vented lead-acid and nickel-cadmium cells, batteries and battery systems (i.e. battery(s) with a rack and/or enclosure) for stationary applications to this Standard. This Annex considers the fact that these systems are often assembled at the stationary end product stage (e.g. ESS or UPS) using standardized lead acid or nickelcadmium batteries that are not first assembled as battery systems and evaluated in accordance with this Standard. Therefore, the evaluation according to this Annex can be conducted to meet the battery technology requirements of this standard for these types of batteries.		N/A
H1.2	This Annex covers both single cell or multi-cell/monobloc batteries, or battery systems consisting of multiple cells or batteries connected in series and/or parallel connections with associated components that may or may not be enclosed.		N/A
H1.3	It is understood that due to the typically standardized, single cell or multi-cell (often referred to as monobloc) design of the lead acid and nickel cadmium batteries used in these systems and their general robustness, they do not require the complex controls that a chemistry such as lithium ion requires. Their charging systems typically have safety controls that monitor and control for voltage and maximum current. For VRLA batteries, remote sensing at the batteries (coupled with temperature compensation of the		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	charge voltage) is often used to meet fire code requirements to monitor and control for potential thermal runaway. The failure mechanisms of concern for these batteries result from external abuse such as short circuiting over terminals or overcharging conditions.		
H1.4	The lead acid and nickel cadmium batteries off-gas small amounts of hydrogen under ambient pressure conditions such as is the case with vented types not fitted with recombiner caps, or much less when under slight increases of pressure in the case of valve regulated. The installation of these types of batteries, whether they are in open racks within rooms or installed within enclosed containers needs to consider the potential for hydrogen off gassing and address venting of this gas in the battery system or in its installation to prevent hazardous concentrations of hydrogen gas.		N/A
H1.5	Systems using vented type batteries needs to address spill control of hazardous electrolytes in accordance with building fire code regulations for installations of these types of batteries. See 45.13.		N/A
H1.6	For families of lead-acid and nickel-cadmium cells and batteries, testing can be conducted on the representative worst case cell or battery (e.g. highest capacity) to cover the family. A family is a group of cells or batteries that have the same basic internal construction but have different capacities. When testing a cell or battery that can have casings that are molded from materials with different flame ratings, the casing with the lowest flame rating shall be used if it can impact the test.		N/A
H2	**Construction**		N/A
H2.1	Valve regulated or vented lead acid or nickel cadmium cells and multi-cell/monobloc batteries shall comply with the Pressure Release Test or the Flame Arrester Vent Cap Test requirements in UL 1989 as applicable to the battery type.		N/A
H2.2	With reference to H2.1, casing material for cells and batteries shall be V-2 minimum.		N/A
	Exception: The casing material for vented type cells and batteries can be HB minimum if the top cover of the casing mounting the flame arrestor/vent cap assembly is V-2 minimum.		N/A
H2.3	The multi-battery battery systems consisting of multiple batteries shall also be provided with markings in accordance with Section 44 and instructions in accordance with Section 45 criteria as applicable to the system. Single cells and multi-call/monobloc batteries shall be provided with		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	instructions that include specifications for use (charging and discharging), storage, installation and disposal.		
H2.4	The construction requirements in this standard apply to a battery system consisting of multiple batteries with associated components if applicable, except for that of 7.9.		N/A
H2.5	A battery system exceeding a nominal voltage of 240 Vdc shall be provided with disconnects to disconnect the series-connected strings into segments not exceeding 240 V in accordance with Article 480 of NFPA 70 or Section 64 of CSA C22.1, for servicing of the battery system.		N/A
H2.6	Nonmetallic materials that are components of a rack support system such as spacers or insulation, shall be rated V-2 minimum or HBF minimum as applicable to the material.		N/A
H3	**Performance**		N/A
H3.1	**General**		N/A
H3.1.1	Table H.1 below outlines the tests that are applied to vented and valve regulated lead acid and nickel cadmium cells, multi-call/monobloc batteries and battery systems		N/A
H3.1.2	During the tests of H3.2 – H3.5, temperatures on the casing and target DUTs of H3.5 shall be measured to determine that temperatures do not exceed the casing material's relative thermal index (RTI) with impact.		N/A
H3.2	**Electrical tests**		N/A
H3.2.1	**Overcharge**		N/A
H3.2.1.1	Single cells or multi-cell/monobloc batteries shall be subjected to an overcharge test as outlined in H3.2.1.2 – H3.2.1.3.		N/A
H3.2.1.2	During the test, temperatures on the cell or battery casings shall be measured and recorded.		N/A
H3.2.1.3	The cells/batteries shall be charged at the maximum charging current at constant current charging until the maximum voltage in (a) or (b) has been reached. The charging is then continued at constant voltage charging for 7 h.		N/A
	a) 2.50 V/cell for VLA and VRLA cells and batteries; or		N/A
	b) 1.67 V/cell for nickel cadmium cells and batteries.		N/A
H3.2.1.4	As a result of the test, there shall be no rupture of the battery casings, leakage of electrolyte, fire or explosion.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
H3.2.2	**Short circuit**		N/A
H3.2.2.1	A short circuit test in accordance with Method 1 in H3.2.2.5 or Method 2 in H3.2.2.6 on the lead acid or nickel-cadmium single cells or multi-cell/ monobloc batteries shall be conducted, and the short circuit current measured.		N/A
H3.2.2.2	The DUTs shall have, an actual capacity Ca of at least the rated capacity Cr as determined using a 3 h rate to EODV of 1.70 V/cell at a selected reference temperature.		N/A
H3.2.2.3	During the test, temperatures on the cell or battery casings shall be measured and recorded.		N/A
H3.2.2.4	Prior to applying the short circuit resistance, the DUTs shall: a) Be fully charged; and b) Have a temperature between 20 °C (68 °F) and 25 °C (77 °F).		N/A
H3.2.2.5	Method 1: The single cells or batteries shall be discharged for 30 s with a current equal to 3 times:		N/A
	a) The 5 min rate current to EODV of 1.80 V/cell at 20 °C (68 °F) or 25 °C (77 °F); or		N/A
	b) With a current equal to the maximum allowable discharge current, both as specified by the manufacturer in their published product specifications.		N/A
H3.2.2.6	Method 2: The single cells or battery shall be subjected to an external resistance of ≤ 3.5 mΩ for 30 s.		N/A
H3.2.2.7	After the completion of the discharge duration, the DUTs shall be at an open circuit voltage condition for 5 min, and their voltage measured and reported.		N/A
H3.2.2.8	The test units shall be examined, after the discharge, internally and externally for effects of high current flow and signs of melting.		N/A
H3.2.2.9	As a result of the test, there shall be no melting at the battery terminals, rupture of the battery casings, leakage of electrolyte, fire or explosion.		N/A
H.3.2.3	**Overdischarge**		N/A
H3.2.3.1	The overdischarge test shall be conducted as outlined in H3.2.3.2 to H3.2.3.4.		N/A
H3.2.3.2	During the test, temperatures on the cell or battery casings shall be measured and recorde		N/A
H3.2.3.3	For VLA and VRLA cells and batteries, the DUT shall be discharged at the 8-h discharge rate using the 1.75 V/cell rate down to an EODV of 1.57 V/cell. For nickel-cadmium cells and batteries, the DUT shall be		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	discharged at the 5-h discharge rate using the 1.0 V/cell rate down to an EODV of 0.9 V/cell.		
H3.2.3.4	At the conclusion of the discharge, the battery shall then be immediately recharged at the float voltage until the float current stabilizes (i.e. no more than a 10 % change in float current over three successive hourly measurements).		N/A
H3.2.3.5	As a result of the test, there shall be no rupture of the battery casings, leakage of electrolyte, fire or explosion.		N/A
H3.2.4	**Temperature**		N/A
H3.2.4.1	The temperature test in accordance with H3.2.4.2 shall be conducted on single cells or multicell batteries where the temperatures on the casing during the overcharge, short circuit and overdischarge test exceeded the relative thermal index of the casing material.		N/A
H3.2.4.2	One sample of the fully charged DUT shall be placed in a chamber at the manufacturer's specified maximum charging temperature until the temperature on the DUT casing is at the chamber temperature. The DUT is then discharged down to the EODV, while measuring temperatures on the cell case and recording the temperatures. The DUT is then allowed to sit at the chamber temperature until the temperature on the DUT case has dropped to the chamber temperature. The DUT is then charged in accordance with the manufacturer's specifications for maximum charging parameters. During this time, temperatures on the case were measured and recorded.		N/A
H3.2.4.3	The maximum temperatures recorded on the DUT casing shall not exceed the material specifications. The accessible surface temperatures do not exceed the limit in Table 20.1 and Table 20.2.		N/A
H3.2.5	**Dielectric voltage withstand**		N/A
H3.2.5.1	Multi-battery battery systems that have a voltage of 60 Vdc or greater shall be subjected to the Dielectric Voltage Withstand Test of Section 22.		N/A
H3.2.5.2	A single cell or monobloc battery intended for use in a system with a voltage greater than 60 Vdc shall be subjected to a Dielectric Voltage Withstand Test of Section 22. The test voltages shall be applied for a minimum of 1 min. The test voltage should be applied between the positive terminal or negative terminal and the accessible non-current carrying part in turn, to avoid short circuiting between the positive and negative terminals. If the case is a polymeric or similar insulating material, a sheet of foil in		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	accordance with 22.5 shall be applied to the case and testing shall be between the terminal and the foil.		
H3.2.5.3	There shall be no evidence of dielectric breakdown.		N/A
H3.2.6	**Continuity**		N/A
H3.2.6.1	This test shall be conducted on multi-battery battery systems that employ cells or batteries with metallic casings.		N/A
H3.2.6.2	The Continuity Test of Section 23 shall be conducted on the battery system.		N/A
H3.2.6.3	The determined (calculated or measured) resistance shall be less than or equal to 0.1 Ω.		N/A
H3.3	**Mechanical tests**		N/A
H3.3.1	**Static force test**		N/A
H3.3.1.1	This is a test for the enclosure/cabinet of a multi-battery battery system.		N/A
H3.3.1.2	The Static Force Test of Section 31, shall be conducted on the battery system enclosure. If applicable, the Dielectric Voltage Withstand Test of H3.2.5 shall be conducted.		N/A
H3.3.1.3	There shall be no damage or breakage of the enclosure that can result in access to live parts. If applicable, there shall be no evidence of dielectric breakdown.		N/A
H3.3.2	**Impact test**		N/A
H3.3.2.1	This is a test for the enclosure/cabinet of a multi-battery battery system.		N/A
H3.3.2.2	The Impact Test of Section 32, shall be conducted on the battery system enclosure. If applicable, the Dielectric Voltage Withstand Test of H3.2.5 shall be conducted.		N/A
H3.3.2.3	There shall be no damage or breakage of the enclosure that can result in access to live parts. If applicable, there shall be no evidence of dielectric breakdown.		N/A
H3.3.3	**Drop impact test**		N/A
H3.3.3.1	Samples of single cell or multi-cell/monobloc batteries shall be subjected to the Drop Impact Test in accordance with Section 33, except as outlined in H3.3.3.2 to H3.3.3.5.		N/A
H3.3.3.2	Each sample shall be subjected to a single drop, and the height for the drop shall be as follows:		N/A
	a) Dropped from a height of 100 mm (3.93 in) for units weighing < 50 kg (110.2 lb);		N/A
	b) Dropped from a height of 50 mm (1.97 in) for units weighing 50 – 100 kg (110.2 − 220.5 lb); and		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	c) Dropped from a height of 25 mm (0.98 in) for units weighing > 100 kg (220.5 lb).		N/A
H3.3.3.3	The sample shall be dropped a minimum of one time. However, if only one drop test is performed, it shall not be a flat drop. If one drop test is a flat drop, then at least one other test shall be performed that is not a flat drop.		N/A
H3.3.3.4	Following the drop, the samples shall be subjected to an observation period of 1 h and are not cycled beforehand.		N/A
H3.3.3.5	As a result of this test there shall be no rupture of the battery casing, leakage of electrolyte, fire or explosion.		N/A
H3.3.4	**Mold stress test**		N/A
H3.3.4.1	The cell or battery with a polymeric molded case shall be subjected to the mold stress test of H3.3.4.2.		N/A
H3.3.4.2	A discharged single cell or multi-call/monobloc battery shall be conditioned in an air circulating oven at 70 °C (158 °F) or 10 °C (18 °F) above the maximum temperature measured on the case during the short circuit, overcharge and discharge test or temperature test as applicable.		N/A
H3.3.4.3	There shall be no warping or damage to the case that can result in electrolyte leakage.		N/A
H3.3.5	**Strength of the support structure test**		N/A
H3.3.5.1	A battery system support structure such as a battery rack shall be subjected to the Strength of the Support Structure Test of H3.3.5.2.		N/A
H3.3.5.2	The support structure shall be subjected to 4 times the total anticipated weight the structure is anticipated to support applied for one minute.		N/A
	Exception: A support rack that complies with UL 2416, or the seismic structural strength criteria of IEEE 693, Telcordia GR-63-CORE, or the ICC IBC need not be tested.		N/A
H3.3.5.3	As a result of the applied force, there shall be no breakage or damage to the support structure.		N/A
H3.4	**Environmental tests**		N/A
H3.4.1	**Salt fog test**		N/A
H3.4.1.1	This test shall only be conducted on those single cells or multi-cell/monobloc batteries with metallic cases that are intended for installation in a marine environment.		N/A
H3.4.1.2	The Salt Fog Test of Section 40 shall be conducted on 3 fully charged samples of the single cells or multi-cell/monobloc batteries.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
H3.4.1.3	As a result of this test, there shall be no rupture of the battery casings, leakage of electrolyte, fire or explosion.		N/A
H3.5	**Single cell failure design tolerance**		N/A
H3.5.1	**Overcharge thermal runaway test**		N/A
H3.5.1.1	This test shall be conducted on 3 samples of a single cell or multi-cell/monobloc battery and is intended to determine if the cell or battery can be driven into thermal runaway.		N/A
H3.5.1.2	During the test, the samples shall be installed in an alcove painted black and separated from the wall by the minimum separation distances recommended by the manufacturer for the end use application. The DUT shall be surrounded by target cells or batteries spaced to represent the minimum clearance distances between cells or batteries specified by the manufacturer. Target cells or batteries may be either discharged samples or just the external casing of the cells or batteries.		N/A
H3.5.1.3	Temperatures on the DUT case, the target cells or batteries and adjacent walls shall be measured during the test and the maximum measured temperatures shall be recorded.		N/A
H3.5.1.4	The DUTs shall be subjected to the Overcharge Test of H3.2.1 except that the charging is continued for a total of 168 h. The samples shall be draped in a single layer of cheesecloth indicator. Temperatures on the casing shall be monitored.		N/A
H3.5.1.5	The cheesecloth indicator shall be untreated cotton cloth running 26 – 28 m2/kg with a count of 28 – 32 threads in either direction within a 6.45 cm2 (1 in2) area.		N/A
H3.5.1.6	The Cell Vent Gas Composition Test of UL 9540A shall be conducted on a cell or monobloc battery driven into thermal runaway. If unable to capture the gas with the samples in the pressure vessel as noted in the Cell Vent Gas Composition Test method of UL 9540A, the gas shall be captured from the vent/valve assembly to a gas collection vessel.		N/A
	Exception: Instead of the off gas testing outlined in Cell Vent Gas Composition Test of UL 9540A, the combustible off gas composition from vented and valve regulated lead acid and Ni-Cd batteries under a thermal runaway condition may be determined through applicable calculations in accordance with IEEE 1635/ASHRAE Guideline 21 as noted in Table H.2.		N/A
H3.5.1.7	The volume of hydrogen gas measured during the testing or calculated and documented. This value can be utilized in the end use to determine the suitable deflagration/explosion protection.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	NOTE: The Test Concepts and Application of Test Results to Installations annex of UL 9540A outlines the approach to addressing the off gassing data to aid in determining the need for deflagration/explosion protection and to inform that design in accordance with NFPA 68 and NFPA 69. Information on explosion control addressing unique properties for hydrogen can be found in the Hydrogen Explosion Control annex of NFPA 2.		N/A
H3.5.1.8	As a result of the test, there shall be no evidence of fire (i.e. charring of the cheesecloth indicator) or explosion for any of the samples tested. The temperatures measured on the DUT and target batteries and gas information shall be documented.		N/A
	NOTE: Refer to UL 9540A for information that is required to be provided for a UL 9540A report.		N/A

I	**APPENDIX I – Test Program for Mechanically Rechargeable Metal-Air Batteries** (normative)		N/A
I1	**General**		N/A
I1.1	Battery systems consisting of mechanically rechargeable Al-Air batteries or mechanically rechargeable Zn-Air batteries shall comply with the applicable construction and test requirements of this standard. They shall additionally be subjected to the requirements outlined in this Annex. This Annex only applies to mechanically rechargeable Al-Air batteries and mechanical rechargeable Zn-Air batteries, which recharge the battery by replacing the oxidized metal electrode with a new metal electrode.		N/A
I1.2	The sample criteria for the cell stack tests is outlined in Table I1.1. Samples for all cell stack tests shall be assembled with fresh anodes which are no more than 6 months from the date of production. The same sample shall be used for test I4.1 and I4.2. Test I4.2 shall be conducted after test I4.1. Samples used for the I4.2 and I4.4 test shall be subjected to the I5.2 leakage test afterwards.		N/A
I1.3	The sample criteria for the mechanically rechargeable metal-air battery system tests is outlined in Table I1.2. Before testing, the battery sample shall be assembled with fresh anodes which are no more than 6 months after the date of production.		N/A
	Exception: At the agreement of the manufacturer, DUT samples may be re-used for more than one test if not damaged in a manner that would affect test results. Minor repairs can be made to samples such as replacement of fuses, etc. in order to reuse		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	samples for multiple tests. After minor repairs, samples should be assembled with fresh anodes as noted above.		
I1.4	Unless otherwise indicated, the battery sample shall then be activated by pumping the electrolyte into the cell stack and be adjusted to be fully charged in accordance with the manufacturer's specifications, and submitted to the tests in Table I1.2 immediately. For mechanically rechargeable metalair batteries, there is no need to conduct charge/discharge cycle after completing the tests on the battery system in accordance with I2.2, but if the control circuit remains operational after test in Table I1.2, the loss of protection controls shall be checked by a method given by manufacturer or other suitable method such as checking that the protection will activate normally when there is a value input above protection limit.		N/A
I1.5	Only the discharge condition of the temperature and operating limits check test shall be conducted for mechanically rechargeable metal-air battery systems. The voltage, current and temperature of each cell stack instead of each cell shall be measured during test. As a result of test, the measured current and temperature of the cell stack shall be compared to its operation limits, and the limits shall not be exceeded.		N/A
I1.6	When conducting the failure of the cooling/thermal stability system test of Section 24, the battery system shall be tested at ambient temperature rather than tested in an elevated ambient within a test chamber.		N/A
I1.7	The dielectric voltage test shall be conducted on the fresh battery sample before the temperature and operating limits check test, and on the discharged battery sample after the temperature and operating limits check test.		N/A
I1.8	The continuity test shall be conducted on the discharged battery sample after the temperature and operating limits check test.		N/A
I1.9	The sample criteria for the electrical components and materials containing electrolyte used in mechanically rechargeable metal-air battery system tests is outlined in Table I1.3.		N/A
I1.10	Unless otherwise indicated, the tests in Table I1.2 and Table I1.3 shall be conducted in an ambient temperature of 25 ±5 °C (77 ±9 °F).		N/A
I2	**Materials Containing Electrolyte – Resistance to Deterioration from Fluids**		N/A
I2.1	Parts containing electrolyte shall be resistant to deteriorations from the fluids they contain. Compliance is determined by the testing outlined in I2.2 and I2.3. As a result of the testing, the tensile		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	strength of tested materials shall not be less than 80 % of the tensile strength of the material in the as received condition.		
I2.2	Three as-received samples of materials conditioned as described in I2.3 shall be tested in accordance with ASTM D638. The tensile strength of the materials under test shall be recorded.		N/A
I2.3	The material shall be immersed in the test liquid representative of the electrolyte contained and conditioned for 7 days, 30 days and 60 days at a temperature of 50 °C (122 °F) in a full-draft air-circulating explosion-proof oven. Samples are evaluated from each of the exposure times with mechanical properties determined and compared with as-received values. The 60 day exposure test may be waived depending upon results of samples subjected to 30 day exposure.		N/A
I2.4	Gasket and seals in contact with electrolyte shall be subjected to the volume change and extraction, tensile strength and elongation after 70-h immersion in the electrolyte in accordance with UL 157. The tensile strength and elongation shall be a minimum of 60 % of as received values and the volume change of minus 1 to plus 25 % of the as received values and extraction (change in weight) no greater than 10 %.		N/A
I3	**Materials Containing Electrolyte – Temperature Exposure**		N/A
I3.1	Parts containing electrolyte shall be suitable for intended temperature use. Compliance is determined by the testing of I3.2 and I3.3. As a result of the oven aging, the part shall not show signs of deterioration such as cracking or embrittlement. The tensile strength of the conditioned part shall not be less than 80 % of the tensile strength of the as received part.		N/A
I3.2	Three as-received samples of the polymeric part and three conditioned samples of the part shall be tested in accordance with ASTM D638. The tensile strength shall be recorded.		N/A
I3.3	Three samples of each part shall be conditioned for 45 and 90 days at a temperature of 70 °C (158 °F) in a full-draft air-circulating oven.		N/A
	Exception No. 1: As an alternative test method, the part shall be conditioned for 30 and 60 days at a temperature of 80 °C (176 °F) in a full-draft air-circulating oven.		N/A
	Exception No. 2: As an alternative test method, the parts shall be conditioned for 15 and 30 days at a temperature of 90 °C (194 °F) in a full-draft air-circulating oven.		N/A
I3.4	Gasket and seals shall be subjected to the air oven aging test of UL 157 based upon anticipated exposure temperatures in the end use application.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	The tensile strength and elongation after oven aging shall be a minimum of 60 % of the as received values.		
I3.5	Gasket and seals used in electrolyte containment systems shall be subjected to the lower temperature test of UL 157 for minus 40 °C (minus 40 °F), or the lowest ambient temperature specified by the manufacturer but not less than 0 °C (32 °F), with no visible evidence cracking in accordance with the test criteria of UL 157.		N/A
I4	**Mechanically Rechargeable Metal-Air Cell Stack Tests**		N/A
I4.1	**Vibration test of cell stack**		N/A
I4.1.1	One sample of a mechanically rechargeable metal-air cell stack shall be subjected to vibration test in accordance with I4.1.2 and I4.1.3. As a result of the vibration conditioning, the cell stack shall not be damaged to the extent that results in leaks.		N/A
I4.1.2	The DUT shall mounted to a vibration text fixture and subjected to a simple harmonic motion with an amplitude of 0.76 mm (0.03 in), and a total maximum excursion of 1.52 mm (0.06 in). The frequency shall be varied at the rate of 1 Hz/min between the limits of 10 Hz and 55 Hz. The entire range of frequencies (10 Hz to 55 Hz) and return (55 Hz to 10 Hz), shall be traversed in 90 ±5 min for each mounting position (direction of vibration). The vibration shall be applied in each of three mutually perpendicular directions.		N/A
	Exception: Another method of vibration representative of the transport conditions of the cell stack such as ISO 13355, or IEC 60068-2-64, etc. may be used if determined to be more suitable for the size and design of the stack.		N/A
I4.1.3	At the conclusion of the vibration test, the same DUT sample shall then be subjected to shock test in accordance with I4.2.		N/A
I4.2	**Shock test on cell stack**		N/A
I4.2.1	One sample of a mechanically rechargeable metal-air cell stack previously has been submitted to vibration test per I4.1, shall be subjected to the shock test in accordance with I4.2.2 and I4.2.3. As a result of the shock conditioning, the cell stack shall not be damaged to the extent that results in leaks. See Table I1.1.		N/A
I4.2.2	The DUT shall be secured to a test machine by means of a rigid mounts supporting all surfaces of the cell stack. Each DUT shall be subjected to a total of three shocks of equal magnitude. The shocks shall be applied in each of three mutually perpendicular directions. For each shock the DUT shall be		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	accelerated in such a manner that during the initial 3 ms, the minimum average acceleration is 75 g (where g is the local acceleration due to gravity). The peak acceleration shall be between 125 g and 175 g.		
I4.2.3	At the conclusion of the shock conditioning, the DUT shall be checked for leaks by subjecting it to the leakage test I5.2.		N/A
I4.3	**Drop impact of cell stack or metal anode**		N/A
I4.3.1	One sample of cell stack or metal anode plate which will be subjected to installation in the battery system during mechanically recharging as specified in the operation/maintenance instruction shall be subjected to a drop impact test to determine that no hazard exists as a result of an inadvertent drop during installation or removal. As a result of the drop impacts, the cell stack to be installed or the cell stack with the metal anode to be installed shall not be damaged to the extent that results in leaks.		N/A
	Exception: This test can be waived if the operation/maintenance instructions of the battery system declare that the cell stack or the metal anode cannot be used if dropped.		N/A
I4.3.2	The DUT (cell stack or metal anode plate) shall be dropped from a minimum height of 100 cm (39.4 in) for products weighing 7 kg (15.4 lbs) or less, 10 cm (3.9 in) for products weighing >7 kg (15.4 lbs), but less than 100 kg (220.5 lbs), and 2.5 cm (0.98 in) for products weighing >100 kg (220.5 lbs), to strike a concrete or metal surface in the position most likely to produce adverse results and in a manner and a height most representative of what would occur during maintenance and handling/removal of the battery system during installation and servicing. The orientation and height of the drop shall be determined by the testing personnel from an analysis of the installation and servicing instructions. If using a metal test surface, it shall be provided with some manner of insulation such as insulating film that will prevent inadvertent short circuiting to the surface, but will not affect test results.		N/A
I4.3.3	The sample shall be dropped a minimum of one time. However, if only one drop test is performed, it shall not be a flat drop. If one drop test is a flat drop, then at least one other test shall be performed that is not a flat drop.		N/A
I4.3.4	The concrete surface shall be at least 76 mm (3 in) thick and the concrete or metal drop surface shall be large enough in area to cover the DUT.		N/A
I4.3.5	At the conclusion of the drop impact test, the DUT shall be checked for leaks by subjecting it to the leakage test I5.2.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
I4.4	**High temperature test on cell stack**		N/A
I4.4.1	One fully charged sample of the mechanically rechargeable metal-air cell stack shall be subjected to the high temperature test in accordance with I4.4.2 and I4.4.3. As a result of the high temperature conditioning, the cell stack shall not be damaged to the extent that results in leaks. See Table I1.1.		N/A
I4.4.2	The DUT shall be conditioned for 7 h in an air circulating temperature chamber at a temperature of 10 ±2 °C (50 ±3.6 °F) below the minimum temperature rating (operating temperature or storage temperature, whichever is lower) of the cell stack. The chamber temperature shall then be adjusted to a temperature of 10 ±2 °C (50 ±3.6 °F) plus the maximum temperature rating of the cell stack or 70 ±2 °C (158 ±3.6 °F), whichever is greater, within 60 min. The DUT shall be then be maintained at that temperature for 7 h.		N/A
I4.4.3	At the conclusion of the high temperature conditioning, the DUT shall be allowed to cool to room ambient and then it shall be checked for leaks by subjecting it to the leakage test of I5.2.		N/A
I4.5	**Short circuit test on cell stack**		N/A
I4.5.1	A sample of cell stack shall be activated by pumping the electrolyte into the cell stack and adjusted to be fully charged in accordance with the manufacturer's specifications.		N/A
I4.5.2	Immediately after conditioning in I4.5.1, the fully charged cell stack shall be subjected to a Short Circuit Test to a total external resistance of less than or equal to 20 mΩ until the cell stack is completely discharged, or the operation of an integral protective device or other results. See Table I1.1.		N/A
I4.5.3	As a result of the Short Circuit Test, there shall be no fire or explosion.		N/A
I4.6	**Forced discharge test on cell stack**		N/A
I4.6.1	A sample of cell stack shall be activated by pumping the electrolyte into the cell stack and adjusted to be fully charged in accordance with the manufacturer's specifications.		N/A
I4.6.2	Immediately after conditioning in I4.6.1, the fully charged cell stack shall be discharged at its maximum discharge current until it's fully discharged, the cell stack shall then be continuously discharged at the maximum discharge current for additionally 30 min. See Table I1.1.		N/A
I4.6.3	As a result of the forced discharge test, there shall be no fire or explosion.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
I5	**Mechanically Rechargeable Metal-Air Battery System Tests**		N/A
I5.1	**Hydraulic pressure test**		N/A
I5.1.1	Electrolyte containment vessels where there is the potential for gas pressure build up having a pressure-times-volume value greater than 200 kPa-L (7.67 psi-gal), and pressure greater than 50 kPa (7.25 psi), shall be subjected to a hydraulic pressure test as described in I5.1.2. As a result of the test, the vessel shall not burst, leak, rupture, fracture, or permanently (plastic) deform.		N/A
	Exception No. 1: Where unmarked pressure vessels are not able to be hydraulically tested, compliance shall be verified by other applicable tests, such as an air pneumatic test at the same test pressure as for the hydraulic test.		N/A
	Exception No. 2: Piping systems under the scope of ASME B31.3, shall be subjected to ultimate strength and leakage testing in accordance with that code.		N/A
I5.1.2	The test pressure shall be the maximum pressure specified by the manufacturer multiplied by five or 1.5 times the operating pressure of a pressure relief device, whichever is greater. A pressure-relief device which is used to limit the maximum pressure shall be inactive during the test. The pressure shall be raised gradually to the specified test value and held at that value for 1 min.		N/A
I5.2	**Leakage test**		N/A
I5.2.1	Leakage from fluid-containing parts shall not result in the risk of fire, electric shock, or injury to persons. As a result of the leakage test, the following in (a) – (g) are considered non-compliant results:		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L– Leakage (external to enclosure of DUT);		N/A
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
I5.2.2	Compliance is determined by subjecting the parts to a fluid pressure of 1.5 times the maximum pressure (if testing with liquid) or 1.1 times the maximum pressure (if air pneumatic testing) of intended use during operation of the system. There shall be no leaks as a result.		N/A
I5.3	**Electrolyte/air pipe blockage tests**		N/A
I5.3.1	A pump failure or a potential electrolyte or air pipe blockage during discharge may lead to a hazardous		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	condition in a Mechanically rechargeable metal-air battery system. The purpose of this test is to determine if the battery system can safely withstand a failure in the fluid (electrolyte and air) supply system of the battery.		
I5.3.2	This test shall be conducted on fully charged samples. Each sample shall be subjected to a fault condition consisting of one of the following in (a) – (c) below which may lead to a hazardous condition. The faulted sample(s) shall then be subjected to the maximum discharging current/power specified by the manufacturer. During the test, active protective devices shall be subjected to single fault conditions, unless the protection circuit has been tested for functionality in accordance with 7.9. a) An electrolyte pump failure; b) Electrolyte piping blockage; or c) An air pipe blockage.		N/A
I5.3.3	The test shall continue until the protection device(s) are activated, or the DUT has been discharged for an additional 30 min after it has been completed discharged, whichever comes first.		N/A
I5.3.4	If the control circuit remains operational after test, the loss of protection controls shall be checked by a method given by manufacturer or other suitable method, such as checking that the protection will activate normally when there is a value input above protection limit. An observation period per 8.5 is then conducted.		N/A
I5.3.5	At the conclusion of the observation period, the samples shall be subjected to an “as received” dielectric voltage withstand test in accordance with Section 22. The DUT shall be examined for signs of rupture and evidence of leakage.		N/A
I5.3.6	As a result of this test, the following in (a) – (h) are considered non-compliant results:		N/A
	a) E – Explosion;		N/A
	b) F – Fire;		N/A
	c) C – Combustible vapor concentrations;		N/A
	d) V – Toxic vapor release;		N/A
	e) S – Electric shock hazard (dielectric breakdown);		N/A
	f) L – Leakage (external to enclosure of DUT);		N/A
	g) R – Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3);		N/A
	h) P – Loss of protection controls.		N/A
I5.4	**Isolation resistance test**		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
I5.4.1	This test is intended to determine that the insulation of the DUT provides adequate isolation of hazardous voltage circuits from accessible conductive parts of the DUT, and that the insulation is nonhygroscopic. This test shall be conducted on a battery sample after being fully discharged.		N/A
I5.4.2	A DUT with accessible parts shall be subjected to an insulation resistance test between the positive terminal and accessible dead metal parts. If the accessible parts of the DUT are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts.		N/A
I5.4.3	The insulation resistance shall be measured after a 60-s application with a high resistance voltmeter using a 500 Vdc potential applied for at least 1 min to the locations under test. For battery systems greater than 500 Vdc, a 1,000 Vdc potential shall be applied instead.		N/A
I5.4.4	The test shall be repeated on a sample subjected to a humidity conditioning for 48 h in a chamber with a relative humidity of 93 ±3 % and at an air temperature maintained within 2 °C (3.6 °F) of any convenient value “t” within the range of 20 to 30 °C (68 to 86 °F) such that condensation does not occur. During this conditioning the DUT is not operating. Before the humidity conditioning the sample shall be brought to a temperature between t and t +4 °C (t +7.2 °F). After conditioning, the sample shall be removed from the chamber, and the insulation resistance measurements shall be made immediately.		N/A
	Exception No. 1: Subassembly including the isolation circuits and insulation components may be subjected to the humidity condition instead of the whole system if representative of the whole system.		N/A
	Exception No. 2: The insulation resistance after humidity conditioning is not conducted if insulation materials consist of non-hygroscopic materials.		N/A
I5.4.5	The measured insulation resistance between the positive terminals and accessible parts of the DUT shall be at least 50,000 Ω.		N/A
I5.5	**Spill/leak containment**		N/A
I5.5.1	If an external spill containment system such as containment vessels and absorption pillows are used for containment, absorption or neutralization of electrolyte spills from a mechanically rechargeable metal-air battery, the materials and parts of the system shall be subjected to the applicable tests of UL 2436.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict
	Exception No. 1: Internal electrolyte containment material and parts shall be subjected to the tests in Section I2 and Section I3 and the Leakage test in UL 2436.		N/A
	Exception No. 2: Tests involving exposure to or use of electrolyte other than sulfuric acid shall be modified from those of UL 2436 based upon the electrolyte utilized in the mechanically rechargeable metal-air battery system under test.		N/A
I6	**Additional Markings for Rechargeable Metal-Air Battery System**		N/A
I6.1	The battery systems shall be marked with a warning marking “Corrosive fluid inside, only maintained by the manufacturer” or equivalent.		N/A
I6.2	The battery systems for indoor use only shall be marked “Indoor Use Only” or equivalent.		N/A
I6.3	The battery systems shall be marked with a warning marking “No User Serviceable parts, only mechanically recharged or refueled by authorized service personnel” or equivalent.		N/A
I7	**Additional Instructions for Rechargeable Metal-Air Battery System**		N/A
I7.1	If the drop test for cell stack or anode metal plate is waived in accordance with the exception of I4.3.1, the instructions shall include the following statement or equivalent: “Do not use a cell stack/anode metal plate if it has been dropped, as it may result in a hazardous condition.”		N/A
I7.2	The battery systems shall be provided with instructions for the proper use including discharging and mechanically charging, storage, recycling and disposal. These instructions shall include temperature and current limits during operation of the battery system as well as instructions regarding the use of any controls or monitoring systems.		N/A
I7.3	The battery systems shall be provided with the instructions for the maintenance of the whole system. The instruction shall indicate the corrosive hazards of the electrolyte, the safe handling of the corrosive hazards, and the emergency contact method in case of exposure to the corrosive electrolyte.		N/A

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Clause	Requirement + Test	Result – Remark	Verdict

2 and Appendix A	TABLE: Critical components list				P
Object/part no.	**Manufacturer/ trademark**	**Type/ model**	**Technical data**	**Standard**	**Mark(s) of conformity**
Remark: Refer to CDF.					
Supplementary information: N/A					

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Clause	Requirement + Test	Result – Remark	Verdict

15-1	TABLE: Overcharge Test (Incorporated CSC MCU (U4) model: MC9S12G)				P
Model	**OCV at start of test for Cell/Cell Blocks, (V dc)**	**Charging Current, (A)**	**Max. Charging Voltage, (V dc)**	**Max. Voltage of Cell/Cell Blocks, (V dc)**	**Results**
Battery 1 (One module with main control box)	2.479	265	188.801	3.473	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)			Yes	
Supplementary information: Results: A – No Explosion B – No Fire C – No Combustible vapor concentrations D – No Toxic vapor release E – No Electric shock hazard (dielectric breakdown); F – No Leakage (external to enclosure of DUT) G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3) H – No Loss of protection controls I – Other (Please explain):					

15-2	TABLE: Overcharge Test (Incorporated CSC MCU (U4) model: AC7811QBFE)				P
Model	**OCV at start of test for Cell/Cell Blocks, (V dc)**	**Charging Current, (A)**	**Max. Charging Voltage, (V dc)**	**Max. Voltage of Cell/Cell Blocks, (V dc)**	**Results**
Battery 2 (One module with main control box)	2.971	265	188.064	3.656	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)			Yes	
Supplementary information: Results: A – No Explosion B – No Fire C – No Combustible vapor concentrations D – No Toxic vapor release E – No Electric shock hazard (dielectric breakdown); F – No Leakage (external to enclosure of DUT) G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3) H – No Loss of protection controls I – Other (Please explain):					

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Clause	Requirement + Test	Result – Remark	Verdict

16	TABLE: High Rate Charge			P
Model	**OCV at start of test, (V dc)**	**Charging Current, (A)**	**Max. Charging Voltage, (V dc)**	**Results**
Battery 1 (One module with main control box)	146.362	636	161.986	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)		Yes	

Supplementary information:

Results:

A – No Explosion

B – No Fire

C – No Combustible vapor concentrations

D – No Toxic vapor release

E – No Electric shock hazard (dielectric breakdown);

F – No Leakage (external to enclosure of DUT)

G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3)

H – No Loss of protection controls

I – Other (Please explain):

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Clause	Requirement + Test	Result – Remark	Verdict

17-1	TABLE: Short Circuit Test (For battery system)			P
Model	**OCV at start of test, (V dc)**	**Max. Short circuit current, (A)**	**Duration at Max. Short circuit current, (μs)**	**Results**
Battery 5 (C06530P25L01-R)	1388.0	10900	540	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)		NO	
Supplementary information: Results: A – No Explosion B – No Fire C – No Combustible vapor concentrations D – No Toxic vapor release E – No Electric shock hazard (dielectric breakdown); F – No Leakage (external to enclosure of DUT) G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3) H – No Loss of protection controls I – Other (Please explain):				

17-2	TABLE: Short Circuit Test (For module)			P
Model	**OCV at start of test, (V dc)**	**Max. Short circuit current, (A)**	**Duration at Max. Short circuit current, (ms)**	**Results**
Module 1 (M02530P25L01)	173.448	5834.4	173	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)		NO	
Supplementary information: Results: A – No Explosion B – No Fire C – No Combustible vapor concentrations D – No Toxic vapor release E – No Electric shock hazard (dielectric breakdown); F – No Leakage (external to enclosure of DUT) G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3) H – No Loss of protection controls I – Other (Please explain):				

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Clause	Requirement + Test	Result – Remark	Verdict

18-1	TABLE: Overload Under Discharge (condition 1)			N/A
Model	**OCV at start of test, (V dc)**	**Charging Current, (A)**	**OCV at end of test, (V dc)**	**Results**
-	-	-	-	-
	Is the DUT operational after test? (Yes or NO)		-	
Supplementary information: Results: A – No Explosion B – No Fire C – No Combustible vapor concentrations D – No Toxic vapor release E – No Electric shock hazard (dielectric breakdown); F – No Leakage (external to enclosure of DUT) G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3) H – No Loss of protection controls I – Other (Please explain):				

18-2	TABLE: Overload Under Discharge (condition 2)			P
Model	**OCV at start of test, (V dc)**	**Charging Current, (A)**	**OCV at end of test, (V dc)**	**Results**
Battery 5 (C06530P25L01-R)	1391.8	607.5	1318.6	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)		Yes	
Supplementary information: Results: A – No Explosion B – No Fire C – No Combustible vapor concentrations D – No Toxic vapor release E – No Electric shock hazard (dielectric breakdown); F – No Leakage (external to enclosure of DUT) G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3) H – No Loss of protection controls I – Other (Please explain):				

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Clause	Requirement + Test	Result – Remark	Verdict

19-1	TABLE: Overdischarge Protection Test (Incorporated CSC MCU (U4) model: MC9S12G)				P
Model	**OCV at start of test for Cell/Cell Blocks, (V dc)**	**Discharging Current, (A)**	**Min. Discharging Voltage, (V dc)**	**Min. Voltage of Cell/Cell Blocks, (V dc)**	**Results**
Battery 1 (One module with main control box)	3.339	265	156.471	3.016	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)			Yes	

Supplementary information:

Results:

A – No Explosion

B – No Fire

C – No Combustible vapor concentrations

D – No Toxic vapor release

E – No Electric shock hazard (dielectric breakdown);

F – No Leakage (external to enclosure of DUT)

G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3)

H – No Loss of protection controls

I – Other (Please explain):

19-2	TABLE: Overdischarge Protection Test (Incorporated CSC MCU (U4) model: AC7811QBFE)				P
Model	**OCV at start of test for Cell/Cell Blocks, (V dc)**	**Discharging Current, (A)**	**Min. Discharging Voltage, (V dc)**	**Min. Voltage of Cell/Cell Blocks, (V dc)**	**Results**
Battery 2 (One module with main control box)	3.339	265	154.265	2.953	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)			Yes	

Supplementary information:

Results:

A – No Explosion

B – No Fire

C – No Combustible vapor concentrations

D – No Toxic vapor release

E – No Electric shock hazard (dielectric breakdown);

F – No Leakage (external to enclosure of DUT)

G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3)

H – No Loss of protection controls

I – Other (Please explain):

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Clause	Requirement + Test	Result – Remark	Verdict

20	TABLE: Temperature and Operating Limits Check Test		P
	Test temperature(ºC) ..... :	55	-
	Max. voltage during charge(V) ..... :	1458.4Vd.c.	-
	Max. current during charge(A) ..... :	1411.3kW	-
	Min. voltage during discharge(V) ..... :	1071.4Vd.c.	-
	Max. current during discharge(A) ..... :	1411.3kW	-
	Results:	A, B, C, D, E, F, G, H	

Model	Temperature measured during test		
	Temperature of part/at	Measured Max. Temp. (ºC)	Limit (ºC)
Battery 5 (C06530P25 L01)	High voltage controlling box		
	Insulation switch ambient	72.6	85
	Contactor ambient	78.0	85
	Hall ambient	74.7	85
	Insulator of bus-bar surface	72.5	100
	Fuse ambient	80.0	85
	Fan ambient	70.7	75
	Pre-charge relay ambient	69.0	85
	Negative connector	87.0	125
	Voltage sampling wire	79.7	105
	SBMU Voltage sampling wires	67.5	105
	SBMU Voltage sampling connector	67.6	125
	SBMU PCB surface	71.7	130
	SBMU insulation chip	72.0	125
	SBMU insulation transformer	73.3	130
	SBMU MCU U914	76.2	125
	SBMU sampling chip U701	72.3	125
	Handle of insulation switch	49.4	130
	Front side of High voltage controlling box	64.0	70
	Battery cabinet		
	Interface metal	50.7	70

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Clause	Requirement + Test	Result – Remark	Verdict

	Module connector	50.8	125
	Cell 1	37.2	65
	Cell 2	37.4	65
	Plastics for sampling wire	42.0	80
	Sampling wire	55.6	105
	Main fuse	82.0	85
	Tube	47.4	125
	Top enclosure	47.1	85
	AFE 1	69.8	105
	AFE 2	55.5	105
	AFE 3	54.2	105
	CSC PCB	57.9	130
	Voltage sampling terminal	53.9	125
	CSC enclosure	61.2	85

Supplementary information:

Results:

A – No Explosion

B – No Fire

C – No Combustible vapor concentrations

D – No Toxic vapor release

E – No Electric shock hazard (dielectric breakdown);

F – No Leakage (external to enclosure of DUT)

G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3)

H – No Loss of protection controls

I – Other (Please explain):

1. Between charging and discharging of each cycle, the system rested for 15 minutes.
2. Between the first and second cycle, the system rested for 2 hours.
3. The test was performed on the product with 24V power module type.

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Clause	Requirement + Test	Result – Remark	Verdict

21-1	TABLE: Imbalanced Charging Test (Incorporated CSC MCU (U4) model: MC9S12G)				P
Model	**OCV of partially charged module/cell before test, (V dc)**	**Charging Current, (A)**	**Max. Charging Voltage, (V dc)**	**Max. Voltage of Cell/Cell Blocks, (V dc)**	**Results**
Battery 3 (Two modules with main control box)	3.298	265	366.296	3.677	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)			Yes	

Supplementary information:

Results:

A – No Explosion

B – No Fire

C – No Combustible vapor concentrations

D – No Toxic vapor release

E – No Electric shock hazard (dielectric breakdown);

F – No Leakage (external to enclosure of DUT)

G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3)

H – No Loss of protection controls

I – Other (Please explain):

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Clause	Requirement + Test	Result – Remark	Verdict

21-2	TABLE: Imbalanced Charging Test (Incorporated CSC MCU (U4) model: AC7811QBFE)				P
Model	**OCV of partially charged module/cell before test, (V dc)**	**Charging Current, (A)**	**Max. Charging Voltage, (V dc)**	**Max. Voltage of Cell/Cell Blocks, (V dc)**	**Results**
Battery 4 (Two modules with main control box)	3.297	265	366.929	3.653	A, B, C, D, E, F, G, H
	Is the DUT operational after test? (Yes or NO)			Yes	
Supplementary information: Results: A – No Explosion B – No Fire C – No Combustible vapor concentrations D – No Toxic vapor release E – No Electric shock hazard (dielectric breakdown); F – No Leakage (external to enclosure of DUT) G – No Rupture (of DUT enclosure exposing hazardous parts as determined by 7.3.3) H – No Loss of protection controls I – Other (Please explain):					

22	TABLE: Dielectric Strength	
Test voltage applied between:	Test potential applied (V)	Breakdown / flashover (Yes/No)
HV+ terminal to PE (BI)	2828 VDC	No
HV- terminal to PE (BI)	2828 VDC	No
HV+ terminal to all communication ports (DI/RI)	4242 VDC	No
HV- terminal to all communication ports (DI/RI)	4242 VDC	No
Supplementary information: BI=basic insulation; RI=reinforced insulation; DI=double insulation		

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Clause	Requirement + Test	Result – Remark	Verdict

E3	Short circuit Test				N/A
Model/ Sample No.	**Charging upper limit temperature, (°C)**	**OCV at start of test, (Vdc)**	**Resistance of circuit, (mΩ)**	**Maximum cell case temperature T, (°C)**	**Results**
-	-	-	-	-	-
Model/ Sample No.	**Charging lower limit temperature, (°C)**	**OCV at start of test, (Vdc)**	**Resistance of circuit, (mΩ)**	**Maximum cell case temperature T, (°C)**	**Results**
-	-	-	-	-	-

Supplementary information:

A - No fire or explosion
B - Fire
C - Explosion
D - Others (please explain)

E4	Cell impact Test				N/A
Model/ Sample No.	**Charging upper limit temperature, (°C)**	**OCV at start of test, (Vdc)**	**OCV at end of test, (Vdc)**	**Maximum cell case temperature T, (°C)**	**Results**
-	-	-	-	-	-
Model/ Sample No.	**Charging lower limit temperature, (°C)**	**OCV at start of test, (Vdc)**	**OCV at end of test, (Vdc)**	**Maximum cell case temperature T, (°C)**	**Results**
-	-	-	-	-	-

Supplementary information:

A - No fire or explosion
B - Fire
C - Explosion
D - Others (please explain)

E5	Drop impact Test				N/A
Model/ Sample No.	**OCV at start of test, (Vdc)**	**OCV at end of test, (Vdc)**	**Weight at start of test, (g)**	**Weight at end of test, (g)**	**Results**
-	-	-	-	-	-
-	-	-	-	-	-

Supplementary information:

A - No fire or explosion
B - Fire
C - Explosion
D - Others (please explain)

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Clause	Requirement + Test	Result – Remark	Verdict

E6	Heating Test				N/A
Model/ Sample No.	**Charging upper limit temperature, (°C)**	**OCV at start of test, (Vdc)**	**Weight at start of test, (g)**	**Weight at end of test, (g)**	**Results**
-	-	-	-	-	-
Model/ Sample No.	**Charging lower limit temperature, (°C)**	**OCV at start of test, (Vdc)**	**Weight at start of test, (g)**	**Weight at end of test, (g)**	**Results**
-	-	-	-	-	-
Supplementary information: A - No fire or explosion B - Fire C - Explosion D - Others (please explain)					

E7	Overcharge Test						N/A
Model/ Sample No.	**Charging upper limit temperature, (°C)**	**OCV at start of test, (Vdc)**	**Measured max. charging voltage, (Vdc)**	**Maximum charging current, (A)**	**Maximum cell case temperature T, (°C)**	**Total time of charging , h**	**Results**
-	-	-	-	-	-	-	-
Model/ Sample No.	**Charging lower limit temperature, (°C)**	**OCV at start of test, (Vdc)**	**Measured max. charging voltage, (Vdc)**	**Maximum charging current, (A)**	**Maximum cell case temperature T, (°C)**	**Total time of charging , h**	**Results**
-	-	-	-	-	-	-	-
Supplementary information: A - No fire or explosion B - Fire C - Explosion D - Others (please explain)							

E8	Forced discharge Test					N/A
Model/ Sample No.	**OCV before application of reverse charge, (Vdc)**	**Measured forced discharge I_t, (A)**	**Constant discharge voltage, (V)**	**Total time for reversed charge application, (min)**	**Maximum cell case temperature T, (°C)**	**Results**
-	-	-	-	-	-	-
-	-	-	-	-	-	-
Supplementary information: A - No fire or explosion B - Fire C - Explosion D - Others (please explain)						

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Clause	Requirement + Test	Result – Remark	Verdict

E9	Projectile Test		N/A
Model/ Sample No.	**OCV at start of test, (Vdc)**	**Maximum cell case temperature T, (°C)**	**Results**
-	-	-	-
-	-	-	-

Supplementary information:

A - No part of the cell casing penetrated the wire screen
B - Cell exploded such that particles from the casing penetrated the wire screen
C - Cell vented without exploding
D - Others (please explain)

---------- END REPORT ----------

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Appendix F

CATL EnerX – UL 1973 Certificate

ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

America

C E R T I F I C A T E

No. U8 004951 0250 Rev. 00

Holder of Certificate: **Contemporary Amperex Technology Co., Limited**
No.2 Xingang Road, Zhangwan Town, Jiaocheng District
352100 Ningde, Fujian
PEOPLE'S REPUBLIC OF CHINA

Certification Mark:

Product: **Batteries (Rechargeable Li-ion Battery System)**

This product was voluntarily tested to the relevant safety requirements referenced on this certificate. It can be marked with the certification mark above. The mark must not be altered in any way. This product certification system operated by TÜV SÜD America Inc. most closely resembles system 3 as defined in ISO/IEC 17067. Certification is based on the TÜV SÜD "Testing, Certification, Validation and Verification Regulations (TCVVR)". TÜV SÜD America Inc. is an OSHA recognized NRTL for USA and a Standards Council of Canada ISO/IEC 17065 accredited Certification body for Canada.

Test report no.: 64280246011901

Date, 2024-09-11

(Harry Zhang)

TÜV SÜD America, Inc. • 401 Edgewater Place Suite #500 • Wakefield • MA 01880 • USA

ZERTIFIKAT ◆ CERTIFICATE ◆ 認證證書 ◆ СЕРТИФИКАТ ◆ CERTIFICADO ◆ CERTIFICAT

C E R T I F I C A T E

No. U8 004951 0250 Rev. 00

Model(s):	**C06530P25L01**
Brand Name:	**CATL**
Brand:	CATL
Tested according to:	CAN/UL 1973:2022 UL 1973:2022
Parameters:	

Nominal voltage: 1331.2Vd.c.
Rated capacity: 4240Ah

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Appendix G

CATL EnerX Product Specifications

EnerX 0.25P Product Specification

Version	Date	Changes
1.0	2024/8/30	First Release

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1 General Introduction

1.1 Confidentiality

This product specification is intended only for persons directly involved in this project. Distribution to other parties, especially to partners, without the consent of CATL must be coordinated by the person in charge of this project at the CATL and is governed by the confidentiality statements in the development contract.

1.2 Purpose of Document

This document is a product specification formulated by Contemporary Amperex Technology Company Limited (CATL) for the Battery Energy Storage System developed by CATL. It describes and specifies the performance index, basic functions, interface and communication, key parameters, safety features of this product, as well as matters requiring user attention and relevant legal statements.

The specifications and parameters of the products are specified in this document. If the contracting parties find any inadequacies, they shall inform CATL so as to develop better products.

CATL possesses the right to update and clarify this document.

1.3 Definitions and Abbreviations

1.3.1 Definitions

BESS: Battery Energy Storage System that uses electrochemical cells to store electrical energy.

Frequency Modulation: The grid should operate at a stable frequency, while other uncontrolled events disturb the frequency. Therefore, active power must be supplied to modulate the frequency of the grid. The BESS provides the active power to the grid.

Voltage Modulation: The grid should operate at a stable voltage, while other uncontrolled events, especially the inductive load and capacitive load, will disturb the voltage. Hence, the reactive power should be supplied to modulate the voltage of the grid. The BESS provides the reactive power to the grid.

Peak Shaving and Valley Filling: When the power plants generate more energy than the demand, the containers must absorb the excess energy which called peak shaving. When the power plants generate less energy than the demand, the containers must release the lack of energy which is called Valley filling.

PV: Photovoltaic power generation.

Wind Power: Energy obtained from the rotation of the blade driven by the wind.

Modbus TCP: The Modbus protocol includes three types of messages: ASCII, RTU, TCP. Modbus TCP is a type of communication protocol that is widely used in the industrial field.

Container: The container for the battery energy storage system.

Module: A mechanically integrated arrangement of cells connected in series and/or parallel, complete with packaging, thermal management, output DC connections, and associated cell sensing.

Cell: The smallest indivisible component of the EnerX system, assembled into a battery module in series and/or parallel array.

RTE: Round-trip efficiency, defined as discharging of the system from 100% SOC to 0% SOC immediately followed by charging the system from 0% SOC to 100% SOC. The Round-trip DC-DC energy efficiency is measured at the DC terminals of the container.

1.3.2 Abbreviations

BMS: Battery Management System.

TMS: Thermal Management System.

CAN: Controller Area Network.

FSS: Fire Suppression System.

PCS: Power Conversion System.

BOL: Beginning of Life.

EOL: End of Life.

SOC: State of Charge.

SOH: State of Health.

CSC: Cell Supervision Circuit, the basic unit of battery management.

SBMU: Slave Battery Management Unit, collects and analyzes the data from the CSC and uploads it to the MBMU.

MBMU: Main Battery Management Unit. The central control unit of the container.

EMS: Energy Management System. Monitor and manage the charging and discharging of the BESS.

Sub Control Box: Including the SBMU, fuse, isolation switch and other components.

Master Control Box: Includes IMM, MBMU, ETH and Fiber Conversion Module.

Distribution Box: Includes auxiliary power supply, UPS, and other components.

2 System Description

2.1 Application

The EnerX container is a modular, fully integrated product consisting of rechargeable lithium-ion batteries with the characteristics of high energy density, long service life, high efficiency. It can provide stable energy release for over 4h when the batteries are fully charged. The EnerX energy storage product is capable of various on-grid applications, such as frequency regulation, voltage support, arbitrage, peak shaving and valley filling, and demand response; in addition, EnerX container can also be used in black start, backup energy, congestion management, microgrid or other off-grid scenarios.

2.2 Overview

The overview of the container is shown in Figure 1. The detailed information can be found in the following chapters. Figure 1 EnerX Liquid Cooling Energy Storage Container (mirrorA) – Left Sideview

Figure 1 EnerX Liquid Cooling Energy Storage Container (mirrorA) – Left Sideview

Figure 2 EnerX Liquid Cooling Energy Storage Container (mirrorA) – Right Sideview

The EnerX container consists of the following parts: batteries, BMS, FSS and TMS, which are integrated together to maintain the normal operation of the container.

2.2.1 Battery

The cell capacity is 530Ah, 2P52S cells integrated in one battery pack, 8 battery packs integrated in one rack, 4 racks integrated in one container. As the core of the ESS, the battery releases and stores energy.

2.2.2 BMS

BMS adopts the distributed scheme, through the three-level (CSC--SBMU--MBMU) architecture to control the BESS, to ensure the stable operation of the ESS. It can manage energy absorption and release, the thermal management system and low voltage power supply according to the detected information: battery voltage, current and temperature. It can monitor high voltage DC/AC security, diagnose and analyze faults according information from various detectors and dry-contacts. And it can keep communication with PCS and EMS through CAN. The BMS is the most important control unit of EnerX container. The BMS possesses the UPS to keep normal function when facing the temporary out of power.

2.2.3 FSS

FSS consists of smoke detectors, heat detectors,H2 detectors, CO detectors, the fire control panel, aerosol (optional), the dry pipe(optional), the smoke exhaust ventilation system, Fiber Optic Networking Card(optional) and the UPS. FSS undertakes functions : monitor the thermal run-away risks of container through the detectors, extinguish the thermal run away, especially the flame fire, control the loss to minimum. The control panel will control and record information for the fire suppression system. The FSS is independent with any other system and it is the security guard of EnerX container.

2.2.4 TMS

TMS consists of one powerful chiller, the PTC heater and the liquid cooling pipe distributed in each battery module. The TMS will control and keep the temperature of battery within reasonable range. The battery will work at best state and reach longest life under the thermal management system.

2.3 Advantages

Our EnerX container possesses the advantages below:

1) Standard design. The 20ft design is very convenient for the transportation. The standard design can be installed one-stop.

2) New generation Cell. EnerX container integrates the LFP 530Ah cells from CATL, with more capacity, longer service life and higher efficiency.

3) High integrated. The cell to pack and modular design will increase significantly the energy density of the same area. The system is highly integrated, and the area energy density is over 382.2 kWh/m2.

4) Extreme safety. The system supports three levels of safety:

5) Firstly, the cell safety, the highly stable lithium iron phosphate is used in the EnerX container. LFP is a kind of safety material especially for the BESS.

6) Secondly, the electrical safety: a) E-Stop design; b)multiple fuse protection design; c) insulation monitor voltage monitor; d) multi-channel isolation design; e) lightning protection design.

7) Thirdly, the fire protection design, CATL has four-level fire control strategy. The first-level is the alarm. The second-level is ventilation and smoke exhausting to prevent deflagration. The third-level is aerosol to extinguish initial fire, and the fourth-level is the dry pipe sprinkle fire protection to prevent fire spread. Adaptive thermal management. EnerX integrated single-cluster water pump, temperature control strategy automatically adjusted with battery status, prolonging battery life.

8) Easy extension. It is very convenient for the augmentation of containers or racks. Furthermore, the EnerX support one PCS connected to 4 containers; this will decrease the covered area significantly.

9) Independent UPS. EnerX container have integrated two UPS system, one is for FSS monitoring system which available capacity is 24 hours, another one is for BMS which available capacity is 15min or 24 hours(optional).

3 System Specifications

In this chapter, the systems specifications will be introduced in detail. For the BESS, the system specifications included the power and energy, electrical specifications, the environmental specifications, the mechanical specifications and certification standards. The product model is C06530P25L01.

3.1 Power and Energy

Table 1 Power and Energy of EnerX

DC Side Data		
Product Model	**C06530P25L01**	**Remark**
P-Rate	0.25P	
Cell		
Cell Type	LFP	
Cell Capacity	530Ah	
Cell Voltage Range	2.5-3.65V	
Cell Rated Energy	1696Wh	
System		
Configuration	4P(2P416S)	
Rated Energy	5644.29kWh	
Rated Voltage	1331.2VDC	
Voltage Range	1040 ~ 1500VDC	
Rated Charging Current	1060A	
Maximum Charging Current	1357A	For 1 minutes
Rated Charging Power	1411.07kW	
Rated Discharging Current	1060A	
Maximum Discharging Current	1357A	For 1 minutes
Rated Discharging Power	1411.07kW	

3.2 Electrical Specifications

For the auxiliary power supply, the standard configuration is 2 auxiliary power circuit. Auxiliary 1 and auxiliary 2 is listed in Table 2. The UPS for the BMS components is include in the auxiliary power circuit. The optional configuration is 1 auxiliary power circuit and the detailed configurations can be consulted to CATL.Table 2 Electrical specifications of EnerX

Table 2 Electrical specifications of EnerX

Auxiliary Power & Communication		
Product Model	**C06530P25L01**	**Remark**

P-Rate		0.25P	
Auxiliary Power 1	**Voltage Range**	3AC+N+PE 380V~480V ±10%，50/60HZ	
	Power	Max. 34.5kW	For reference
	Inrush Current	≤60A	
Auxiliary Power 2	**Voltage Range**	1AC+N+PE 110V~230 ±10%，50/60HZ	
	Power	Max. 0.5kW	For reference
	Inrush Current	5A	
UPS for BMS	**Time**	DC24V. 15min.(optional 1) DC24V. 2h.(optional 2)	The UPS is only used to supply power to BMS components. The UPS is included in the Aux power supply
Communication Protocol		CAN, Modbus/TCP	

3.3 Mechanical Specifications

Table 3 Mechanical Data of EnerX

Mechanical Data		
Product Model	**C06530P25L01**	**Remark**
Transportation	Land or sea transportation	
Size	2896mm(H)*2438mm(D)*6058mm(W)	
Weight	~45t	
Color	RAL7035/7042/6021/9003 （Optional）	
IP Level	IP55 (Battery Room)	
	IP55 (Electrical Room)	
	IP67 (Electrical Control Box of Chiller)	

3.4 Environmental Specifications

Table 4 Environmental Specifications of EnerX1

Environment Condition		
Specifications	**Range**	**Remark**
Operation Temperature Range	-35℃…+55℃	With TMS
Storage Temperature Range	-35℃…+60℃	

Application Altitude	≤4000m（no derating）	
Relative Humidity	0 ~ 95 % (non-condensing)	
The anti-corrosion level of container shells	C5	
Seismic Level	IEEE 693-2018 Moderate design level	

3.5 Certification Standard

Table 5 Certification Standard2

Standards & Certificates		
Cell	UN38.3	UN Transportation Testing for Lithium Batteries
	UL1973	Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications
	IEC62619	Safety requirements for secondary lithium cells and batteries, for use in industrial applications
	UL9540A	Energy Storage Systems and Equipment
Container	UL1973	Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications
	NFPA855	Standard for the Installation of Stationary Energy Storage Systems
	NFPA69	Standard on Explosion Prevention Systems
	UL9540A	Energy Storage Systems and Equipment
	IEC 62477	Safety requirements for power electronic converter systems and equipment – Part 1: General
	IEC 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications

	IEC 62933-5-2	Electrical energy storage (EES) systems – Part 5-2: Safety requirements for grid-integrated EES systems – Electrochemical-based systems
	IEC61000-6-2	Generic standards – Emission standard for industrial environments
	IEC61000-6-2/4	Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields

4 Battery Management System(BMS)

4.1 BMS Overview

BMS is used in energy storage system, which can monitor the battery voltage, current, temperature, managing energy absorption and release, thermal management, low voltage power supply, high voltage security monitoring, fault diagnosis and management, external communication with EMS and ensure the stable operation of the energy storage system.

4.2 BMS Architecture

BMS includes three-level constructure, composed of 1 unit of MBMU, 1 unit of IMM, 1 unit of ETH, 1 unit of optical fiber, 4 units of SBMUs, 32 units of CSCs. This is the architecture that one PCS connected to one container (Figure 3). What’ s more, the system can also support one PCS match 4 containers (Figure 4).

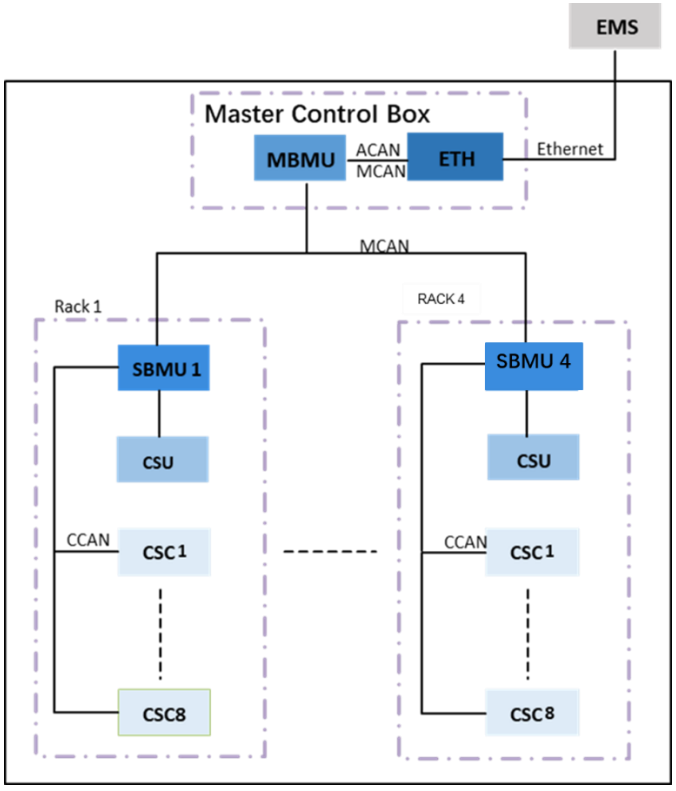


Figure 3 Three-Level BMS Architecture for One Container

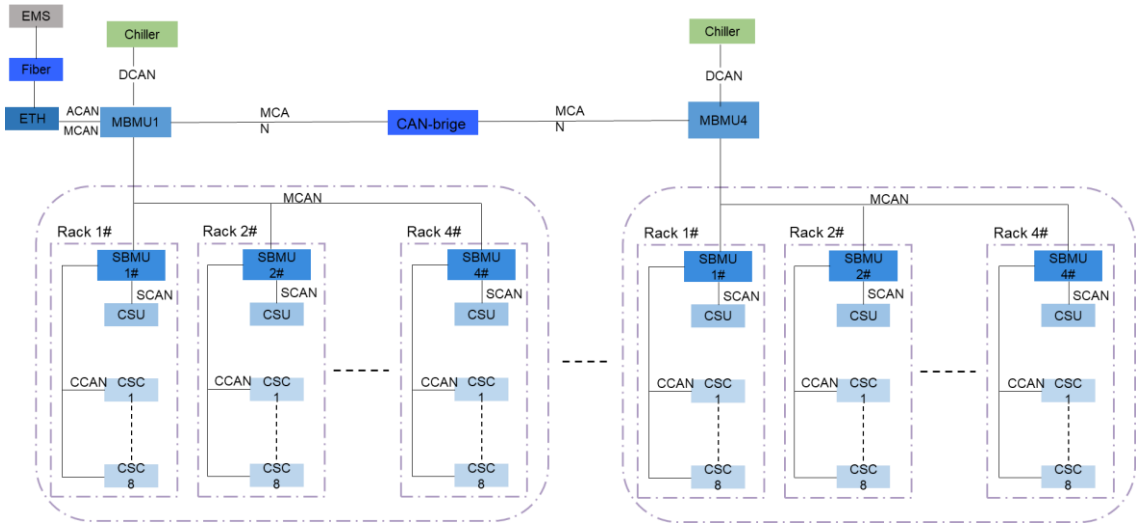


Figure 4 Three-Level BMS Architecture for Four Container

4.3 BMS Function

The detailed information of BMS can be seen in Table 6. The parameters including: Cell voltage sampling, Cell temperature sampling, Current sampling, HV sampling, Ambient temperature detection, Insulation detection and other important parameters.Table 6 Detailed Performance Parameters of BMS

Table 6 Detailed Performance Parameters of BMS

Item	**Performance Parameters**	**Value**	**Note**
Working voltage	Range	20V~26V	
Cell voltage sampling	Range	1V~4.85V	
	Accuracy	±5mV	0℃ ~ +60℃
		±10mV	-40℃ ~ 0℃or60℃ ~ 85℃
Cell temperature sampling	Range	-40℃ ~ +125℃	
	Accuracy	±2℃	-20℃ ~+60℃
		±3℃	-40℃~-20℃&+60℃~+85℃
Current sampling	Range	± 500A	
	Accuracy	<1%FSR	-40℃ ~ 85℃
HV sampling	Range	0V ~ 1500V	
	Accuracy	1%FSR	
Cell balance	Current	100mA@3.2V	Opened in all channels
SOC	Accuracy	＜± 5%	LFP, according to specific conditions
SOH	Accuracy	＜± 5%	After calibratio
	Range	-40℃ ~ +85℃	

Ambient temperature detection	Accuracy	±3℃	
Insulation detection	Range	0 ~ 10MΩ	
	Accuracy	-30% ~ 0%	
	Detection Time	≤10s	Y capacitor<0.47μF (for single side)

4.3.1 Battery Status Monitoring

1) BMS monitors the battery's parameters, including cell voltage, module temperature, battery module current and total battery module voltage.
2) BMS detects the battery status such as State of Charge (SOC) accurate to within 5%, SOH and the accurate to within 5%.
3) BMS functions as a safety management system in such cases as under voltage, over discharge, over voltage, over temperature, and over current of the battery. In case of failure, the system will give an alarm to the supervisory equipment, limit the charge and discharge current or power, and control the disconnection of all HV contactors. This can protect the battery while safeguarding the power systems security.
4) BMS shall provide battery information (including data recording and fault waveform recording) to EMS.

4.3.2 Charging/Discharging Management

1) BMS controls and monitors the high voltage main contactors, auxiliary relays and low voltage coils.
2) BMS has pre-charge control within the parallel connection among racks.
3) BMS works in the management of charge and discharge. It will calculate the charge and discharge power limit according to the existing status of the battery (temperature, SOC) and actual performance of electrical components and then report to EMS which has the function of controlling to these limits.
4) BMS has the function of balance management to extend the reliability of the battery system.

4.3.3 Thermal Management

1) BMS has the function of sample collecting of battery cell temperature and chiller operating status.

2) BMS controls the liquid cooling TMS system based on cell & coolant’s temperature.

4.3.4 Program Refreshing

BMS can flash programs on site, which supports the flashing of MBMU, SBMU, IMM, CSC and ETH by using the host computer through MCAN. BMS has the function of remote software flash, which enables to update BMS from a remote client via Ethernet. Furthermore, the system supports the BMS program refreshing through EMS.

4.3.5 High Voltage Safety Monitoring

1) BMS has the function of system insulation detection.
2) BMS has the function of high voltage sampling (collecting data of the main positive voltage).
3) BMS supports the detection of the dry contact of Fuse and Switch, as well as the auxiliary contact of the primary loop contactor.

4.3.6 Peripheral Monitoring and Control Management

1) BMS has the function of ambient temperature sampling and humidity sampling, which matches according to project requirements.
2) BMS has multiple high-side drivers and can drive and control peripheral devices according to project requirements.
3) BMS has multiple dry contact interfaces and can monitor external signals according to project requirements.

4.3.7 Fault Diagnosis Management

1) BMS stores information such as operational parameters and historical alarms that can be viewed by ESS host computer.
2) BMS enables storage of latest historical alarms.

5 Fire Suppression System(FSS)

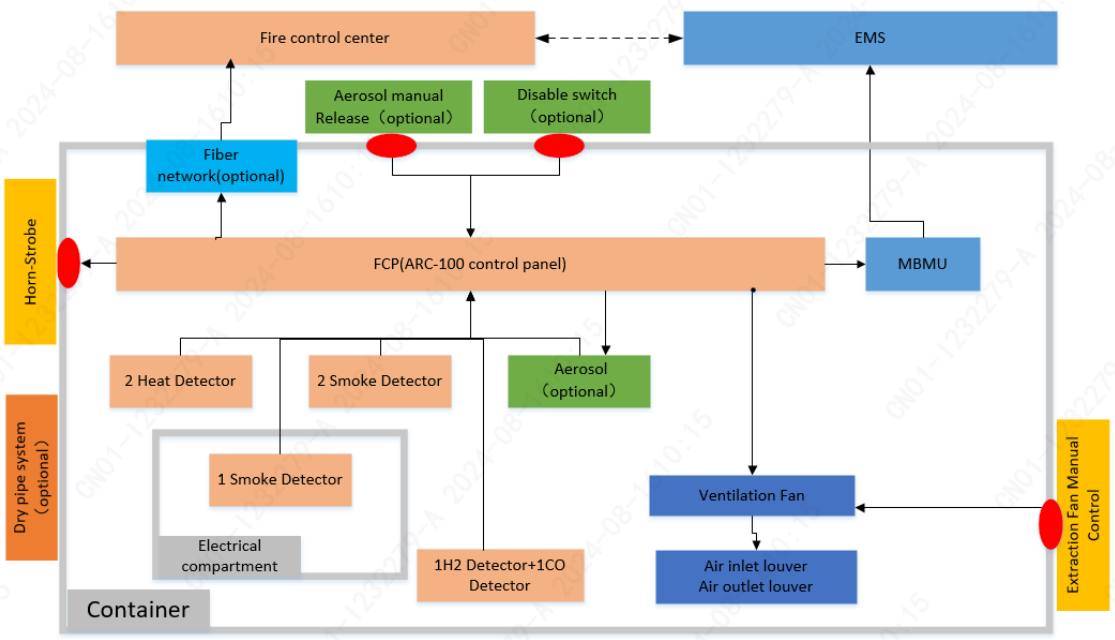
5.1 FSS Overview

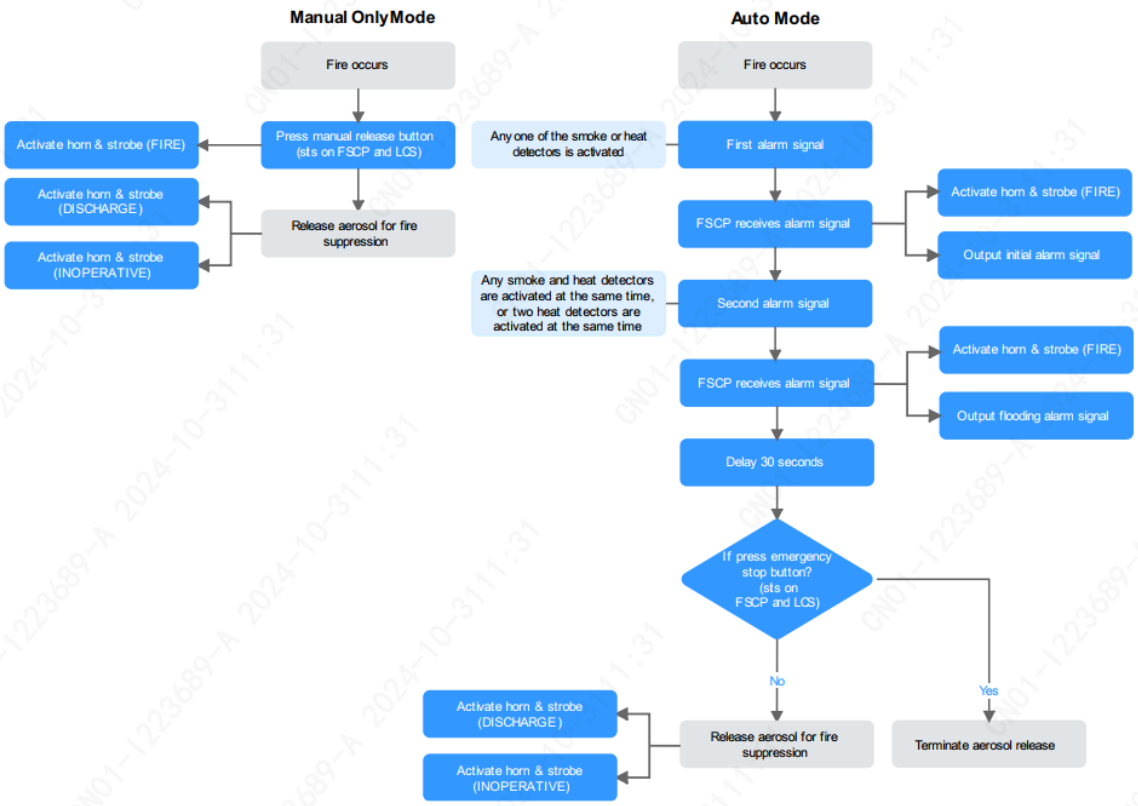
As an outdoor non-walk-in battery energy storage system, EnerX provides a perfect set of fire suppression system solutions with detection, explosion control and fire extinguishing functions. The fire extinguishing control strategy is divided into four levels:

- First level, alarm warning;
- Second level, ventilation and smoke exhaust to prevent deflagration;
- Third level, aerosol is released to extinguish the initial fire;
- Fourth level, dry pipe spraying to control the spread of fire.

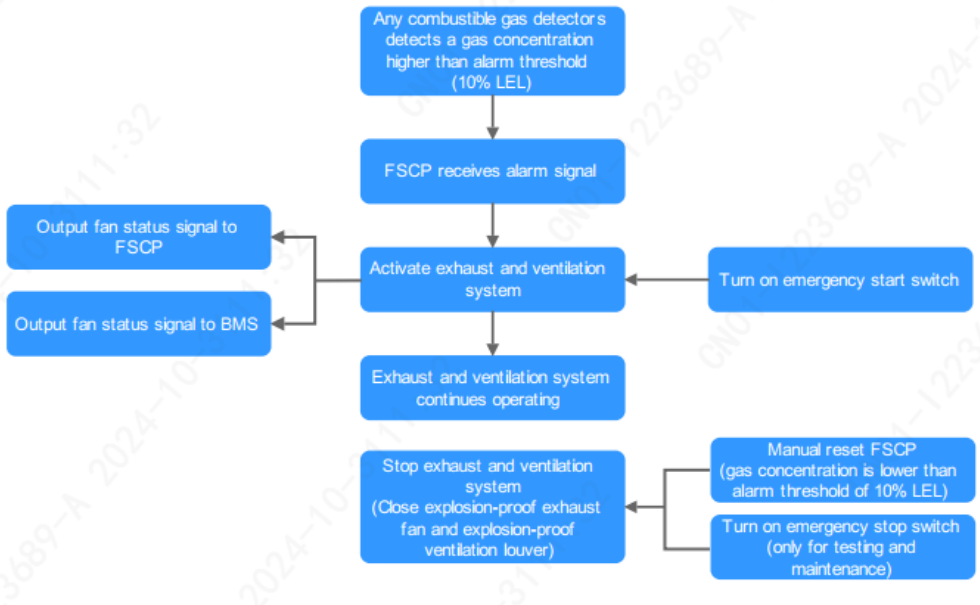
5.2 FSS Function and Logic

The fire suppression system is divided into three parts: detection system, explosion-proof system and fire extinguishing system. The information of the interactive interface is shown in the following Figure 5.





System Flow Diagram (Fire alarm and Suppression Control)



System Flow Diagram (Early detection and exhaust part)

Figure 5 The Interactive Interface and Logic of FSS

5.2.1 Detection System

The detection system has three types of detectors, the number and installation position of which are shown in Table 7 and Figure 6. All detection signals are received and processed by the fire control panel, and the hydrogen(H2) detector can be linked with the smoke exhaust ventilation system system. Table 7 Detector Type and Position Description

Table 7 Detector Type and Position Description

No	type	quantity	Configuration	remarks
1	Heat detector	2	Standard	Detection of temperature, in the battery room
2	Smoke detector	3	Standard	Detection of smoke particles, two in the battery room, and one in the electrical room
3	H2 detector	1	Standard	Detection of H2, in the battery room
5	Fire control panel	1	Standard	Receive detector signals and control fire extinguishing system and explosion-proof system, in the electrical room
6	Aerosol	12	Optional	When activated, aerosol power will be released rapidly to extinguish thermal runaway
7	Dry pipe	1	Optional	When activated, dry pipe spraying to control the spread of fire.
8	Fiber network	1	Optional	Communication between fire control panle and between two network cards and eventually to the terminal host AFC-1000, in the electrical room

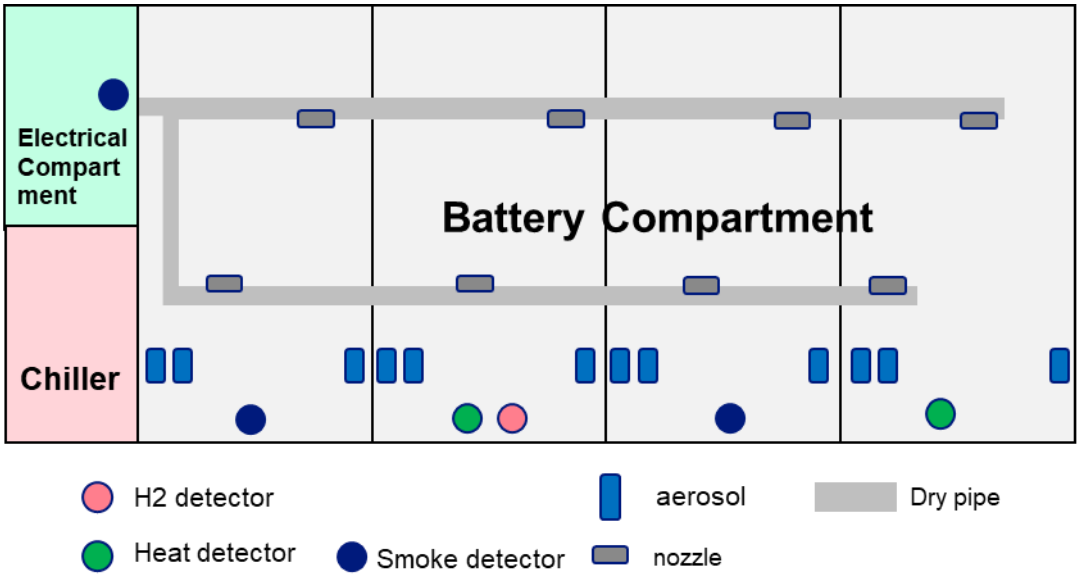


Figure 6 Type and Location of Detectors

5.2.2 Smoke exhaust ventilation System

Smoke exhaust ventilation system system meets NFPA855 (NFPA 69) standard, which is shown in Figure 7.Figure 7 Smoke exhaust ventilation system

Figure 7 Smoke exhaust ventilation system

The air inlet electric louver receives the alarm signal sent by the H2 detector and opens the electric louver. The parameters of the Inlet and outlet louver are shown in Table 8.

Table 8 The Parameters of the Inlet and outlet louver

Item	Specification
Supply voltage	24V DC

Rated power	60W
Position	Integrate in racks

The air outlet electric louver will turn on the smoke exhaust ventilation system and releases the combustible gas in the battery room after receiving the alarm signal from the H2 detector. The smoke exhaust ventilation fan will not automatically turn off even if the concentration of combustible gas falls within the reasonable threshold. Professional fire personnel need to determine whether the thermal runaway is over and reset on the fire control panel to stop the fan.

The parameters of the exhaust port are shown in Table 9.

Table 9 The Parameters of the Exhaust Port

Item	Specification
Supply voltage	230V AC
Rated power	128W
Position	Integrate in racks
Maximum air volume	820CFM

5.2.3 Fire Extinguishing System

5.2.3.1 Aerosol

When an initial fire occurs in the battery room, a fire alarm signal will occur, and the fire extinguishing system will automatically control the release of aerosol, which can also be triggered manually. The fixed position of aerosol is shown in Figure 6.

5.2.3.2 Dry pipe

As the last line of defense, the dry pipe system can effectively control the spread of fire, which is shown in Figure 8.

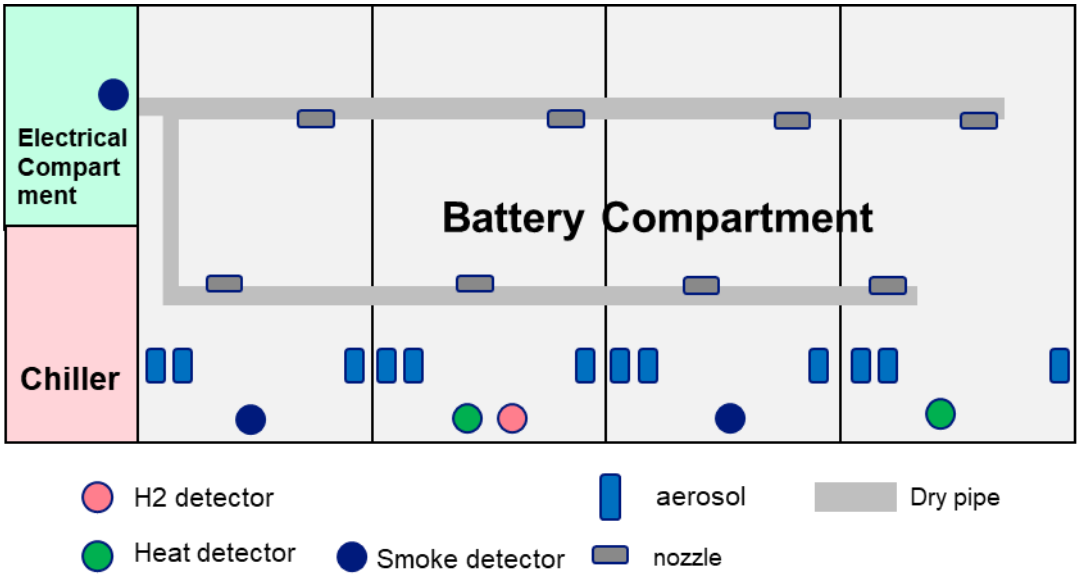


Figure 8 Dry Pipe System

The flange is installed at the entrance of the dry pipe fire protection system, for the connection between the pipes.

Table 3 The Paraments of The Flange

Item	Specification
Model	NPS 2’
Standard	ASME B16.5
Material	ASTM A105
Class	Class 150
Flange type	Threaded
Certificate	Integrate in Rack

The V2709 Standard Horizontal Sidewall Nozzles are open type nozzles with rubber plug, designed for directional spray application in fixed fire protection system.

Table 4 The Parameters of the Nozzle

Item	Specification

Model	V2709
Type	Standard Horizontal Sidewall
Maximum working pressure	250 psi/1725 kPa
End connection	½ NPT

6 Thermal Management System(TMS)

6.1 TMS Overview

The TMS system of EnerX is liquid cooling, which main function is to maintain the temperature of the battery system to an allowable operating temperature range. Thus, the battery shall work at the best conditions, adsorb and release the maximum energy, slow degradation the SOH and maintain the longest life.

The Thermal management system is composed with the high-efficiency liquid cooling unit, the liquid cooling pipe under the bottom of battery and the PTC heater. The TMS works under the control of BMS. BMS sends the start up or shut down signals to the cooling unit, then the cooling unit and the PTC heater will work together to change the temperature of circulating coolant liquid for heat exchange in the cooling pipe. The circulating liquid will exchange the heat with the battery through the pipe. Thus, the temperature of battery will increase or decrease into appropriate range.

For example, the cooling unit will be started if the BMS detect the battery temperature over the setting value. The cooling mode will be activated to decrease the temperature of circulating liquid until reaching the setting value. When the BMS detects the battery temperature less than the setting value, the heat mode will be activated to increase the temperature of circulating liquid until the setting value. Detailed information will be described below.

6.2 TMS architecture

Figure 9 Overview of the cooling unit of EnerX(mirror A)

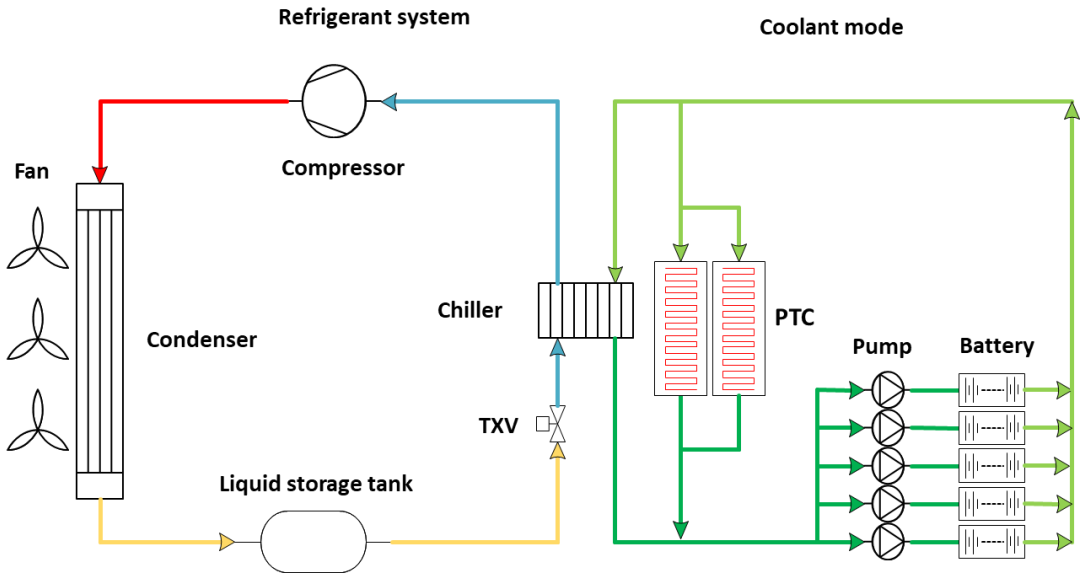


Figure 10 Architecture of Thermal Management System

The overview of cooling unit has been listed in Figure 9. EnerX own one high power cooling unit at the side of the container. TMS architecture can be described above (Figure 10). The composites parts are listed below:

a) Compressor. The function of compressor is to compress the low temperature and low pressure refrigerant gas into high temperature and high pressure refrigerant gas. Then the gas flow to the condenser through the pipe.

b) Condenser. The function of condenser is condensing the high temperature and high pressure refrigerant gas into ambient temperature and high pressure refrigerant liquid. Excess liquefaction heat will be taken away by the fan. Then the liquid flow to the chiller through the pipe.

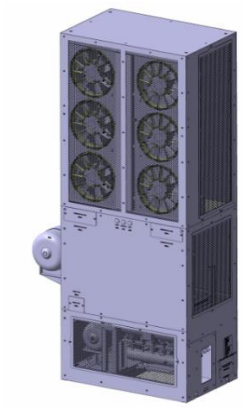
c) Chiller. The function of chiller is to exchange the heat from the refrigerant liquid with the coolant. The ambient temperature and high pressure refrigerant liquid will evaporate into low temperature and low pressure refrigerant gas. The heat will transfer from the coolant to the refrigerant liquid. The low temperature coolant will flow to the cooling plate to cool the batteries while the refrigerant gas return to the compressor. The circle process will continue and the heat of battery will be taken away.

d) PTC Heater. The positive temperature co-efficiency resistance. The PTC will heat the coolant when the TMS get signals that the temperature of coolant is below the setting value. Then the coolant will be heated until the temperature increases to the setting value. The battery will be warmed up by the coolant.

e) Pump. The pump will force the coolant into circulating in the pipe.

6.3 TMS Specification

Table 12 Main Feature of Thermal Management System5

	Coolant: 50%Ethylene glycol,50% Deionized water
	Max. ambient temperature: 55°C
	Power supply: 3AC 380…480V
	40kW Cooling capacity for 0.25P System
	Cooling capacity is auto-adjustable according to ambient temperature & discharge/charge status

The main features of TMS are listed above, which is shown in Table 12. The TMS will work under the ambient temperature range from -25℃ to 55℃. The cooling power is auto-adjustable according to ambient temperature & discharge/charge status. There are four operating modes for the TMS, including shutdown mode, cooling mode, heating mode and self-circulation mode.

Table 13 Power Consumption of Thermal Management System

Type of EnerX	**0.25P System**
Cooling Capacity	40kW
Maximum Heating Power	21.29kW
Maximum Cooling Power	27.87kW
EER	≥2.76 (18℃ TMS liquid , @35℃ ambient)

7 User Interface

7.1 PCS Requirements

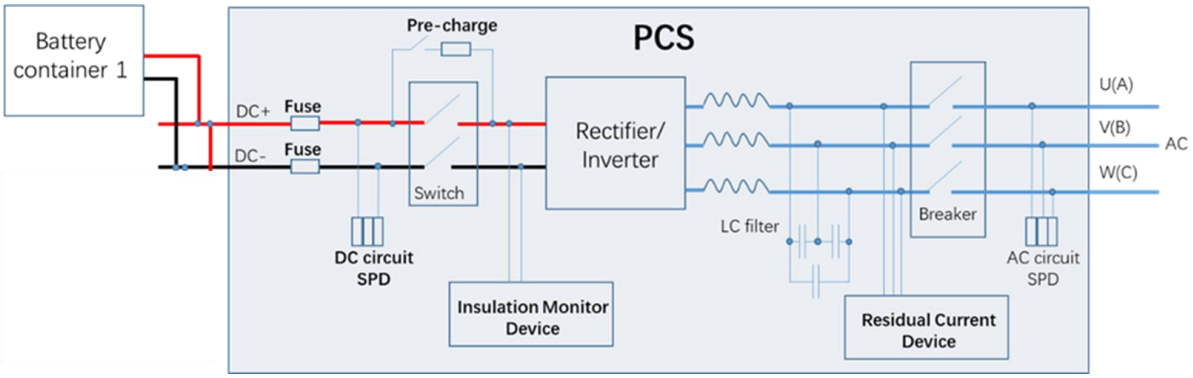


Figure 11 PCS Matching

- Please make sure to use one single copper Busbar for battery containers cable connection for positive or negative pole in PCS side.
- Please make sure to use Fuse(F) for DC circuit in PCS. The Fuse breaking time in PCS should less than the breaking time of fuse in battery container when short circuit occurs.
- Please make sure PCS have pre-charge circuit.
- Please make sure the PCS has a main circuit switch on the DC side .
- PCS should have SPD in DC high voltage bus.
- PCS should have SPD in AC side.
- PCS should have insulation monitor device. It is recommended that BMS monitor the insulation of DC bus before battery DC relay is closed. PCS monitor the insulation of DC bus after battery DC relay is closed. Communicate specific project strategy with CATL.
- PCS should have residual current device to monitor the leakage current on AC side.
- When the battery is in a low SOC state after discharge, the grid cannot charge the battery in time and needs short-term storage. In this scenario, it is necessary to ensure that PCS is disconnected from the battery to prevent the battery from being over discharged.

7.2 Fuse Matching

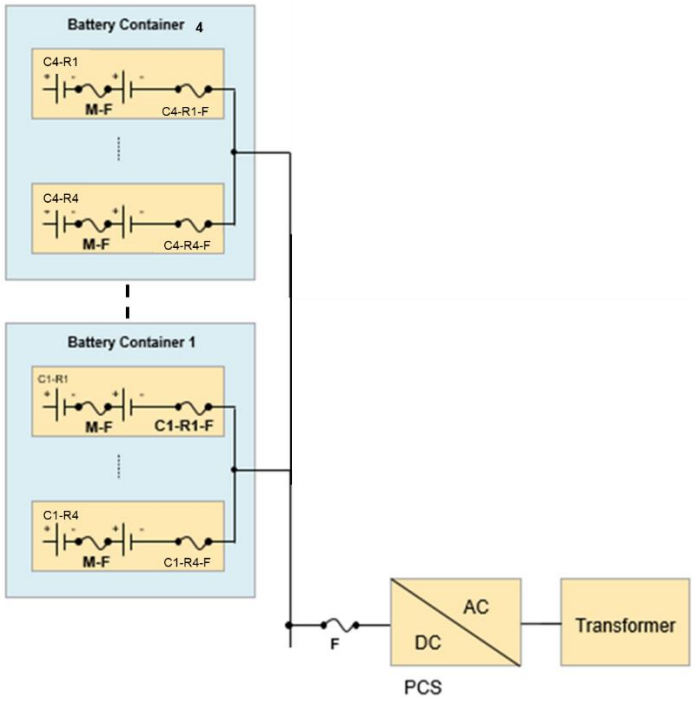


Figure 12 Fuse Matching

- The principle of fuse matching：
- Fuse Breaking Time: F<C-R-F<M-F. the F fuse means the fuses at the DC side of PCS. The C-R-F fuses means the fuses installed in the main control boxes. The M-F fuses means the fuses installed in the packs. The breaking time of F fuse is the minimum value of these three.
- Voltage Level：1500V
- One Container Fuse F short current: ~ 55kA

1. One PCS connect four battery containers. Every container has 4 racks .
2. PCS DC side fuse is Fuse F.
3. Battery rack fuse is C-R-F.
4. Module fuse is M-F.

7.3 Common Mode Voltage

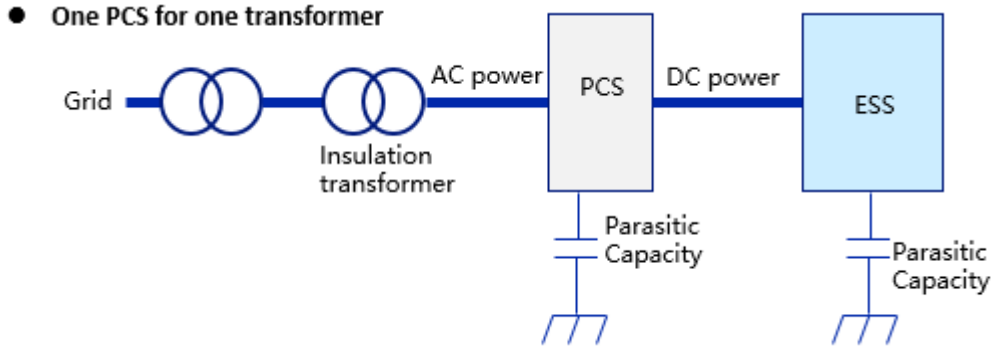


Figure 13 One PCS for One Transformer

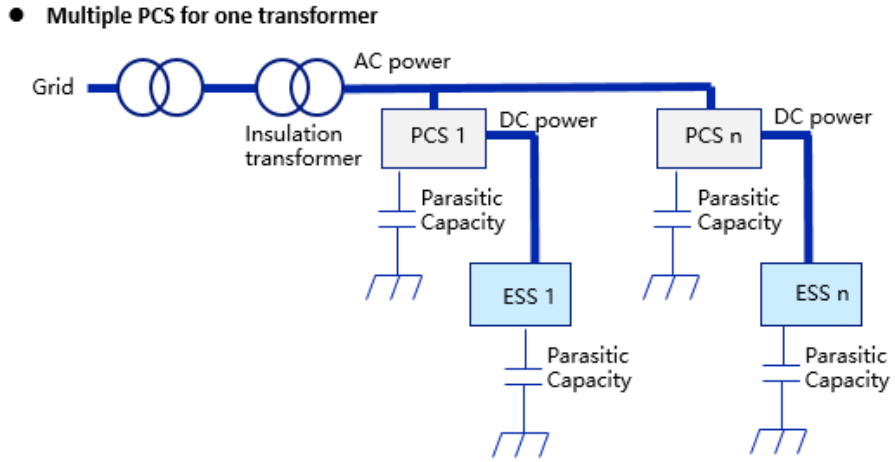


Figure 14 Multiple PCSs for One Transformer

The common mode voltage or current will affect the BESS reliability and personal safety. PCS will generate the common mode voltage and current due to the converter theory. Due to parasitic capacitance, the PCS should improve the insulation resistance isolation.And it is recommended to use insulation transformer. When multiple PCS are parallel connected, make sure that the switching of IGBT inside each PCS will not affect the other PCS to reduce the common mode voltage. The carrier synchronization should be considered in PCS control.

Make sure not to mix the AC and DC power cables, not to mix input and output cables, not to mix power cables and control cables.

7.4 Communication

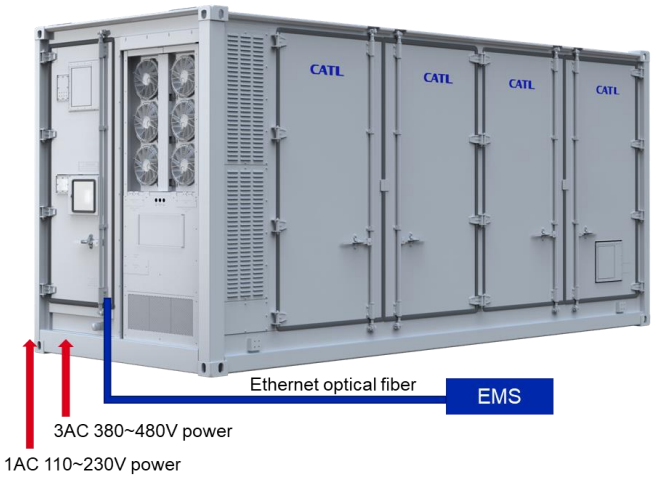


Figure 15 The Communication Architecture of the System with four containers in parallel

PCS should respond within 1s after BMS sending out the requirement.

PCS should respond within 1s after BMS sending out the emergency requirement by emergency dry contact.

PCS operation power should not exceed battery power limitation.

PCS should derating power to 0 W within 2s once receiving BMS limit to ZERO current requirement.

When the length of CAN communication loop exceeds to 30m, it is necessary to add CAN bridge to enhance communication signal.

It is recommended to use Ethernet optical fiber to communicating with EMS.

The A-CAN Bus or 485 Bus can be optional. If using the A-CAN Bus or 485 Bus, the Ethernet optical fiber will be not used.

8 Appendix

The attached is the triple view and the dimensions of EnerX. The front view, the side view, the top view. The detailed installation information can be found in the users’ manual.

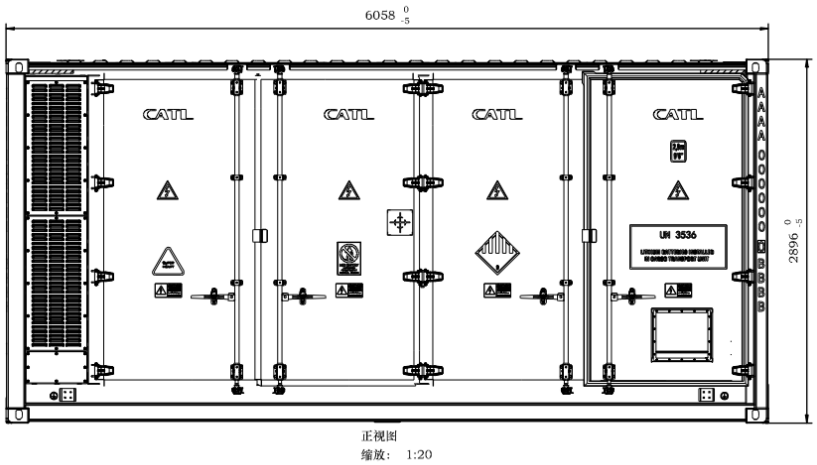


Figure 16 The Front View and Dimensions of EnerX(mirror A)

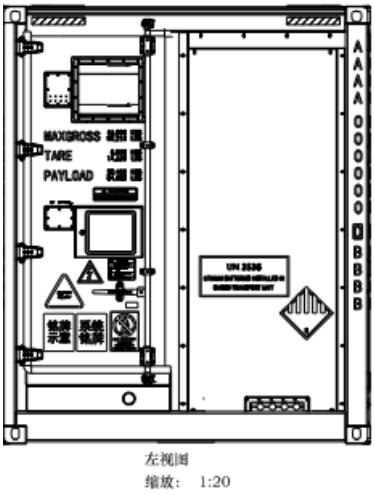


Figure 17 The Side View and Dimensions of EnerX(mirror A)

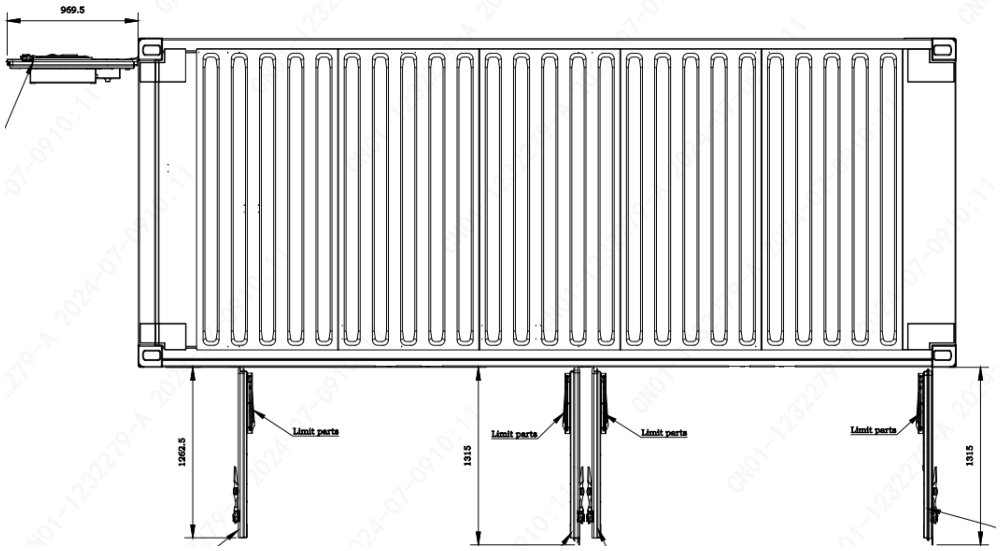


Figure 18 The Top View and Dimensions of EnerX (mirror A)

The recommended installation layout is as follows at Figure 19(Four containers in parallel).

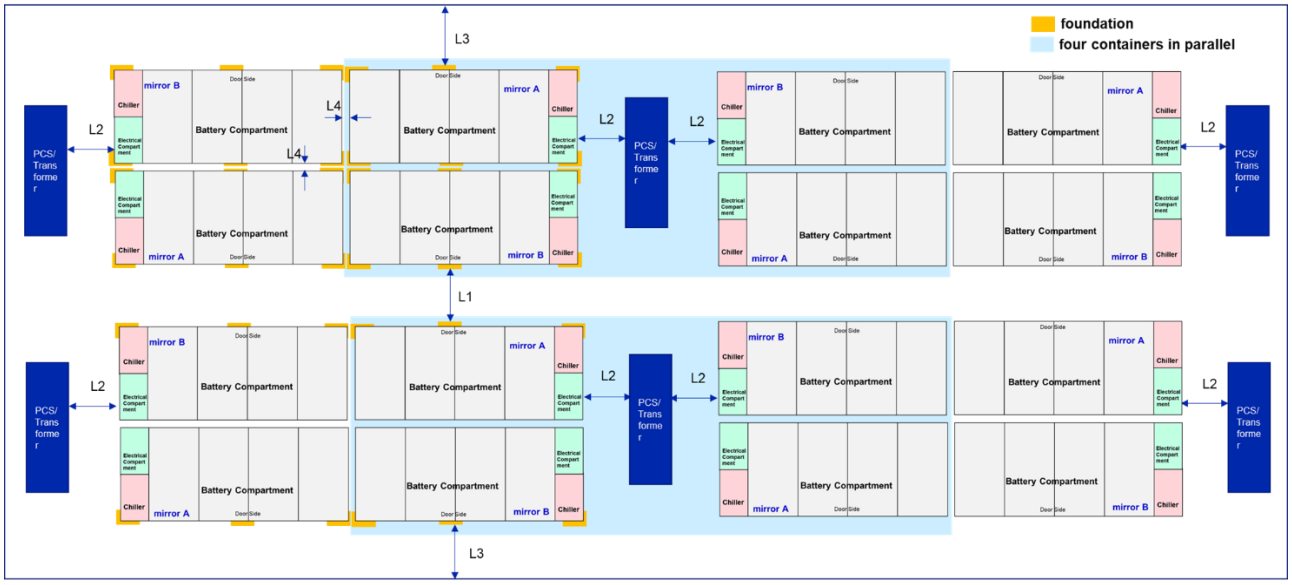


Figure 19 Containers installation layout(Four containers in parallel)

The recommended installation layout is as follows at Figure 20(There containers in parallel).

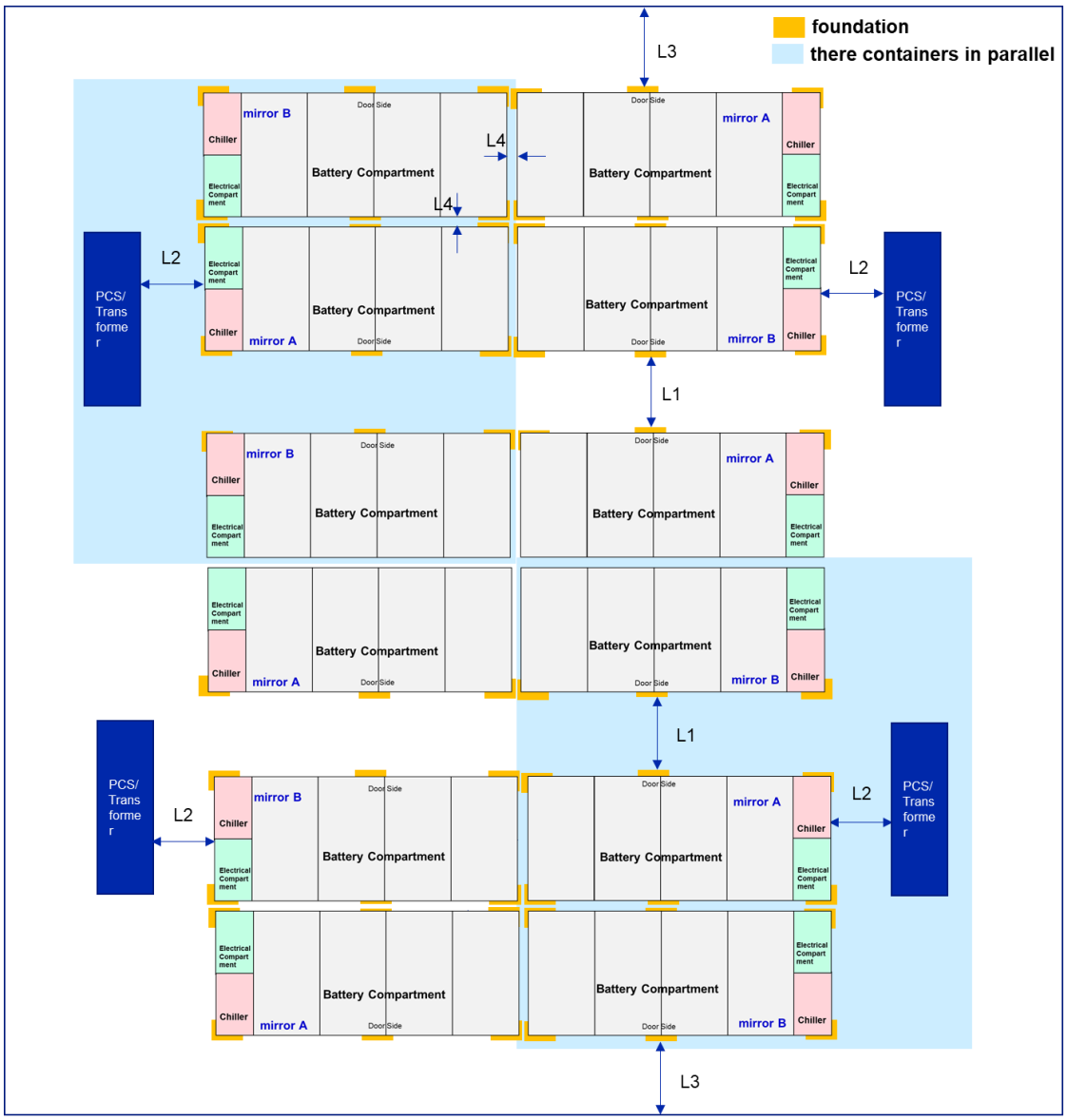


Figure 20 Containers installation layout(There containers in parallel)

To avoid the hot air interaction for two containers ,and to maintain the container, the minimum distance must be followed (note: L1 and L3 is the net distance excluding the foundation overhang):

L1 : 3.5m　　L3 : 3.5m　L4 : 0.90m

L2 : 3m (Customers need to check the required distance consider the influence of hot air interaction between PCS and container according to the specific selection of PCS)

To avoid the uneven current caused by the difference of cable resistance between parallel containers under one PCS, the recommended cable length is as follows:

The length of the cable between the container bus and PCS is less than 20m.

The cable length difference between parallel containers under the same PCS is less than 3 m.

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Appendix H

CATL EnerX User Manual

EnerX 0.25P

Operating Instruction and Maintenance Manual

Responsible agency:		**Confidential level:**	**Confidential**
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- CATL Confidential -

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1 Important Safety Instructions

SAVE THESE IMPORTANT SAFETY INSTRUCTIONS

Installation and service of the EnerX battery container requires knowledge of high voltage electricity and should only be performed by qualified persons. CATL assumes no liability for injury or property damage resulting from repairs attempted by unqualified individuals or a failure to properly follow these instructions. These warnings and cautions must be followed when using the EnerX product.

1.1 Electrically Safe Working Condition

A condition in which an electrical conductor or circuit component has been disconnected from BESS energized parts, LOTO procedures must be implemented, the isolation switches in this product must be locked and tagged, and the absence of voltage must be verified. If necessary, temporarily ground to protect personnel.

1.2 Qualified Person

A person who has demonstrated skills and knowledge related to the design, operation, and installation of BESS products and has received safety training to identify hazards and reduce associated risks.

Qualified persons shall be trained and knowledgeable in the operation of the battery system and specific work practices, and shall be trained to avoid the electrical hazards that are present. Such persons must be familiar with the proper use of precautionary techniques and PPE. Qualified person training shall include the following:

1. Skills and techniques to avoid the risk of electric shock:
    a) Between exposed energized surfaces, which may include temporarily insulating or guarding parts to allow the worker to work on exposed energized parts.
    b) Between exposed energized surfaces and grounded equipment, other grounded objects, or the earth itself, which may include temporarily insulating or guarding parts to allow the worker to work on exposed energized parts.
2. The method of determining the working limits of the battery system.

1.3 Safety Symbols

The following are some basic safety symbols and descriptions that apply to all BESS equipment.

	DANGER When energized, this equipment presents a potential hazard of electric shock, burn or death. Only authorized personnel who are thoroughly familiar with the equipment and adequately trained may install, operate or maintain this equipment. To prevent death, personal injury, or damage to equipment, follow all site safety procedures as indicated by HSE Plan. To minimize hazard of electrical shock, death and burns, approved grounding practices must be strictly followed.

	WARNING To prevent personal injury or damage to equipment, personnel shall adhere to site protocol regarding working at heights. To prevent personal injury or equipment damage by equipment malfunction, only adequately trained personnel should modify any programmable machine. Always ensure applicable standards and regulations are followed and only properly certified equipment is used as a critical component of the safety system. Never assume that critical-safety control loop is closed.

	WARNING — Shock Hazard Do not come into contact with system connectors or terminals. Do not open the enclosure doors unless appropriate LOTO procedures are followed, PPE and related training as required by local codes and regulations are part of the maintenance plan.

	WARNING — Arc Flash Hazard There is an arc flash hazard associated with all electrical equipment. There is an increased risk of arc flash with any equipment modification (e.g., open doors). Serious injuries can occur in arc flash incidents. Appropriate PPE and training as per local codes and regulations is required.

	WARNING — Fire Hazard Fire is possible under certain, extreme fault conditions.

	CAUTION
	Indicates a procedure, condition, or statement that, if not strictly observed, could result in damage to or destruction of equipment.

The following directives must be followed when working with or near the BESS equipment.

1. Safety parameters and procedures are site-specific, and therefore, must be developed by the customer.
2. Review and refer to all safety warnings contained in this manual before beginning operations. Follow all the safety procedures as prescribed be the supplier manufacturer published safety procedures for each equipment.
3. Establish a clear, permanent, restricted access around the system. Fire extinguishers must be readily available on-site.
4. The system requires a clean, mechanically stable operating environment, free from conductive contaminates, combustibles, moisture, liquids and gases and corrosive substances. The system may be operated only when the ambient temperature is between **-35°C to 55°C**. Do not tap, drill puncture or attach anything to the equipment enclosures. Ensure there is enough clearance on all sides of the enclosures to allow access to the system. Remove watches, jewellery, rings and other metallic objects and always use tools with insulated handles.
5. Follow all applicable Lock Out/Tag Out (LOTO) procedures always. If proper LOTO procedures are not followed, serious injury or death could result. With power applied to the equipment, hazardous voltages will be present on some components. To prevent accidental death or injury, do not touch any components within the enclosure unless specifically directed to do so. To reduce risk of electrical shock, verify that all equipment is properly grounded.
6. Strobes and alarms within the system for evacuation are activated by the FSS system.

	WARNING
	Only authorized, adequately trained energy storage personnel with proper Personal Protective Equipment (PPE) can access the system. Do not open the equipment access doors unless qualified person.

1.4 Primary Risks Associated With BESS

The primary risks associated with the BESS system are:

1.4.1 Hazardous Voltage

Hazardous Voltage
• High AC at MV Switchgear, Isolation transformer and Auxiliary Transformer. • High AC at PCS input, aux transformer input. • 1500 VDC at PCS output, Battery container.
Consequence
• Electrocution, Fire, Explosion.
Avoidance
• Only qualified and authorized person should only be allowed restricted access. • Equipment barriers must remain in place. • PPE must be appropriate for the task and equipment

1.4.2 Arc Fault

Arc fault
• When insulation breakdown or accidental contact between high voltage conductors, an arc fault will be happen through the air gap between conductors.
Consequence
• Arc fault creates an electrical explosion. • Light and heat emitted from the explosion is known as **arc flash**. • Pressure wave caused by the tremendous temperatures of the arc flash is known as **arc blast**.
Avoidance
• Only qualified and authorized person should only be allowed restricted access. • Restricted access. • Equipment barriers must remain in place. • PPE must be appropriate for the task and equipment.

1.5 Arc Flash Hazard Boundary

The US National Fire Protection Association (NFPA) has developed specific approach boundaries designed to protect employees while working on or near energized equipment. These boundaries are:

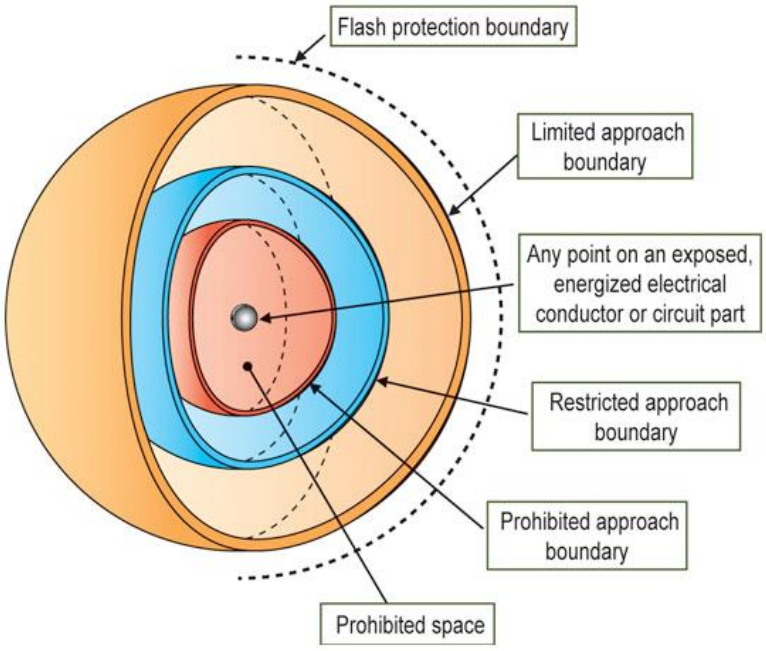


Figure 1-1 Arc Flash Boundaries

- Flash Protection boundary (outer boundary) – this is the furthest established boundary from the energy source. If an arc flash occurred, this boundary is where an employee exposed to a curable second-degree burn. The issue here is the heat generated from a flash that results in burn.
- Limited approach – An approach limit at a distance from an exposed live part where a shock hazard exists.
- Restricted approach – An approach limit at a distance from an exposed live part which there is an increased risk of shock.
- Prohibited approach (inner boundary) – A distance from an exposed part which is considered the same as making contact with the live part.

1.6 Arc Flash Label

According to “Maximum Power Method” in NFPA 70E, the estimated DC arc flash incident energy at the maximum power point can be calculated, and then the hazard boundary is defined as following figure.

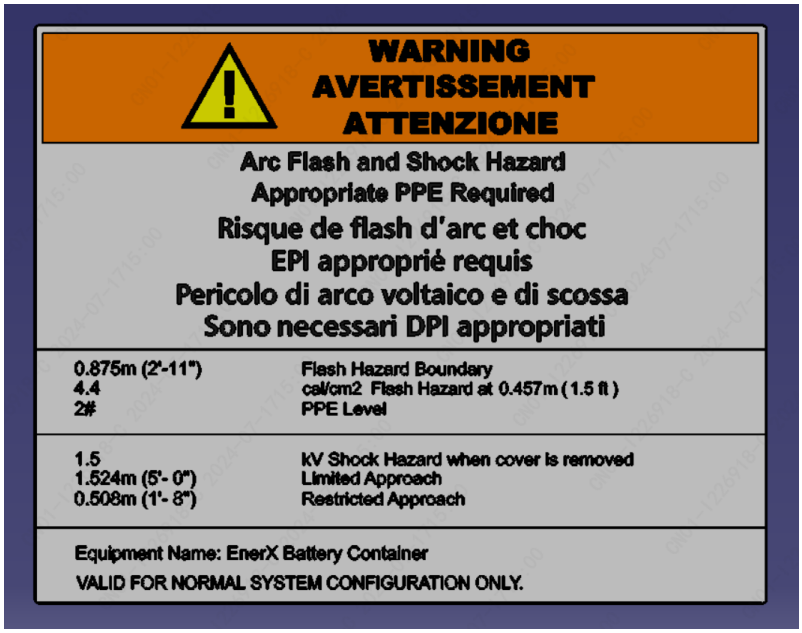


Figure 1-2 Arc Flash Label

1.7 Personal Protective Equipment (PPE)

The PPE is determined by the incident energy which is the temperature produced (in cal/cm²) at a distance (usually eighteen inches) from an arc flash.

PPE requirement for one EnerX battery container operational precautions is category 2

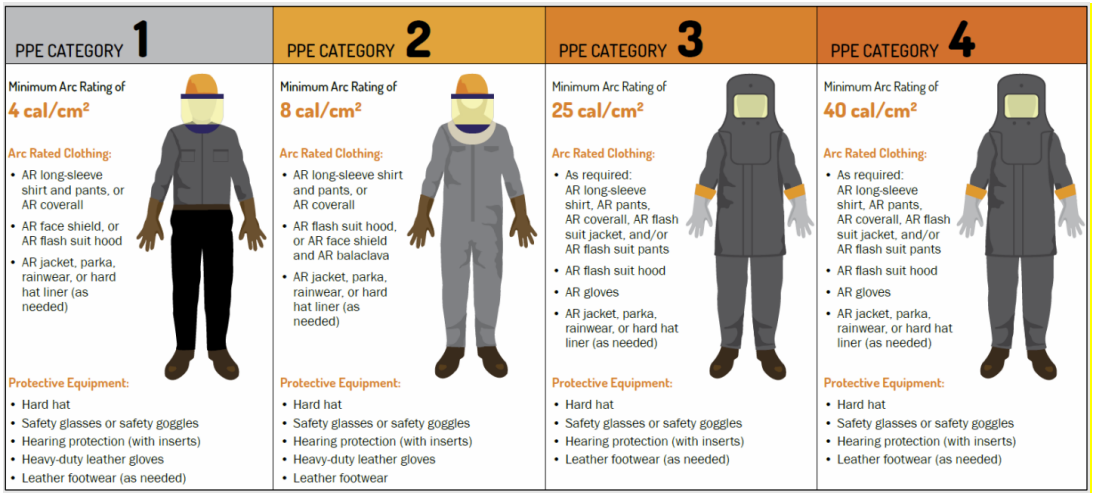


Figure 1-3 PPE Category

1.8 LOTO Procedure

1. The battery container needs to be powered off first. Check the status of PCS and battery containers from EMS, make sure that the circuit breakers/contactors of PCS DC side are all disconnected, and the HV contactors of all racks in the battery containers are disconnected.
2. PPE 2 is required for operator.
3. Turn off the AC circuit breaker QF1, QF2,QF3, QF4 , QF5, QF6(or QS),QF7 and QF8 inside the container distribution box that connect the external auxiliary power. Hang a LOTO warning sign on the door of the distribution box to prevent it from being turned back on.
4. Turn off the on-site AC circuit breaker which supplies the external auxiliary power of the battery containers. Apply a LOTO adapter and LOTO lock and tag to the circuit breaker handle to prevent it from being turned back on.
5. Check, with a multi-meter, that the 1,500 VDC bus bar reads 0 V.
6. Switch off the isolation switch of the rack to “OFF” state. Pull out the LOTO ring of the isolation switch handle and apply LOTO lock and tag to the LOTO ring to prevent it from being turned back on.
8. Install a safety ground clamp from the positive 1,500 VDC bus bar to the ground bar. Use a shotgun stick to make the initial contact between the positive 1,500 VDC bus bar and ground.
9. Install a safety ground clamp from the negative 1,500 VDC bus bar to the ground bar. Use a shotgun stick to make initial contact between the negative 1,500 VDC bus bar and ground.

2 Manual Overview

2.1 Applicable Scope

This manual is applicable to the EnerX battery container.

All references to “battery container” in this manual, unless specifically indicated here in, refer to the product series mentioned above.

2.2 General

This manual has been prepared primarily for Battery Energy Storage System (BESS) operators and service personnel and provides three essentials: operation, maintenance and parts information for the BESS. A distribution of text revisions when necessary will be made to all recipients of the Operations and Maintenance manual.

Personnel who practice good operating and maintenance procedures ensure BESS reliability. It is of vital importance that station personnel, trained or untrained in BESS operation, become thoroughly familiar with the information contained in this manual. Prior to BESS operation, a sound program of maintenance should be developed and instituted. Adherence to such a program will result in reduced operating costs, fewer outages, and shorter periods of downtime.

2.3 Manual Updates

An experienced staff from the best information available has compiled the manuals provided for this BESS equipment prior to the time of shipment. Due to your shipping requirements and our desire to meet manual delivery commitments, manuals may be shipped with missing information. All manuals in your hands should be updated as material is received from CATL Company. To assist you in revising and updating your manuals, we offer the following suggestions:

1. Identify those individuals or functions who will be using the sets of manuals.
2. Assign the manuals to each individual or function and number each set.
3. Maintain a log of manual sets and the associated owners.
4. If possible, assign a librarian to ensure all controlled (or numbered) sets of manuals are updated as material is received from CATL. If this is not possible, each owner must keep their set of manuals current.
5. Retain shortage/revision instructions sheet at the front of the appropriate volume. This acts as a log of updates received.
6. Follow instructions for insertion of new material exactly. If the material is not filed properly, it cannot be easily found.
7. Insert shortage/revision material in manuals as soon as received. Some updates are small and can be misplaced.
8. All other manuals left from installations, etc., should be clearly labelled as extras, spares, or not controlled copies.

2.4 Abbreviation

CATL	Contemporary Amperex Technology Limited
BMU	Battery Management Unit
BMS	Battery Management System
BESS	Battery Energy Storage System
EMS	Energy Management System
PCS	Power Conversion System
CSC	Cell Supervision Circuit
CSU	Current Sample Unit
ETH	Ethernet Module
FSS	Fire Suppression System
HV	High Voltage
LV	Low Voltage
LOTO	Lockout/Tagout
MBMU	Master battery management unit
SBMU	Slave Battery Management Unit
IMM	Insulation monitoring Module
CAN	Controller Area Network
ACAN	CAN between BMU and PCS
CCAN	AN between BMU and CSC
SCAN	CAN between BMU and CSU
DCAN	CAN for calibration
BOL	Begin of Life
EOL	End of Life
SOC	State of Charge
SOE	State Of Energy
SOH	State of Health
SOP	State Of Power
TMS	Thermal Management System

3 Product Introduction

3.1 Product Overview

EnerX Battery container is the core unit in the energy storage system and acts as the equipment for storing electrical energy. It can be applied to many applications including renewable energy integration, frequency regulation, and voltage regulation of the grid.

Battery container consists of battery system, battery management system (BMS), fire suppression system (FSS), thermal management system (TMS) and auxiliary distribution system.

Figure 3-1 EnerX Liquid Cooling Energy Storage Container (mirrorA) – Left Sideview

Figure 3-2 EnerX Liquid Cooling Energy Storage Container (mirrorA) – Right Sideview

The basic units for whole system is list as following:

Table 3-1 Components of battery container

System	Sub Components	Number	Remark
Battery Racks	20 Feet Container	1	2896mm(H)*2438mm(W)*6058mm(D)
	Battery Module	32	With CSC
BMS	Master Control Box	1	Including IMM, MBMU, ETH, fiber optic module
	Sub Control Box	4	Including SBMU, fuse, isolation switch and so on
TMS	Liquid Cooling Unit(Chiller)	1	Including compressor, pump, fan, heater and others
FSS	Fire Suppression System	1	Including fire control panel, smoke detectors, gas detectors, heat detectors, explosion-proof fan, aerosol(optional), dry pipe(optional), fiber optic networking card(optional)
Auxiliary Power Supply	Distribution Box	1	Including transformer, circuit breaker, UPS/24V power module, E-stop circuit, circuit protection and power supply on-off control circuit, type II SPD for AC power supply

3.1.1 Battery rack system overview

The battery system consists of 4 battery racks connected in parallel.

Figure 3-3 EnerX liquid-cooling energy storage container overview – inside

The battery system consists of 4 battery racks connected in parallel, each battery rack contains 8 battery modules, each battery module consists of 104S(2P52S) battery cells connected in series, so the battery system contains 3328 battery cells.

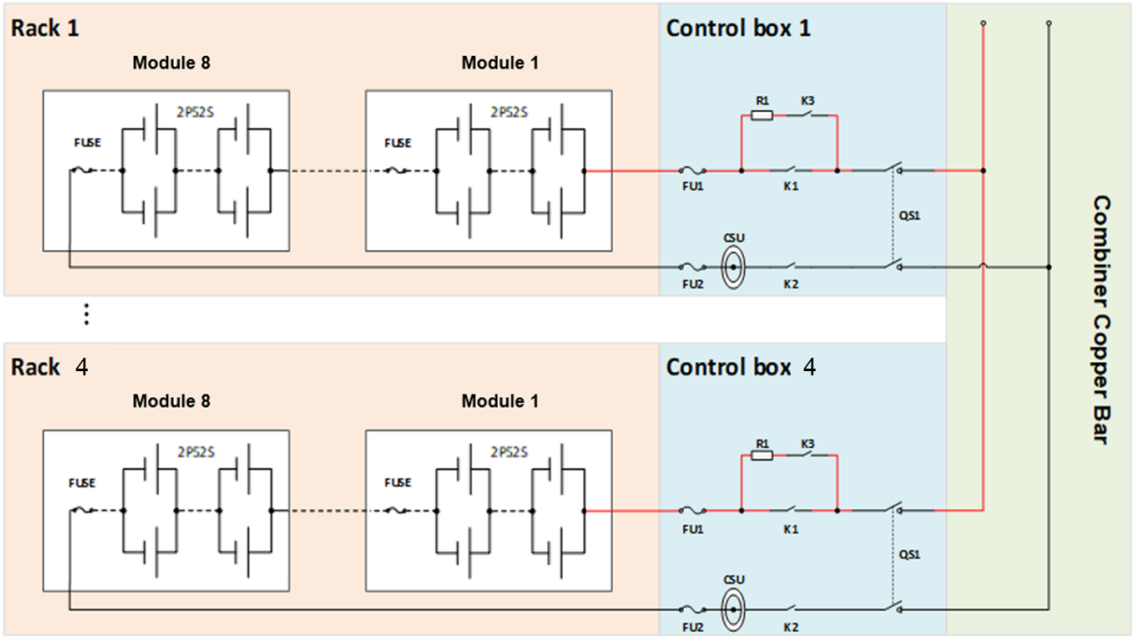


Figure 3-4 Circuit diagram of battery racks

3.1.2 Battery module overview

A total 104 (2P52S) lithium-iron cells (530Ah/3.2V) in series connection are used for each battery module. An internal high speed DC fuse is included for safety protection.

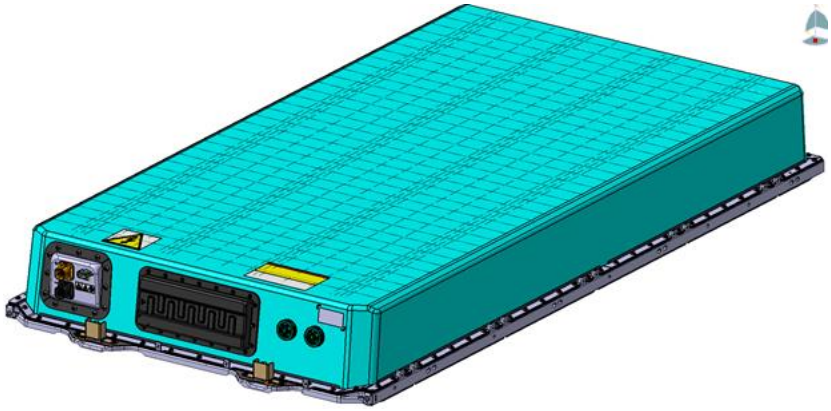


Figure 3-5 Battery module -- exterior overview

3.1.3 Master Control Box

The MBMU, IMM, ETH, fiber optic module are integrated to master control box together.

3.1.3.1 Functional Description of the Master Control Box

Table 3-2 Module Function of the Master Control Box

Module	Function
MBMU	1. Controlling system power on and off MBMU detects the state of system power button to switch state. When receive system power on command from EMS, MBMU can turn itself on from off; When receive system power off command, MBMU can turn itself off from on. 2. Synchronize time ● MBMU synchronizes the time via CAN communication. 3. CAN communication ● MBMU consists of 3 channels of CAN communication including MCAN, DCAN and ACAN： 1) MBMU communicates with SBMU, ETH, PC monitor via MCAN. 2) MBMU communicates with TMS (Thermal Management System) via DCAN. 3) MBMU communicates with ETH via ACAN. 4. Environment temperature detection ● MBMU contains 2 temperature detection inputs: - 40℃~85℃ range, ±3℃ accuracy. ● One temperature sensor is located on the fire control panel and one temperature sensor is located on the transformer T1 in the distribution box. ● MBMU gives a Level 1 alarm when the environment temperature exceeds 60 °C. 5. Addressing ● MBMU can address CAN and RS485. 6. System status upload ● MBMU can upload SOC, SOH, SOP and operation status of the system. 7. Contactor driver and auxiliary equipment power supply ● MBMU controls the rack HV relays to turn on or off when a PCS or EMS command is received via the SBMU.

Module	Function
	● MBMU has high-side outputs that can be used to drive a power supply relay for external devices or to supply power directly to auxiliary devices. High-side output also has fault diagnosis function. 8. Dry contact detection ● MBMU has dry contact detection, which is used for identifying the working states of SPD, UPS, FSS, auxiliary power supply and so on. 9. Insulation status judgment ● MBMU can calculate and determine the current insulation status of the system based on the insulation value provided by the current IMM test board, and send it by means of communication. 10. Relay split and combine commands ● MBMU can control SBMU to turn on and off the relay of single or all electrical cabinets according to control commands from PCS and EMS. 11. Ventilation fan status detection ● MBMU can detect the status of the ventilation fan, whether the fan is open or closed.
IMM	1. Insulation testing ● Support insulation detection function to measure insulation resistance between HV+ and case and between HV- and case. 2. CAN communication ● It has a CAN communication function to communicate with MBMU.
ETH	1. Ethernet communication: ● ETH communicates with PCS and EMS externally via RJ45 interface. Based on TCP/IP, the IP address allocation method can be configured as fixed IP or DHCP according to requirements. The Modbus protocol is now supported. 2. Remote update: ● ETH supports to remote update of the BMS system from client via Ethernet. 3. CAN communication: ● ETH has two CAN interfaces, which receive the status information of the BMS system through MCAN, and can also receive and send PCS information through ACAN.

Module	Function
	4. The ETH has an Ethernet interface
Fiber optic module	Convert Ethernet to optical signal.

3.1.3.2 Interface description of Master Control Box

Figure 3-6 Master Control box---Outside view

- JX1: A-CAN bus. The A-CAN bus can be connected to the PCS.
- JX2: RS485 bus. The RS485 bus can be connected to the PCS.
- JX3: Debug. This is an internal CAN bus for debugging.
- JX4: JX4 is an internal communication port.
- JX5: Emergency dry contact. Includes emergency dry contact to PCS and emergency dry contact from EMS.
- JX6: M-CAN bus. JX6 pin1 and 2 are the M-CAN bus for parallel containers communication. If you choose CAN bridge in the container, the M-CAN bus for parallel containers communication is the CAN bridge.

The definition for communication terminal JX1, JX2, JX3, JX4, JX5,JX6 see Table 3-3

Table 3-3 connector information of master control box

No.	Connector	Definition	Connector information	Remark
1	JX1-1	A-CAN-H	A-CAN Bus	Communicate with the PCS through CAN port
2	JX1-2	A-CAN-L		

3	JX1-3	GND_ACAN		
4	JX1-4	Reserve		
5	JX2-1	RS485A	485 Bus	Communication with the PCS through 485 port
6	JX2-2	RS485B		
7	JX2-3	GND		
8	JX3-1	D-CAN-H	Internal CAN bus for debugging	Debugging
9	JX3-2	D-CAN-L		
10	JX3-3	A-CAN-H		
11	JX3-4	A-CAN-L		
12	JX3-5	M-CAN-H		
13	JX3-6	M-CAN-L		
14	JX3-7…10	Reserve		
15	JX4-1	M-CAN-H	Internal communication. Installed by CATL in factory	Communication between SBMU and MBMU
16	JX4-2	M-CAN-L		
17	JX4-3	SBMU_Code_Out		
18	JX4-4…6	Reserve		
19	JX4-7	M-CAN-H		
20	JX4-8	M-CAN-L		
21	JX5-1	E_Stop_to_PCS+	Emergency dry contact	Emergency dry contact to PCS.
22	JX5-2	E_Stop_to_PCS-		
23	JX5-3	E_Stop_to_BMS+		Emergency dry contact to BMS
24	JX5-4	E_Stop_to_BMS-		
25	JX6-1	M-CAN-H	M-CAN bus for parallel containers communication.	M-CAN is used for parallel containers.
26	JX6-2	M-CAN-L		
27	JX6-3	MCAN_GND		
28	JX6-4	Reserve		
29	JX6-5	CAN bridge_24V+		
30	JX6-6	CAN bridge_24V-		
31	JX6-7	M-CAN-H		
32	JX6_8	M-CAN-L		

3.1.4 Sub control box

Sub control box integrates SBMU, HV contactors, precharge circuit, high breaking capacity and high speed DC fuses, which can control battery rack by SBMU and send battery status data to MBMU via CAN bus. A total of four sub control boxes are contained in one container, the panel diagram of which is shown in Figure 3-7.

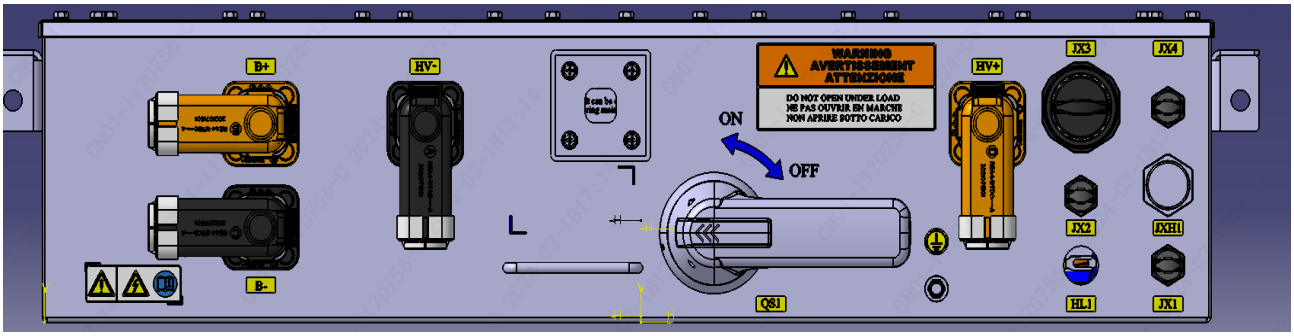


Figure 3-7 Sub Control box

Table 3-4 connector information of sub control box

No.	Connector	Definition	Remark
1	JX1-1	M-CAN-H_OUT	Connect to the next sub control box
2	JX1-2	M-CAN-L_OUT	
3	JX1-3	SBMU _Code _OUT	
4	JX1-4	Reserve	
5	JX2-1	M-CAN-H_IN	Connect to the previous sub control box
6	JX2-2	M-CAN-L_IN	
7	JX2-3	SBMU _Code _IN	
8	JX2-4	Reserve	
9	JX3	C-CAN	The physical connection of the 8 battery modules in the rack
10	JX4-1	M-CAN-H	Debug for commissioning
11	JX4-2	M-CAN-L	
12	JX4-3	C-CAN-H	
13	JX4-4	C-CAN-L	
14	JXH1-1	C_Box_24V+_OUT	Auxiliary power supply for the next sub control box
15	JXH1-2	C_Box_24V-_OUT	
16	JXH1-3	C_Box_24V+_IN	Auxiliary power supply for the previous sub control box
17	JXH1-4	C_Box_24V-_IN	
18	HV+	Positive output	Connect to high voltage
19	HV-	Negative output	
20	B+	Positive input	Connect to the battery module
21	B-	Negative input	

Table 3-5 Information of switch

No.	Switch	Name of switch	Function
1	QS1	Isolating switch	To turn the output of the battery system on and off. (Cannot operate under load)

3.1.5 FSS overview

As an outdoor non-walk-in battery energy storage system, Ener X provides a complete set of fire suppression system solutions with detection, explosion control and fire suppression functions. The fire suppression control strategy is divided into four levels:

- The first level: Alarm warning;
- The second level: Smoke exhaust ventilation system to prevent deflagration;
- The third level: Aerosol is released to extinguish the initial fire;
- The fourth level: Water spraying to control the spread of the fire.

The fire suppression system is divided into three parts: detection system, exhaust ventilation system and fire suppression system.

The main components are listed as follows.

Table 3-6 Main components of FSS

NO.	Category	Product name	Quantity	Configuration	Remark
1	Detection and alarm system	Fire control panel	1	Standard	Receives detector signals and control fire suppression and smoke exhaust ventilation system, in the electrical compartment
		Fiber optic networking card	1	Optional	Converts the signal from the fire suppression control panel to a fiber optic signal. It is used for the signal between two network cards and the terminal host AFC-1000
2		H2 detector	1	Standard	Detection of hydrogen, in the battery compartment
3		Heat detector	2	Standard	Detection of temperature, in the battery compartment
4		Smoke detector	3	Standard	Detection of smoke particles, two in the battery compartment, and one in the electrical compartment
5		Releasing circuit disable switch	1	Optional	In the electrical compartment
6		Horn and strobe	3	Standard	On the electrical compartment

					door
7		Two relay two input module	4	Standard	In the electrical compartment
8	Smoke exhaust and ventilation system	Explosion-proof exhaust fan	1	Standard	Adjacent to the thermal management system
9		Explosion-proof ventilation louver	2	Standard	On the battery compartment door
10		Fan emergency switch	1	Standard	On the electrical compartment door
11	Fire suppression system	Aerosol	12	Optional	In the battery compartment
12		Fire alarm pull station	1	Standard	On the electrical compartment door
13	Dry pipe system	Nozzle with rubber plug	8	Optional	In the battery compartment
14		Flange	1		Adjacent to the thermal management system

The information of the interactive interface of FSS is shown in the following Figure 3-8.

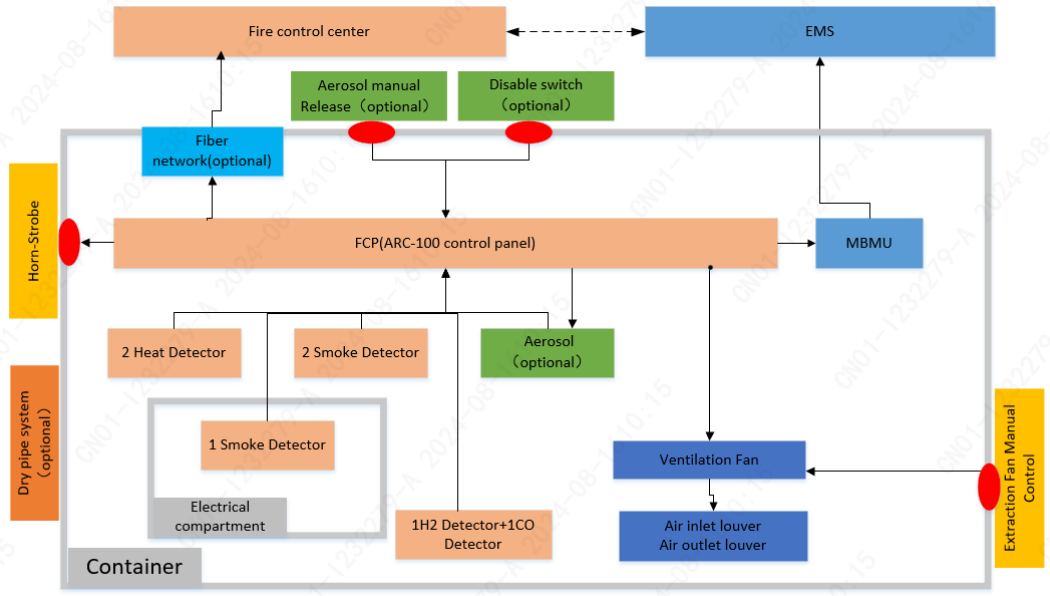


Figure 3-8 The interactive interface of FSS

The detection system has three types of detectors, the number and installation position of which are shown in Table 3-6 and Figure 3-9. All detection signals are received and processed by the fire suppression control panel.

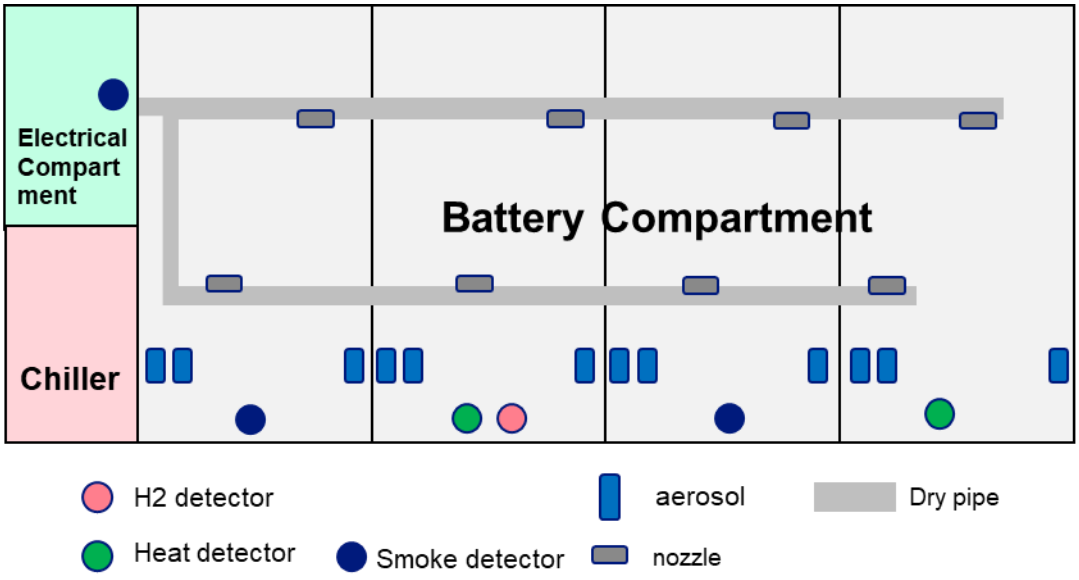
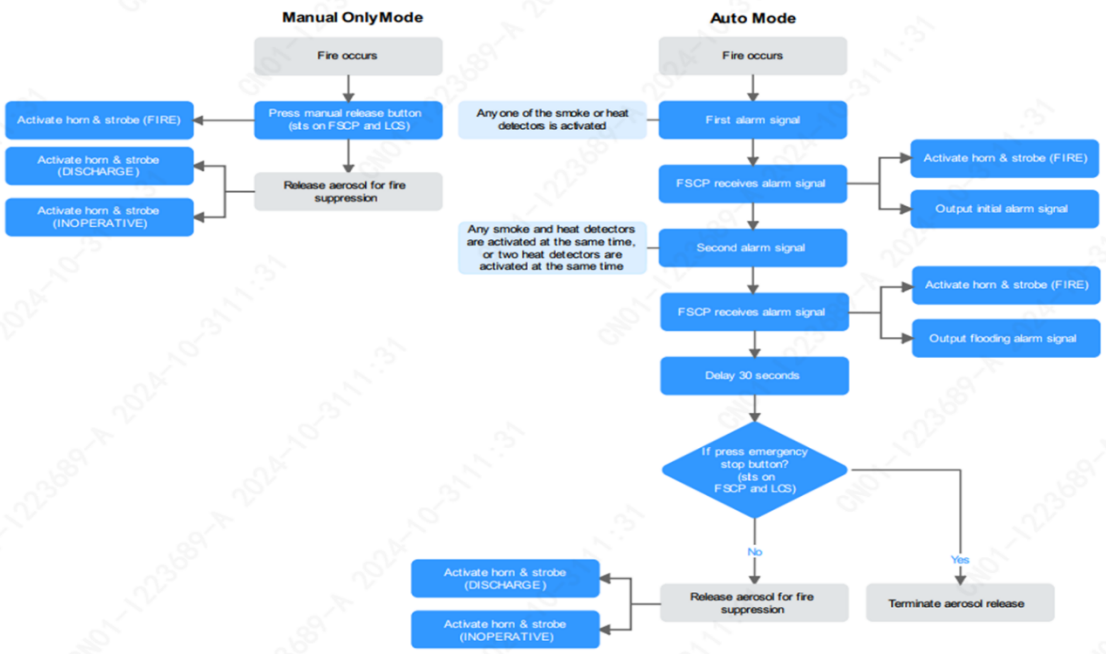
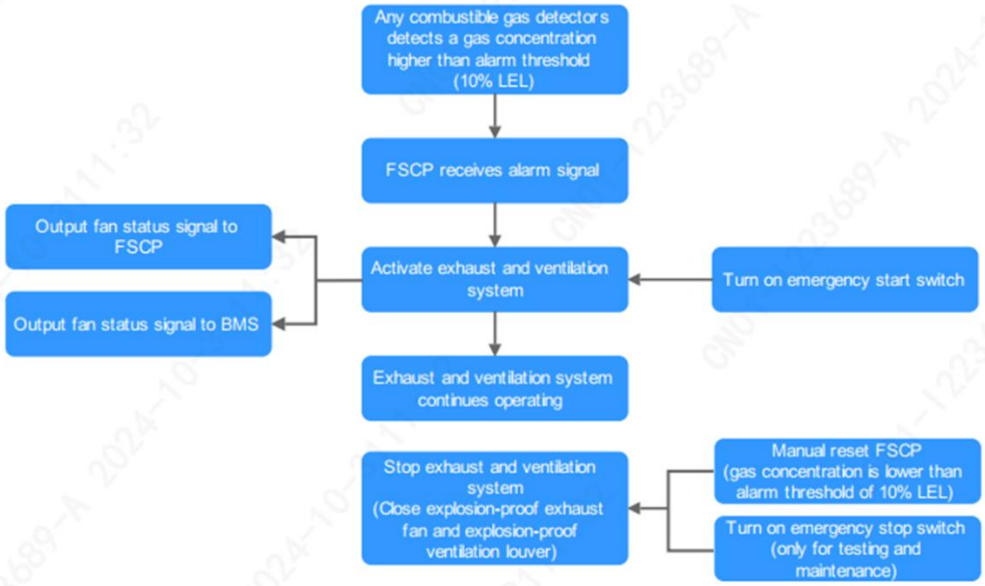


Figure 3-9 Type and location of detectors（Top view）



System Logic Diagram: (Fire Alarm and Suppression Control Part)



System Logic Diagram: (Early Detection and Exhaust Part)
Figure 3-10 FSS control logic overview

3.1.5.1 Smoke exhaust ventilation system

Using Smoke exhaust ventilation system to meet NFPA69 standard. As shown in Figure 3-11.

Figure 3-11 The design of smoke exhaust ventilation system

The smoke exhaust ventilation system receives the alarm signal from the FCP after the FCP receives the alarm signal sent by the H_2 detector, then turns on the air electric louver and the explosion-proof fan, and discharges the combustible gas in the battery compartment. The explosion-proof exhaust fan doesn't turn off automatically after opening. The parameters of the Inlet are shown in Table 3-8.

The parameters of the smoke exhaust fan are shown in Table 3-9.

Table 3-8 The paraments of the inlet and outlet louver

Item	Specification
Supply voltage	24V DC
Rated power	60W
Position	Integrate in racks

Table 3-9 The paraments of the smoke exhaust fan

Item	Specification
Rated power	128W
Supply voltage	230V AC
Maximum air volume	820±15%CFM

3.1.5.2 Fire extinguisher system

1) Aerosol fire extinguisher system（optional）

In the event of an initial fire in the battery compartment, a fire alarm signal will be emitted, and the fire extinguisher system will automatically control the release of the aerosol, which can also be triggered manually. The fixed position of the aerosol is shown in Figure 3-9.

2) Dry pipe system（optional）

The dry pipe system can effectively control the spread of the fire. As shown in Figure 3-12.

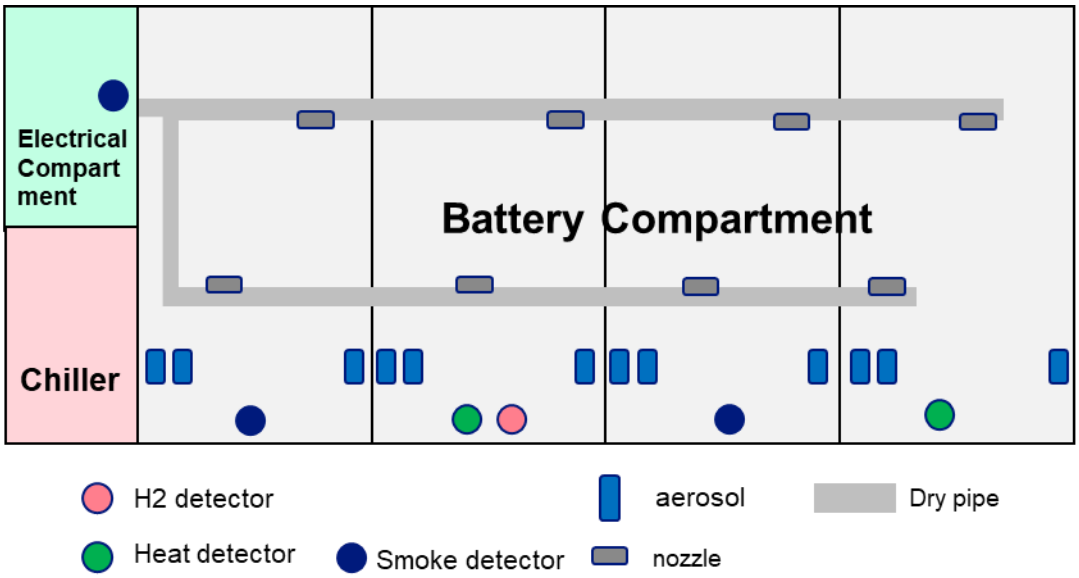


Figure 3-12 The design of dry pipe

The flange is installed at the entrance of the water fire protection system, for the connection between the pipes. The parameters of the flange are shown in Table 3-10.

Table 3-10 The paraments of the flange

Item	Specification
Model	NPS 2”
Standard	ASME B16.5
Material	ASTM A105
Class	Class 150
Flange type	Thread
Certificate	Integrate into rack

The Water Spray Nozzles are open type (non-automatic) nozzles with rubber plug, designed for directional spray application in fixed fire protection system. The parameters of the nozzle are shown in Table 3-11.

Table 3-11 The paraments of the nozzle

Item	Specification
Model	V2709
Type	Standard horizontal sidewall
Maximum working pressure	250 psi/1725 kPa
End connection	½ NPT

3.1.5.3 Instruction of UPS for FSS

In order to keep the FSS working normally for at least 24 hours standby and 2 hours alarm without external auxiliary power supply, an internal UPS has been incorporated into the FSS control panel, and two DC 12V batteries have been connected in series. For safety reasons, the battery connection must be disconnected during transportation process. The power supply of the explosion-proof system requires additional backup power from the customer.

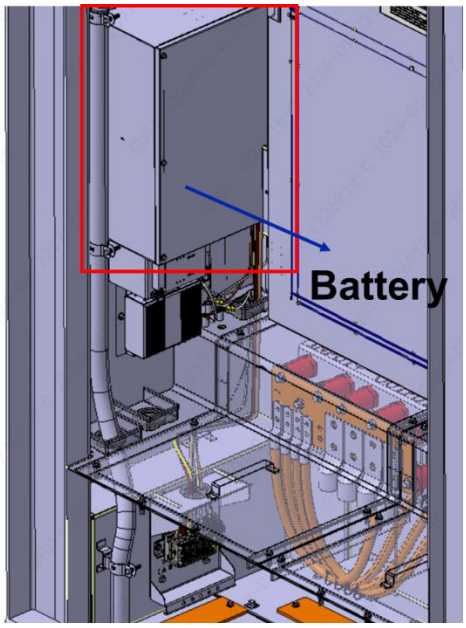


Figure 3-13 The UPS for Fire Control Panel

	CAUTION
	Note that overdischarge risk of UPS battery for FSS operation if long period without auxiliary power. If lost AC auxiliary power 24 hours above, please energize in external backup power to continuously enable FSS, or disconnect the battery connection to stop FSS operation to prevent over discharge.

3.1.6 TMS overview

The TMS is a liquid cooling system whose primary function is to maintain the temperature of the battery system within an acceptable operating temperature range. The following is the layout of the coolant pipes.

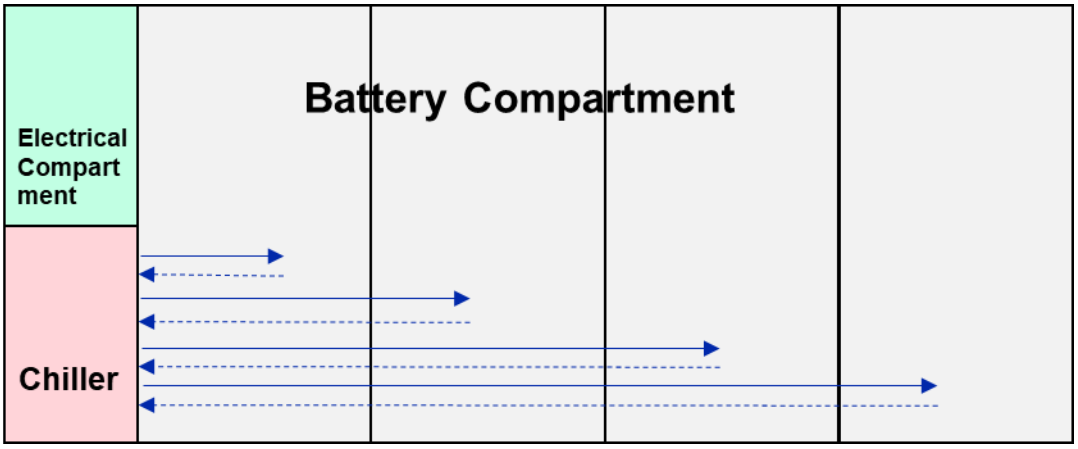


Figure 3-14 Pipe layout of TMS（Top view）

Table 3-12 Main feature of TMS

	✓ Coolant: 50% ethylene glycol+50% DI water ✓ Max. ambient temperature: 55 °C ✓ Power supply: 3AC 380DI…480V (external) ✓ 40kW cooling capacity for 0.25P system ✓ One unit of TMS (chiller) per container ✓ Cooling power is automatically adjusted according to ambient temperature & discharge/charge status ✓ The working status of the TMS system components depends on the target battery cell temperature controlled by BMS. In total, there are four operating states for TMS, which can be read by the bit 0- bit 1 via register address 0 x 0060

Table 3-13 Status of TMS components

Status	**Cooling** (bit 0 = 0, bit 1=1)	**Heating** (bit 0 = 1, bit 1=0)	**Self-circulation** (bit 0 = 1, bit 1=1)	**Sleeping** (bit 0 = 0, bit 1=0)
Compressor	Run	Stop	Stop	Stop
Pump	Run	Run	Run	Stop

Fan	Run	Stop	Stop	Stop
PTC Heater	Stop	Run	Stop	Stop

Table 3-14 Power Consumption of TMS

Type of EnerX	**0.25 P System**
Quantity of Cooling Unit	1
Refrigerating Capacity	1 x 40 kW
Maximum Heating Power	21.3 kW
Maximum Cooling Power	27.9 kW
Maximum Cooling current	50.1A
Maximum Heating current	31A
EER	⩾2.76 (18℃ TMS liquid , @35℃ ambient)

3.1.7 Auxiliary distribution box overview

The Auxiliary distribution box is for providing the auxiliary power for whole control system and liquid cooling system.

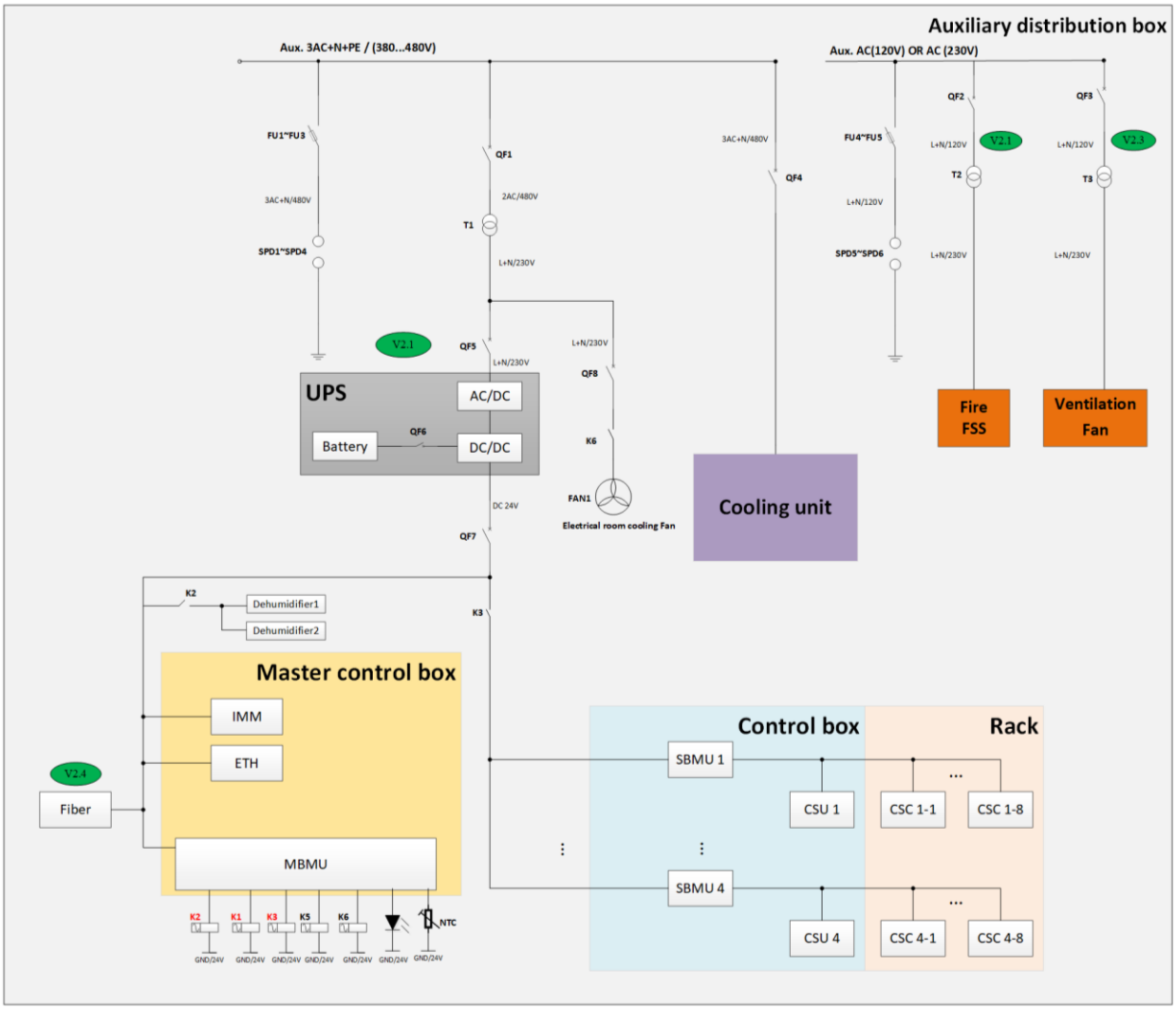


Figure 3-15 Single line graph for two auxiliary power of UPS (Two auxiliary power supply or one auxiliary power supply are optional)

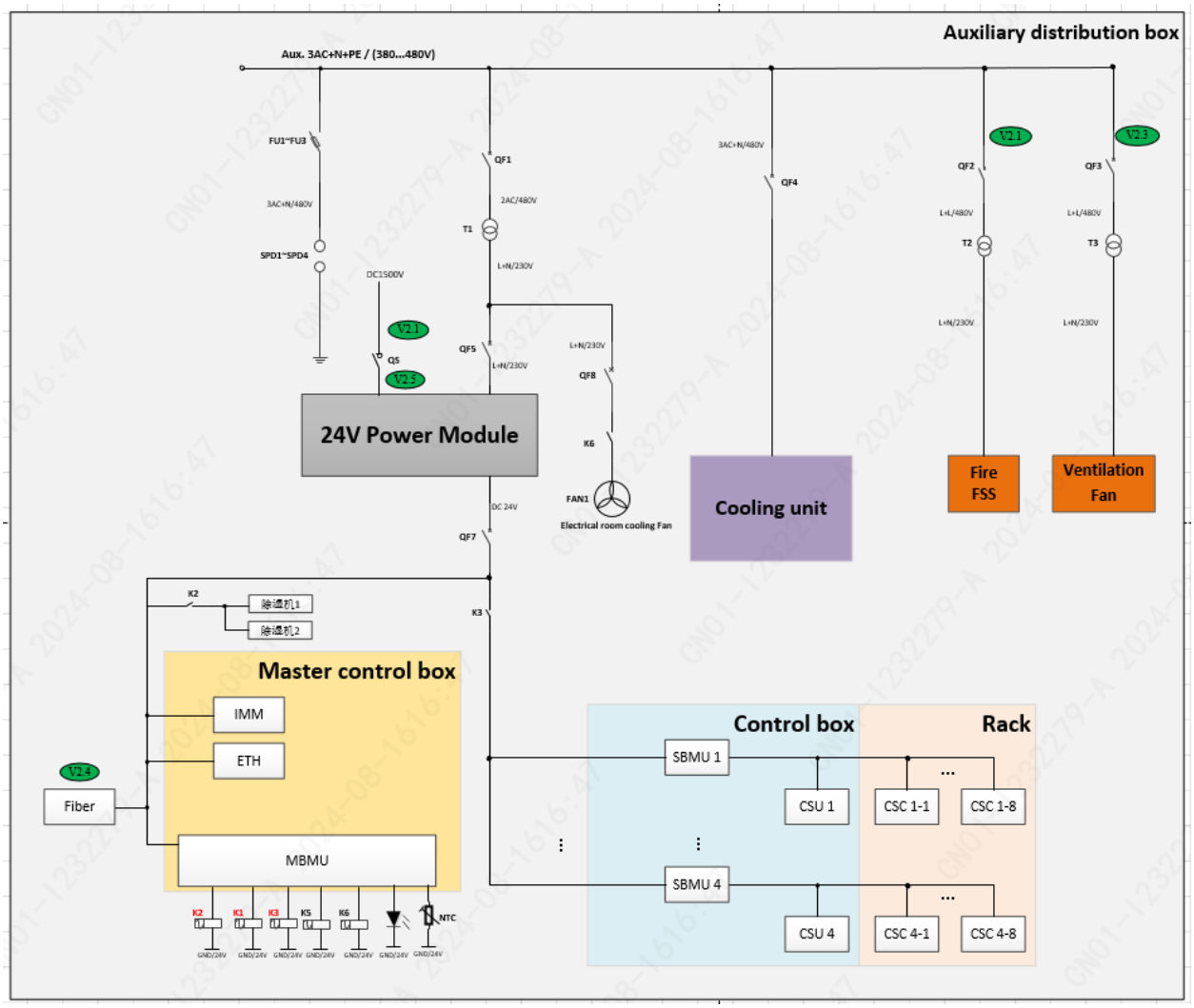


Figure 3-16 Single line graph for one auxiliary power of 24V power module (Two auxiliary power supply or one auxiliary power supply are optional)

Table 3-15 main feature of distribution box(Two auxiliary power supply)

✓ Auxiliary power supply input : 3AC + N+PE 480V(380...480V)±10%, 50/60Hz & 1AC 230V(L+N+PE) ±10%, 50/60Hz ✓ Include DC24V power supply output & DC24V UPS for BMS system, ✓ Include 230V power supply output for FSS and Explosion-proof system, ✓ Include 380V power supply output for Chiller system ,

- ✓ Include E-stop circuit,
- ✓ Include circuit protection and power supply on-off control circuit,
- ✓ Include Type II SPD for AC Power supply.

3.2 Product Specification

EnerX liquid-cooled energy storage container				
Product model		**C06530P25L01**		
Product Type		**LFP battery bank**		
NO.	**Item**		**Specification**	**Remark**
1	Configuration		4P2P416S	
2	Rated Energy		5644.29kWh	
3	Rated Voltage		1331.2VDC	
4	Voltage Range		1040~1500VDC	
0.25 P System				
5	Charging Current (0.25 P)	Rated	1060A	
		Maximum	1357A/1 minute	
6	Charging Power (0.25P)	Rated	1411.07kW	
7	Discharging Current (0.25P)	Rated	1060A	
		Maximum	1357A/1 minute	
8	Discharging Power (0.25P)	Rated	1411.07kW	
9	Auxiliary power supply (0.25P)	Voltage range	AUX1:3AC+N+PE 480V(380…480V)±10%, 50/60Hz AUX2:1AC 230(L+N+PE)±10% , 50Hz/60Hz	
		Power	AUX1:Max. 34.5kW AUX2:Max. 0.5kW	
10	Operating Ambient Temperature	Operating Ambient Temperature	-35 ℃…+55℃	
11	Environment condition	Storage temperature	-35 ℃…+60℃	
		Relative Humidity	0 ~ 95 % (non-condensing)	
		Application altitude	≤4000m	
12	General Parameters	Size	6058mm(W)*2438mm(D)*2896mm(H)	
		Weight	~45.0t (Metric Ton)	

		IP Level	IP55（Battery Room）	
			IP55（Electrical Room）	
		Cooling mode	Liquid Cooling	
		Communication agreement	CAN, RS485, TCP/IP	
		Power connection	Cable lug: 8 x M12	
		Communication connection	Fast plug	
		Aux power connection	Terminal	
		Coolant	50% Ethylene glycol+50% DI water	
13	Fulfill standard	Cell	UN38.3	
			UL1973	
			IEC62619	
			UL9540A	
		Container	UL1973	
			NFPA855	
			UL9540A	
			UL9540	
			IEC 62477	
			IEC 62619	
			IEC 62933-5-2	
			IEC 63056	
			IEC 61000-6-2/ IEC 61000-6-4	

3.3 BMS introduction

3.3.1 BMS system overview

BMS is used in conjunction with the energy storage system, which can monitor the battery voltage, current, temperature, manage energy absorption and release, thermal management, low voltage power supply, high voltage safety monitoring, fault diagnosis and management, external communication with PCS and EMS, ensure the stable operation of the energy storage system.

The BMS system is composed of 1 unit of MBMU, 1unit of IMM, 1 unit of ETH, 4 units of SBMU, 32 units of CSC.

	CAUTION

	Note that over discharge risk of UPS battery operating if long period without auxiliary power. please recharge the UPS within one week after the auxiliary power supply is cut off. For long-term storage, please recharge the UPS battery every three months.

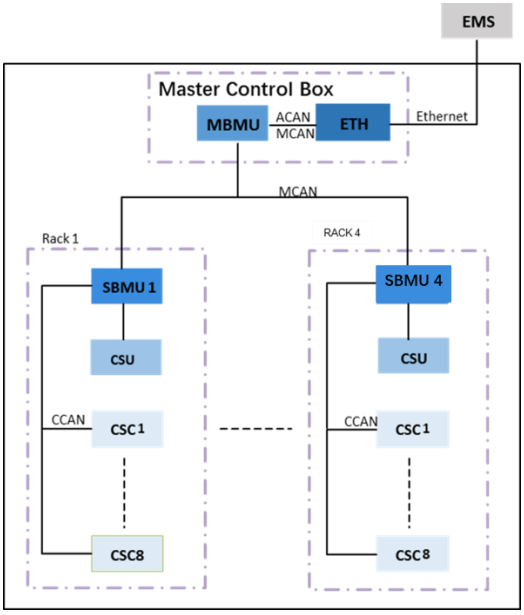


Figure 3-16 Three-level BMS architecture

3.3.2 BMS power on and off

The BMS does not have on/off button. Turn on the power supply to the BMS, then the BMS is turned on and operates normally; turn off the power supply to the BMS, then the BMS shut down.

3.3.3 Battery status monitoring

1. The BMS monitors battery parameters including cell voltage, module temperature, battery current and total battery voltage.
2. The BMS detects the battery status such as State of Charge (SOC) accurate to within 5%, SOH and the calculation of SOP.
3. The BMS functions as a safety management system in cases such as under-voltage, over-discharge, over-voltage, over-temperature, and over-current of the battery. In the event of a fault, the system alarms the supervisory equipment, limits the charge and discharge current or power, and delays the disconnection of all HV relays. This can protect the battery while maintaining the safety of the systems.

4. The BMS provides battery information including data recording and fault information recording to the EMS.

3.3.4 Charging/discharging management

1. The BMS controls and monitors HV relays, including the low voltage coils of the contactor and the high-voltage contact (auxiliary contact).
2. The BMS has precharge control within the parallel connection between racks.
3. The BMS works in charge and discharge management. It will calculate the charge and discharge power limit according to the existing status of the battery (temperature, SOC) and the actual performance of electrical components and then report to the EMS which has the function of controlling to these limits;
4. The BMS has the function of balance management to extend the operability of the battery system.

3.3.5 Thermal management

1. The BMS has the function of sampling the battery cell temperature and the chiller operating status.
2. The BMS controls the liquid cooled TMS based on the battery cell and the coolant temperature.

3.3.6 Program update

The BMS can flash programs on site, which supports flashing of MBMU, SBMU, IMM, CSC and ETH by using the host computer through MCAN.

3.3.7 High voltage safety monitoring

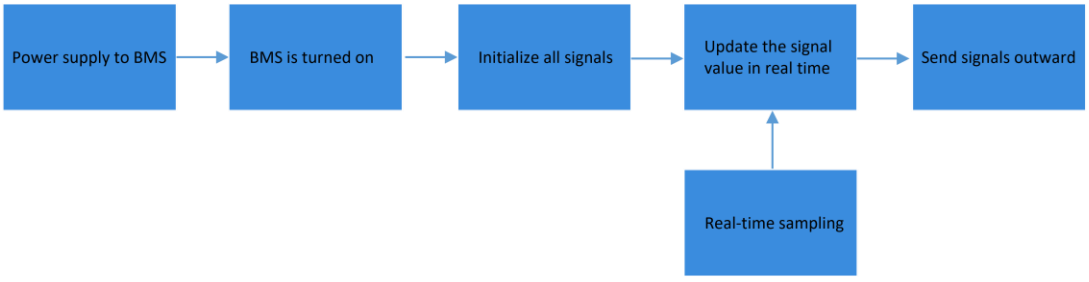
1. The BMS has the function of high voltage sampling (collecting data of the main positive voltage)
2. The BMS supports the detection of the dry contact of the fuse and switch, as well as the auxiliary contact of the primary loop relay.

3.3.8 Fault diagnosis management

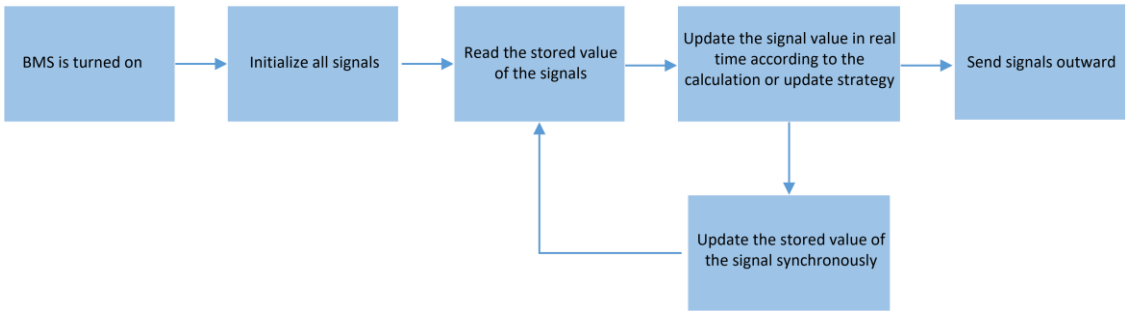
1. The BMS stores information such as operating parameters and historical alarms, which can be viewed by the ESS monitoring tool.
2. The BMS allows storage of recent alarms.

3.3.9 BMS data recovery function after abnormal power off

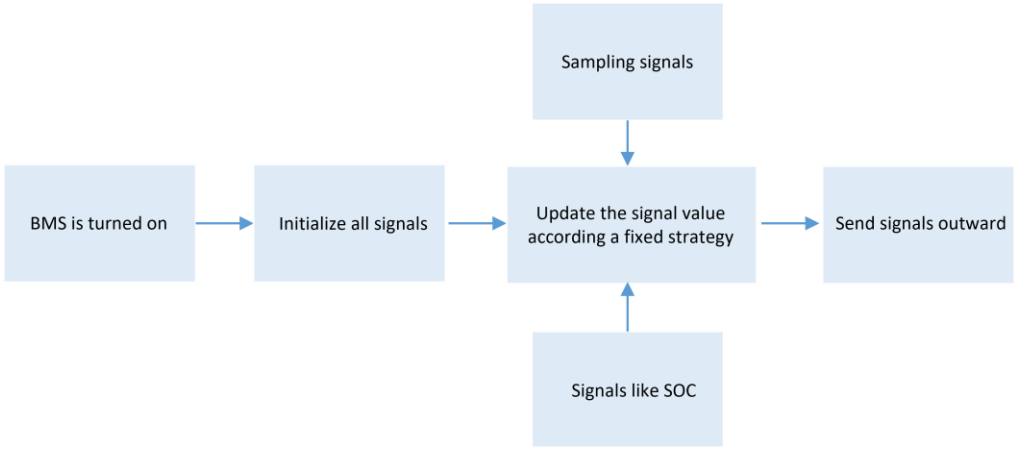
1) Real-time sampling signals, such as voltage, temperature, current, etc., are first initialized after the BMS is turned on. Then the signal value will be updated in real time with the sampled values.



2) Signals that need to be stored, such as SOC, SOH, SOE, etc., are also initialized when the BMS is turned on. These signals then read the stored value from the BMS once. After that, these data are updated in real time according to their update strategies, and their corresponding stored values will be updated synchronously.



3) Other types of signals are updated by the above two types of signals according to certain logical processing.



3.3.10 BMS system for four container parallel application

When four containers connect to the PCS at the same DC public connection point, these four containers must adopt the following communication architecture.

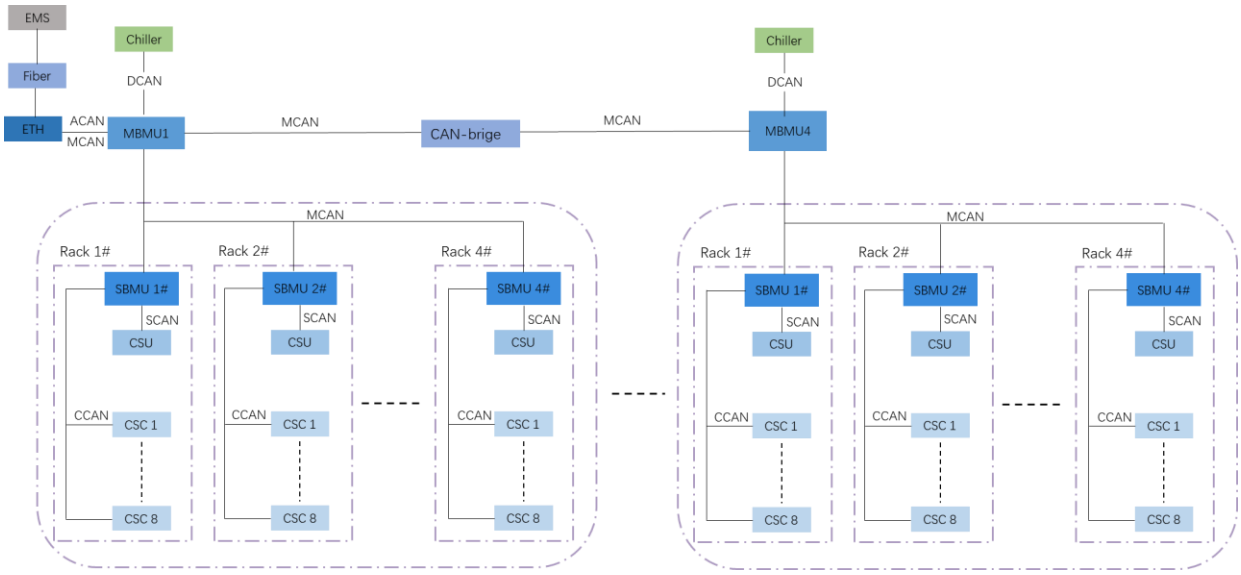


Figure 3-17 Communication circuit for four container parallel application

4 Transportation and Storage

4.1 Transportation process and requirements

Transportation methods: sea freight and land freight.

During loading and unloading, it should be handled with care to prevent throwing, rolling, and heavy pressure; during transportation, external mechanical impact should be avoided.

- Battery container transportation requirements for land freight
  1) The transportation scheme for bulky cargo must be evaluated in advance;
  2) The high-speed driving speed of the vehicle (truck) shall not exceed 100 km / hour & domestic legal requirement;
  3) It is forbidden to make sudden braking and sharp turns while driving;
  4) Keep the vehicle in good condition, check the vehicle's carrying status frequently, find and solve the problems in time.
- Battery container transportation requirement for sea freight

  Keep the vehicle in good condition, check the vehicle's carrying status frequently, find and solve the problems in a timely manner.

Requirements for Battery Container Transport

Based on battery features and with the purpose of maximizing battery performance, the transportation and storage of battery container should meet the following requirements:

- Allowable transport temperature: -35~+60℃.

- Humidity: ≤95% (no condensation).
- Take appropriate protective measures to keep the SOC level at about 23%, and make sure that no short circuit occurs, or no liquid is allowed to enter the battery container, or the battery container is soaked in liquids (e.g. water, oil, etc.).

4.2 Hoisting & lifting equipment

Equipment requirement

1) According to the site conditions and mechanical equipment, the selection of good performance of lifting equipment, rigging, shackle calculation selection; Ensure that the crane and rope meet the load-bearing requirements.
2) All kinds of lifting equipment, including sling, shackle, etc. should be checked in good condition before entering the site; before formal lifting, it should be reconfirmed that the specifications and quality meet the requirements of this lifting.
3) The lifting point is located at the top of the four terminal corners of the container.
4) When installing or removing a lifting device, do not drag the container. Otherwise, the container may be damaged.

4.2.1 Container hoisting parameters of single-point crane

Table 4-1 single point lifting

Preloaded weight	Cable length	Cable quantity	Acceleration
~45t(Metric Ton)	＞ 6.3m	4	≤0.5g

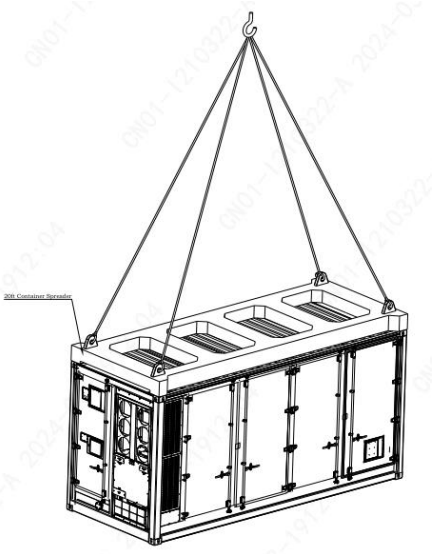


Figure 4-1 Single-point lifting

Note：Lifting equipment is provided by customer

	CAUTION
	The gravity center of the battery container must be kept stable during lifting process.

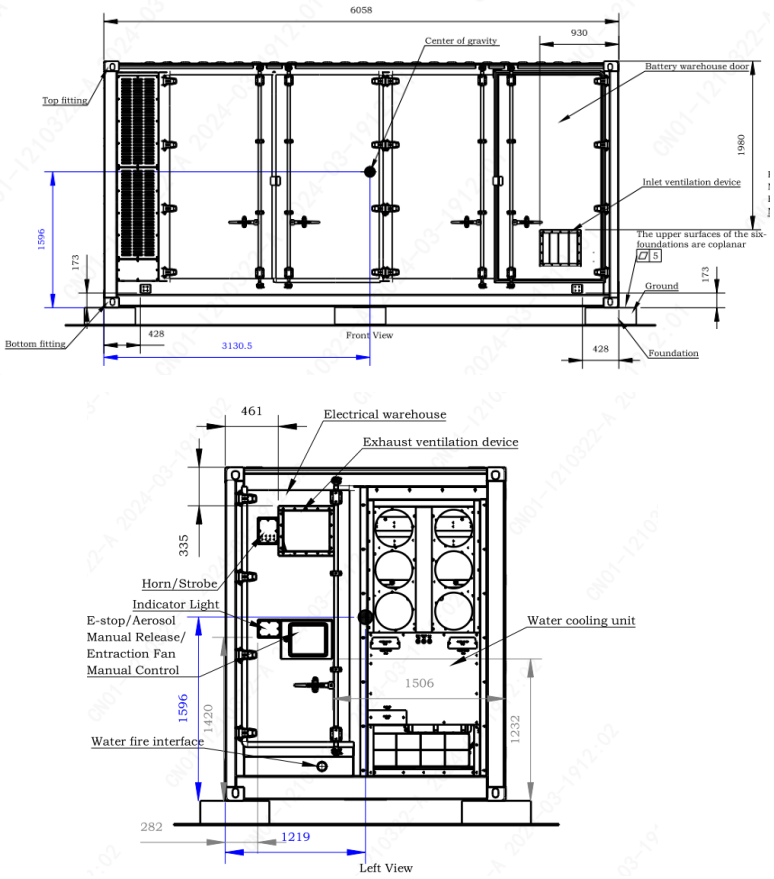


Figure 4-2 Gravity center of the battery container(mirror A)

4.2.2 Container hoisting parameters of four points vertical crane

Figure 4-3 Top lifting by four points vertical crane

4.2.3 Precautions for hoisting

Hoisting process	Precaution
Before lifting	The lifting capacity and working radius of the crane meet the requirements. If the onsite working conditions do not meet the requirements, seek professional evaluation.
	For outdoor use, you are advised to lift containers when the weather is clear and there is no wind & rain.
	Ensure that the crane and steel cable meet the requirements before hoisting.
	The doors of the container are all closed and locked.
	Ensure the cable connection is safe and reliable.
During lifting	It is strictly forbidden for irrelevant personnel to enter the lifting area, and it is strictly prohibited to stand under the lifting arm.
	Ensure that the crane is in a proper position, not long distance hoisting.
	Keep the container steady, and the diagonal inclination of the container is less than or equal to 5°.
	Hoisting gently, the box body should be slow and steady when falling, to avoid impact on internal equipment.
	When the container is in contact with the base, remove the steel hoisting cable after the base is evenly stressed.

	Containers can be hoisted only after they are secured.

4.2.4 Risk identification for hoisting

	WARNING
	To prevent personal injury or equipment damage, the risk identification must be done before hoisting

1) The crane in the operation of the human body caused by extrusion or impact;
2) The crane hook overloading fracture, lifting when the sling slip out of the hook;
3) Heavy objects fall in the lifting cause striking, heavy objects fall from the air to the ground and rebound wounding;
4) Accidental contact of spreader or sling with conductive slip line;
5) Truck crane working site ground is not smooth, support unstable, weight imbalance, heavy weight exceeds the rated lifting weight caused by crane overturning;
6) Excessive wind, illegal operation caused the crane overturned;
7) People standing under the boom and other dangerous areas;
8) A person standing or sitting on a hook;
9) When lifting, there is no command, there are people staying in the working area, and the spares and heavy objects of the crane in operation swing and strike pedestrians;
10) The crane and other operators do not wear safety helmet and other personal protective equipment;
11) The driver's cab glass is not cleaned, resulting in unclear vision;
12) The driver has poor communication with the commanding personnel, or misunderstands the hoisting signal;
13) The hanging method is not correct, causing heavy objects to fall out from the hook;
14) The sling used exceeds the safety factor;
15) The wire rope jumps out of the pulley groove;
16) Brake crack, friction gasket wear too much.

4.2.5 Measures of hoisting safety

	WARNING
	To prevent personal injury or equipment damage, the safety measure must be followed

1) Strengthen the management of the construction site, set up a warning area on the hoisting site, send full-time safety personnel to supervise and alert, non-operation personnel are strictly prohibited to enter;
2) Carefully do the preparatory work before lifting, according to the requirements of the plan to prepare machinery and heavy lifting rigging. Strictly implement the lifting equipment performance inspection, lifting rigging inspection, pre-lifting detection and lifting procedures to ensure the safe and reliable lifting operation;
3) Detailed technical disclosure shall be made to all personnel participating in the construction operation in advance, so that they must understand the essentials, procedures and requirements of the operation. After the crane enters the site, the crane driver will be introduced to the hoisting scheme in detail, and the unified command signal will be made clear.
4) Crane position operation and walking route should be carried out according to the requirements of the scheme, the outrigger pad must be safe and reliable. Special subgrade box cushion is used under the leg to expand the unit force surface. Crane lifting operation should be smooth, slow action, lifting operation should pay close attention to the settlement of the crane leg;
5) The contact between the site commander and the crane driver should be timely and reliable, and the command signal, flag language and gesture should be clear. If abnormal conditions are found, the commander in chief of the lifting site should be reported in time, so as to take effective measures as soon as possible;
6) When the wind is level 5 or above, it is strictly prohibited to lift in thunder, rain and fog days;
7) Construction personnel entering the hoisting operation site must strictly implement the safety rules and regulations of the site, wear labor protection clothing and safety helmet according to the provisions;
8) Hoisting operation should be unified command, operation personnel should do their duty, closely cooperate, so as to complete the hoisting operation safely and smoothly.

4.3 Storage

The battery container should be stored in a place without harmful gases, flammable or explosive products and corrosive chemicals nearby. Keep away from mechanical impact, heavy pressure and strong magnetic field. The distance to heat source should be far away.

4.4 Ambient thermal insulation

The battery system must operate within the range of optimum operating temperature, so that the service life of a battery can be extended, and the safety performance of a battery can be improved. The limitation

of temperature should completely comply with various definitions in the specification, the installation space of the battery system should be well-ventilated and be designed with the function of thermal insulation.

5 Product Installation

5.1 Site and environment requirements

EnerX battery container applies to general outdoor scenarios. In accordance with local laws and regulations, the site selection requirements are as follows:

1 The installation position of the node cannot be in a low-lying area, and the site level is higher than the highest historical water level in the area.

2 The soil condition is good and the ground is solid. No bad geological conditions such as rubber soil and soft soil layer are allowed. The ground that is easy to accumulate water and sink should be avoided.

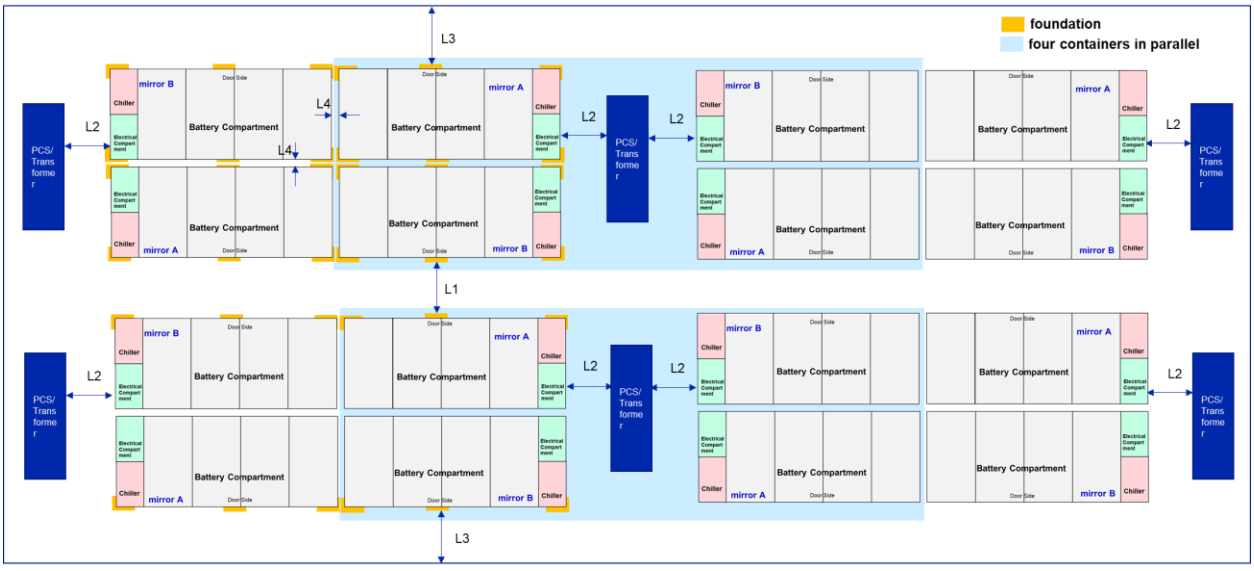
3 Invest in a well-ventilated place.

4 Keep away from strong vibration, noise sources, and electromagnetic interference areas. Try to avoid places with existing underground facilities.

5 Keep away from places that produce dust, fume, harmful gases, and produce or store corrosive, flammable, and explosive materials. The distance from the airport, landfill, river bank, shore or dam should not be less than 500m.

6 Choose an open location according to the requirement of Figure 5-1, and ensure that there are no obstacles from the surrounding area.

7 Keep at least 50m away from residential areas to avoid noise pollution.



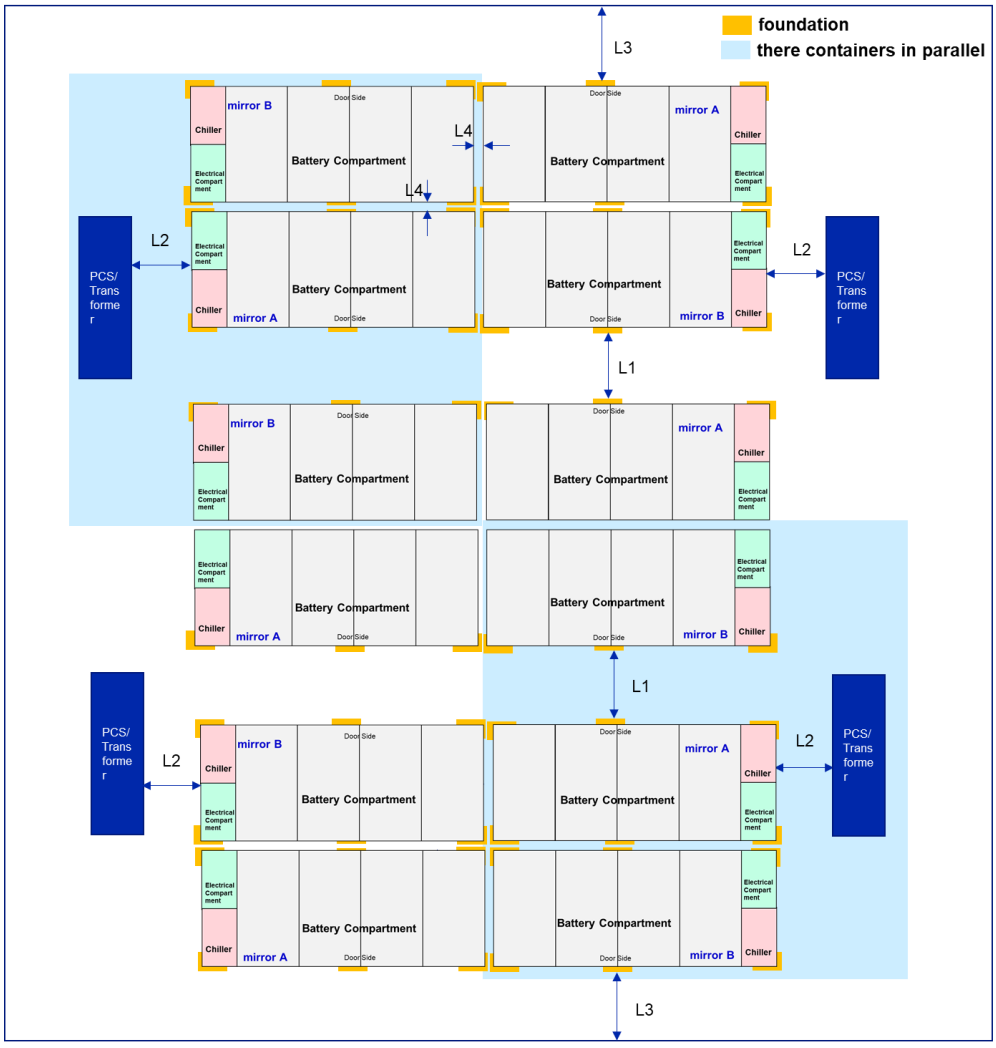


Figure 5-1 Clearance requirement

To avoid the hot air interaction for two containers, and to maintain the container, the minimum distance must be followed(note: L1 and L3 is the net distance excluding the foundation overhang): :

L1 : 3.5m

L2 : 3.0m (Customers need to check the required distance consider the influence of hot air interaction between PCS and container according to the specific selection of PCS)

L3 : 3.5m

L4 : 0.9m

To avoid the uneven current caused by the difference of cable resistance between parallel containers under one PCS, the recommended cable length is as follows:

The length of the cable between the container bus and PCS is less than 20m.

The cable length difference between parallel containers under the same PCS is less than 3m.

5.2 Foundation requirements

Before installing this container, build the foundation and trench on the selected ground. The requirements for foundation construction are as follows:

- The size of foundation meets the requirements of container installation and bearing capacity as following shown.

Table 5-1 Installation site requirement

Ground type	Condition requirements	Note
Concrete floor	Support at least six points in the Figure 5-2.	
Plain land surface	The ground needs to be able to bear a static load of 45 tons, considering the seismic conditions, it should meet the requirements of the support reaction in the drawing	Ground should fulfill: ◆ Flatness deviation ≤5mm/6 foundations

- Foundation and installation requirement:
  - ➢ At least six foundation points must be in place to support the container as shown in Figure 5-2.

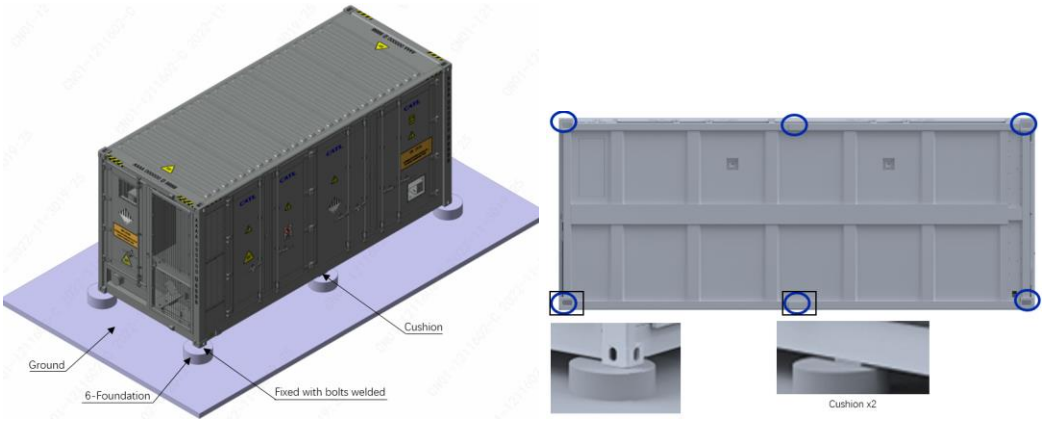


Figure 5-2 six bottom support point of a container

  - ➢ Welding installation is recommended: The container bottom frame is welded to the embedded steel plate in the foundation. The recommended foundation height is 200mm (at least 80mm for bottom module maintenance).The number of welding points of single-container layout and grid layout are shown in Figure 5-3 and Figure 5-4.
    - single-container layout

For single-container layout, 6-point welding is recommended to meet IEEE 693-2018 High seismic design level as shown in Figure 5-3.

It is mandatory to fix four corner foundation points for single-container layout.

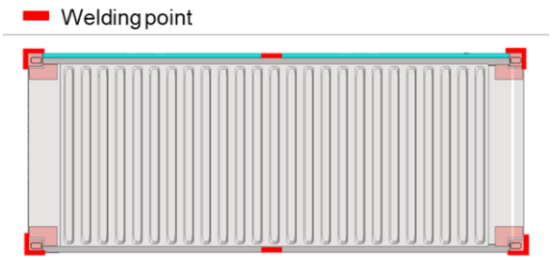


Figure 5-3 welding point of single-container layout

- grid layout

For grid layout, 4 points welding as shown is recommended to meet IEEE 693-2018 High seismic design level as shown in Figure 5-4.

If the container spacing is sufficient, all 6 points welding like single-container layout in Figure 5-3 is recommended.

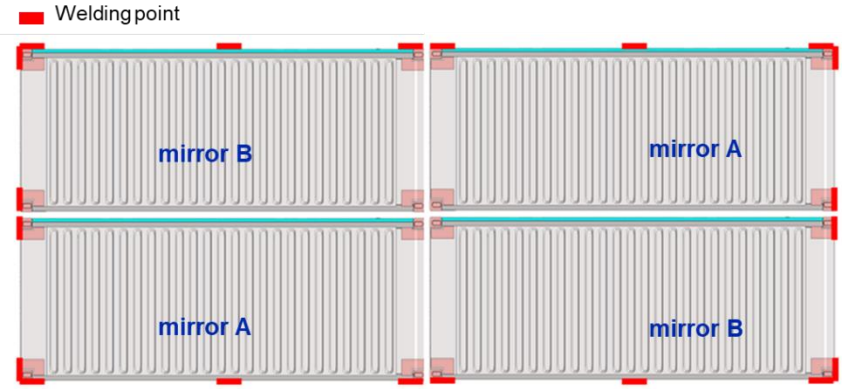


Figure 5-4 welding point of grid-container layout

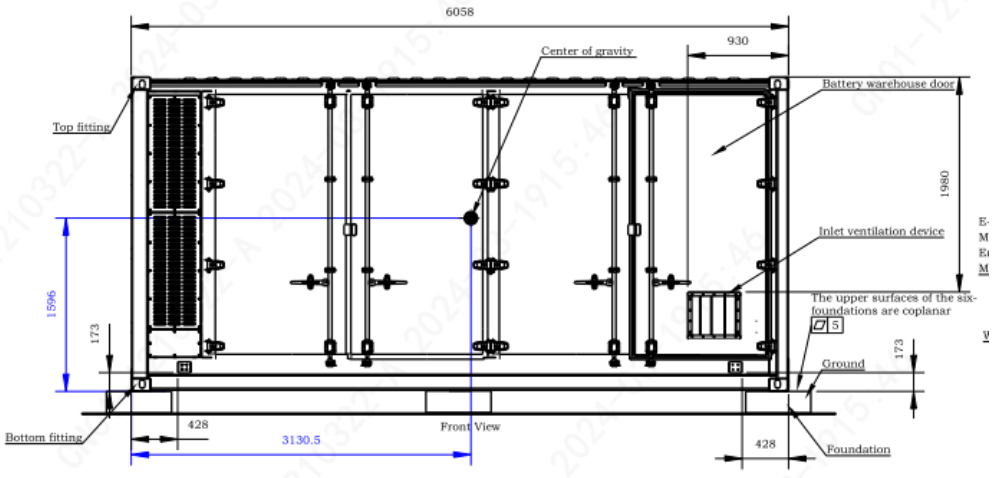


Figure 5-5 Spacing of the bottom foundation points of a container

1) Bury the ground grid and install a ground bar at the designated position of the container. Connect one end of the ground grid to the embedded ground grid and the other end to the container's ground point. When embedding the ground network, ensure you reserve enough length for the ground lug to connect to the container's ground point.
2) The grounding resistance of the container is less than or equal to 0.1Ω.
3) The containerized energy storage system uses underside cabling, so the cables must be buried under the power cabin in advance.
4) The inner diameter of the protective pipe should not be less than 1.5 times the outer diameter (including the protective layer) of the cable.
5) Foundation construction should meet the local historical maximum rainfall drainage requirements. The discharged water must be treated in accordance with local laws and regulations.

5.3 Installation procedure

Table 5-2 Installation procedure

Step	Procedure
1	Determine the position for installing containers based on the foundation design diagram;
2	Measure the support points of foundation containers fulfilling the requirement of chapter 5.2
3	Use a crane to lift containers according to chapter 4.2
4	Adjust the container and level the container using washers to ensure that the support points at the bottom are evenly supported. Note: The washer has been packed with the box and placed at the protective cover of the water pipe in the electrical cabin
5	Open and close all side doors and the electrical cabin doors. There is no lag in operation and no rigid contact between the side door and the cabin body. If there is interference between the door and cabin, washer should be added in the corresponding position
6	Remove the lifting rope and release the crane after the side door and electrical cabin door meet requirements
7	Secure the container.

5.4 Anti-vibration and anti-collision requirement for installation

Inside the battery container, battery racks are connected in parallel, the management system and a variety of sensors are installed. The entire battery system must be installed firmly and reliably without loosening or shaking. An anti-collision device with sufficient strength must be installed at the periphery of the installation space of battery system so as to ensure that no safety accident (e.g. direct short circuit,

overheating and combustion) will be caused by general collision which will not directly harm the battery system and batteries.

5.5 Locking the container

After securing the container, it is recommended that the side and end doors of the container be locked by padlock (as shown in the figure below) to prevent unauthorized access.

Figure 5-6 Lock of battery container

The regular maintenance and inspection of the padlock should be conducted regularly.

5.6 Wiring

5.6.1 Connection interface

The battery container has four main connection interfaces: DC power cable connection, AC auxiliary power connection, communication interface, and FSS communication interface.

5.6.2 Removal and installation of metal covers between electrical compartment and copper busbar compartment

There are two metal covers between the electrical compartment and the copper busbar compartment to reduce the effects of condensation in the electrical compartment as shown in Figure 5-7.

Each metal cover is fastened with 12 M6*16 bolts

Before connecting the high-voltage wiring harness, auxiliary power wiring harness, and other external wiring in the field, you must use tools to remove the bolts and open the metal covers as shown in Figure 5-8.

After the external wiring is completed, the metal covers must be installed before the container is officially commissioned as shown in Figure 5-7.

Bolts： M6*16

Torque： 10±0.5N.m

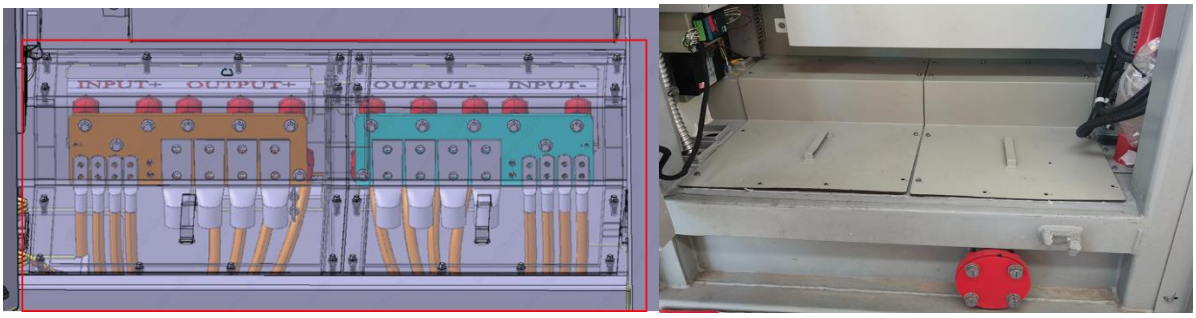


Figure 5-7 Photos of Metal Covers

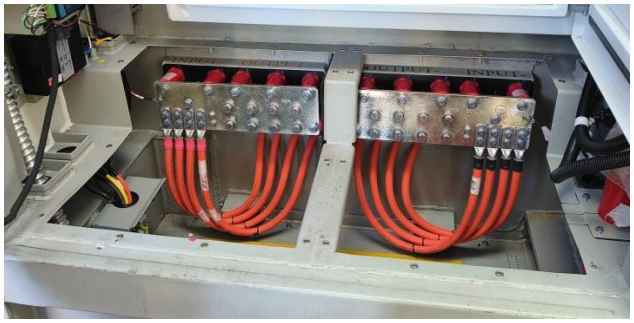
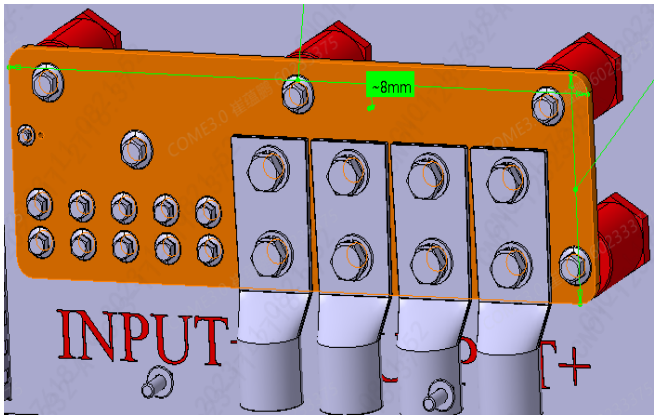


Figure 5-8 Photos of removing metal Covers

5.6.2.1 DC power cable connection

As Figure 5-9 shown, The DC power cable connection of the battery container is located in the busbar of the electrical room. The positive and negative copper bar each have 4 x double M12 holes for connection.



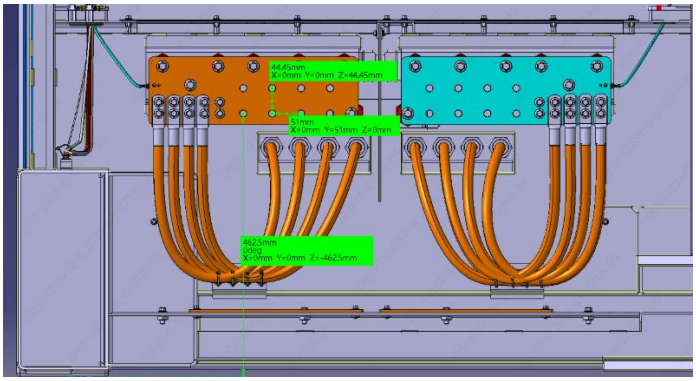


Figure 5-9 DC power cable connection interface

It is recommended to use a dual hole cable lug as shown in Figure 5-7 for the external HV cable connection, and the bolt assembly should follow the scheme shown in Figure 5-8 .

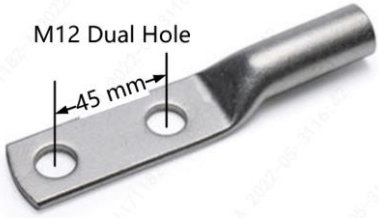


Figure 5-10 External DC power cable lug

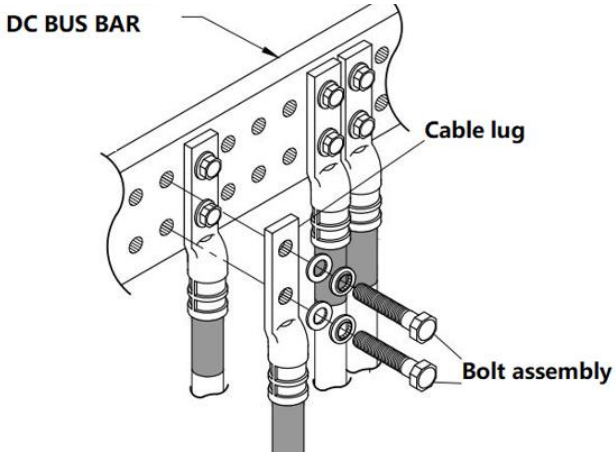


Figure 5-11 External DC power cable connection

Table 5-3 Description of DC power cable connection interface

Pole	Connection	Requirement

HV+	➢ Cable type: copper ➢ Cable lug :4 *M12, ➢ Recommend cable cross-section(copper conductor): 4 *150 mm² or 4 *AWG 300 ➢ Screw: M12 * 35 ➢ Torque: 50 N·m	1. The terminal is a double-hole terminal, the center-line distance between the two holes is about 45mm; 2. The connecting cables should meet the following service requirements: the rated voltage is 1500V DC and the continuous current is 1220A, the maximum current is 1560A; 3. Route as shown in Figure 5-6 DC power cable connection interface. 4. After the external wiring of the container is completed, it is necessary to fill the gap between the threading opening and the wiring harness with fireproof mud and other materials for sealing. It is required that the filling be uniform, tight, seamless, and the beautiful in appearance.
HV-	➢ Cable type: Copper ➢ Cable lug :4 *M12, ➢ Recommend cable cross-section(copper conductor): 4 x 150 mm² or 4x AWG 300 ➢ Screw: M12 x 35 ➢ Torque: 50 N·m	

5.6.2.2 Auxiliary power cable connection

Auxiliary Power1：3AC+N+PE，Auxiliary Power2：1AC+N+PE

As shown in Figure 5-12, the auxiliary power cable connection can be accessed at the bottom of electrical room.

Auxiliary power 1 cable connection (3AC 380~480V)

The connection requirements of auxiliary power supply (3AC+N+PE):

1) The 3AC 380V…480V , 50/60 Hz power supply can be connected to the XT8 terminals;
2) Be sure to connect the U/V/W/N/PE (A/B/C/N/PE) terminals in the correct order;
3) Use flexible or hard wires with cold-pressed tube terminals: Locking torque requirement: 3.2~3.7N·m;
4) 25mm² is recommended for single wire.

Auxiliary power 2 cable connection (1AC 110~230V)

The connection requirements of auxiliary power supply (L+N+PE):

1) The AC230V 50/60Hz power supply can be connected to the XT10 terminals;
2) Be sure to connect the L/N/PE terminals in the correct order;
3) Use flexible or hard wires with cold-pressed tube terminals. Locking torque requirement: 1.5~1.8 N·m;

4) Continuous current 5A（AC 1`0/230V). 2.5mm^2 for single wire is recommended.

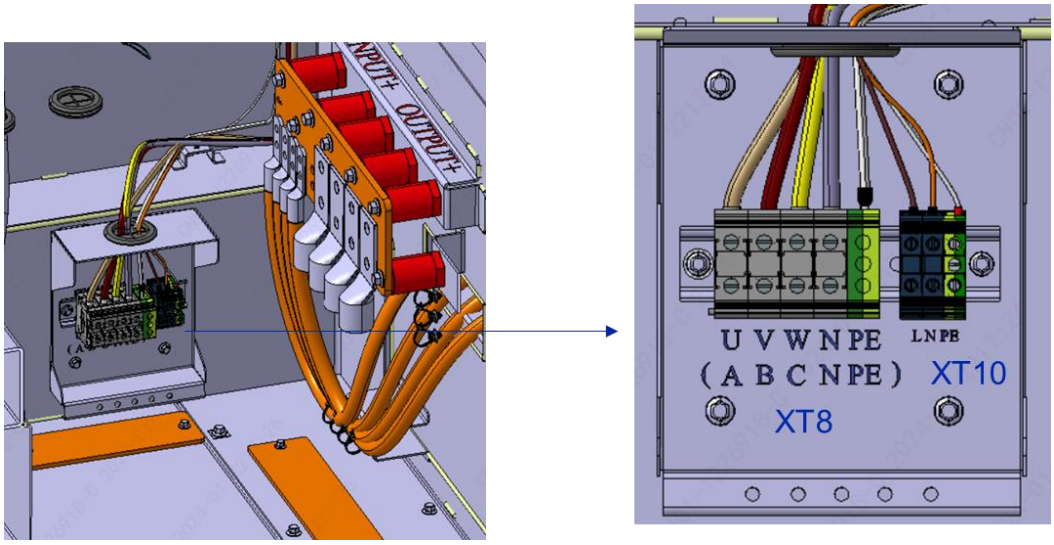


Figure 5-12 AC auxiliary power cable connection interface

Table 5-4 Auxiliary power cable connection interface

XT1 Terminal	**For 3AC 380~480V**	**Power capacity requirement**	**Cross-section**
XT8-1	U/A	Max: 34.5kW	Type: Copper Recommend: 25mm²
XT8-2	V/B		
XT8-3	W/C		
XT8-4	N		Torque： 3.2-3.7N·m
XT8-5	PE		
XT10 Terminal	**For 1AC 110~230V**	**Power capacity requirement**	**Cross-section**
XT10-1	L	Max: 0.5kW	Type: Copper, Recommend: 2.5mm²
XT10-2	N		
XT10-3	PE		

			Torque： 1.5-1.8N·m

5.6.2.3 Grounding connection

As shown in Figure 3-2 and Figure 3-3, there are two grounding connection points for the EnerX container.

The minimum cross-section of the earthing conductors must meet the following requirement.

Figure 5-13 Grounding connection point

Table 5-4 Earthing cable requirement

Cross-section S of line phase conductor	Minimum cross-section of earthing conductors
S ≤ 16 mm^2	≥ S
16 mm^2 < S ≤ 35 mm^2	≥ 16 mm^2
S > 35 mm^2	≥ 0.5 * S
Recommend earthing cable cross-section for 0.5P system: 3x 150mm^2 or 3 x AWG 300	

Using M12x35 combination hexagon bolt. The torque is 50N·m .

The resistance of grounding connection point should be ⩽0.1Ω.

5.6.2.4 Communication cable connection

For optic fiber connection, the optic fiber conversion module is contained in the electrical room, which can convert TCP/IP to fiber signal, and the single mode ST port is used

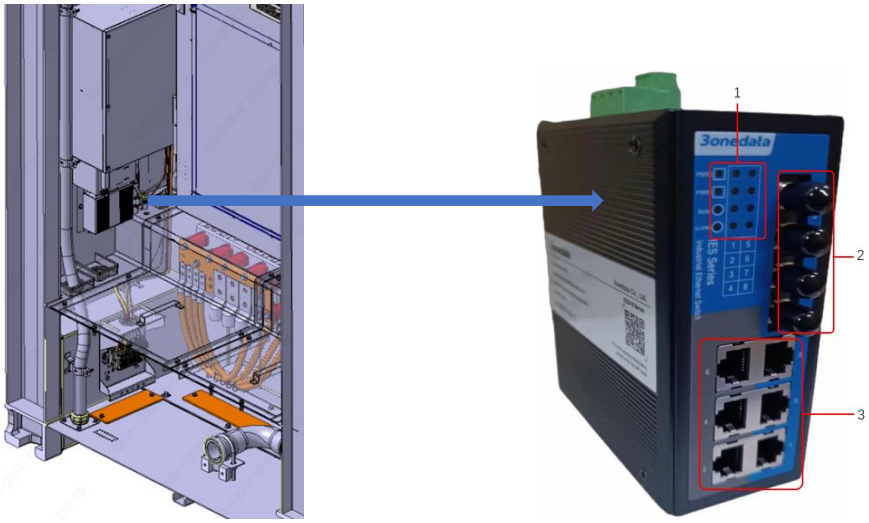


Figure 5-14 Interface of optic fiber conversion module

Figure 5-15 Type of fiber optic connector: **ST**

Table 5-1 Fiber optic conversion module connector information

No.	Item	Connector information
1	Led indicator	Power/Alarm/Working indicator
2	ST port	Two ST (single mode) ports
3	ETH port	Six RJ45 ports.

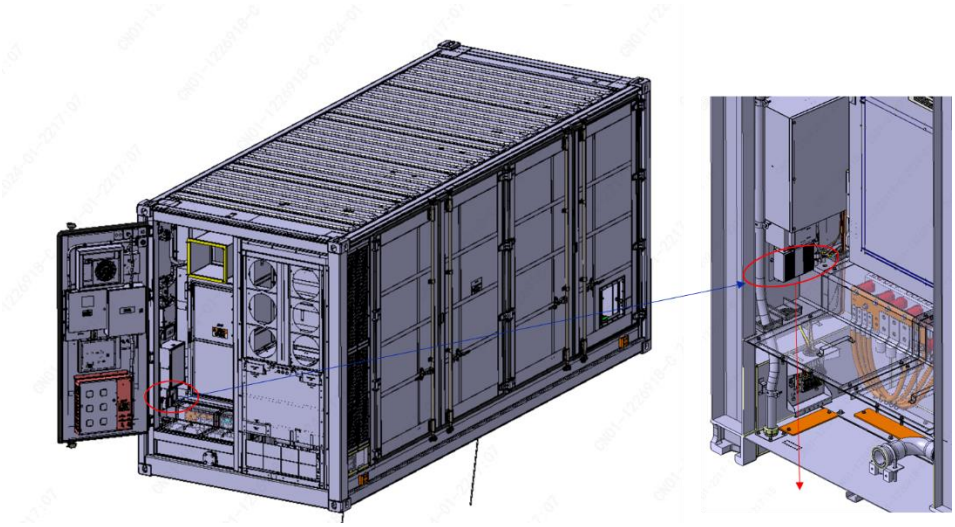


Figure 5-16 Schematic diagram of fiber optic routing

5.6.2.5 The configuration instructions of the terminal resistance

The configuration instructions of the terminal resistance:

- The MCAN terminal resistors are installed on the ETH and MBMU boards, and the terminal resistors can be accessed by shorting the corresponding ports on the board.
- In the MCAN communication circuit, use one of MBMU or ETH as a communication terminal resistance.
- The SBMU board and IMM board are not equipped with MCAN terminal resistance. Generally, the terminal resistance is configured on the MCAN interface of the electrical cabinet where the last SBMU is located.
- The whole MCAN loop has two 120Ω terminal resistors in parallel, equivalent to 60Ω resistance. Use multi-meter to measure the resistance of any MCAN loop interface.

5.6.2.6 FSS dry contact interface

- There are five dry contact interfaces in FSS.
  - Fire system fault level 1
  - Fire system fault level 2
  - Exhaust ventilation state
  - Exhaust ventilation body warning
  - Fire system failure warning
- **FSS dry contact**

Fault name	Function	Dry contact status	External FSS or EMS action
Fire system fault level 1	To indicate that any one sensor of FSS is in alarm.	Close	No action
		Open	Cut off PCS power by EMS and check the detail fault information on the FCP.
Fire system fault level 2	To indicate that one heat detector and one smoke detector in battery room give an alarm or two heat detectors give an alarm	Close	No action
		Open	Cut off PCS power by EMS and check the detail fault information on the FCP.
Exhaust ventilation state	To indicate that the ventilation fan is open	Close	No action
		Open	Cut off PCS power by EMS and check the detail fault information on the FCP.
Exhaust ventilation body warning	To indicate that fan or louver can't operate when exhaust ventilation fan is turned on	Close	No action
		Open	Check the detail fault information on the FCP
Fire system failure warning	To indicate the fault of FSS in battery container.	Close	No action
		Open	Check the detail fault information on the FCP

5.6.3 Wiring quality requirements

1. Inspect whether the polarity of DC cables is correct, nuts are installed properly, and cable signs are correct.
2. Inspect whether the phase sequence of AC cables is correct, wiring terminals are secured properly, and cable signs are correct.
3. Inspect whether the insulation impedance of all racks meet the requirements.
4. Inspect whether the positive and negative poles of DC racks are short-circuited, and terminals U, V, W, N and PE of AC cables are short-circuited.
5. Inspect whether grounding conduction of grounding wires is good.
6. Before power on, check the connection cable of the whole system, and make sure that the cable connection is reliable without aging fracture and insulation damage.
7. Check whether all communication wires and cables and sub connections at the connection end are tight and reliable;

6 CATL Monitor Software

As the LFP battery energy storage running monitor, CATL Real–time Monitoring System can realize following fundamental functions, and the installation process and instruction can refer to follow chapters

1) Data monitoring and recording
2) Rack numbering
3) CSC numbering
4) Rack on-off controlling
5) Fault Alarm checking and analyzing

6.1 Commissioning Tool

For LFP Battery Energy Storage Running Monitor System Installation, following commissioning tools need be installed.

Table 6-1 Commissioning tool

Tool	Description	Overview
ZLGCAN II /ValueCAN4	ZLGCAN tools and ValueCAN4 tools provide connections between CATL BESS and the real time monitoring system (computer). Flashing and configuring are both done by these tools.	
DB9 connector	DB9 connector and rack connectors are used for connection between CAN tools and BESS.	

6.2 Commissioning system hardware setup

As the debug interface, JX3 terminal in EnerX Master Control box can be used for external commissioning

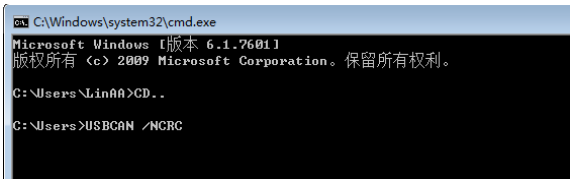
Ener X Master Control Box
JX3 MCAN interface

ZLGCAN II

Commissioning PC

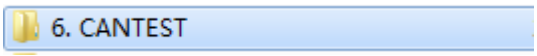
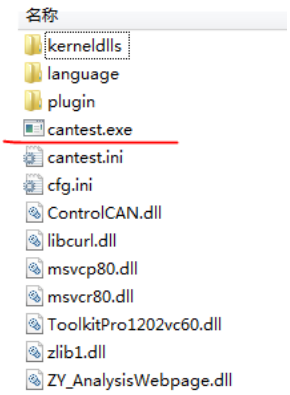
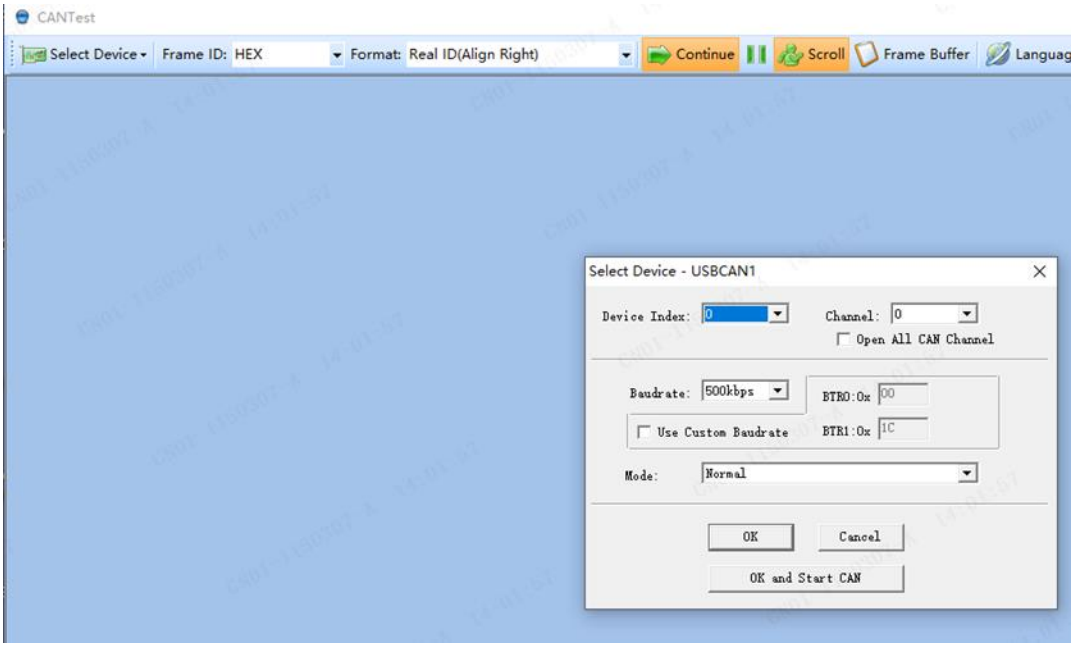
6.3 Commissioning system software setup

1) ZLGCAN Ⅱ driver installation

Step	Solution 1	Solution 2
1	Extract the diver USBCAN_I_II_2A_drive.rar → 【驱动程序】USBCAN-I_I+_II_II+_2A_I-MINI windows驱动安装 → USBCAN_AllInOne_x86_x64_2.0.0.1.exe	Extract the diver USBCAN_I_II_2A_drive.rar → 【驱动程序】USBCAN-I_I+_II_II+_2A_I-MINI windows驱动安装 → USBCAN_AllInOne_x86_x64_2.0.0.1.exe
2	Install the driver. USBCAN_AllInOne_x86_x64_2.0.0.1.exe	Rename the document as 'USBCAN.exe' and save it to the folder 'user' in Disk C
3	End	Open CMD command in folder 'user'
4		Input 'USBCAN /NCRC' and press 'enter' to start the installation of the driver. 
5		End

2) CANTEST Usage

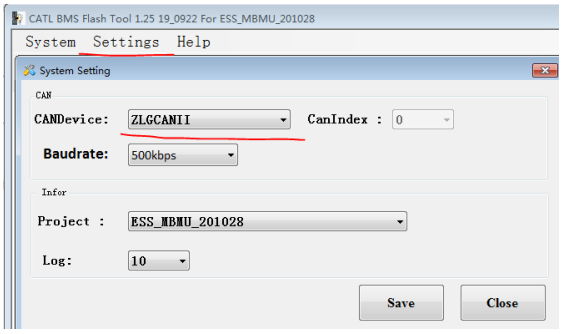
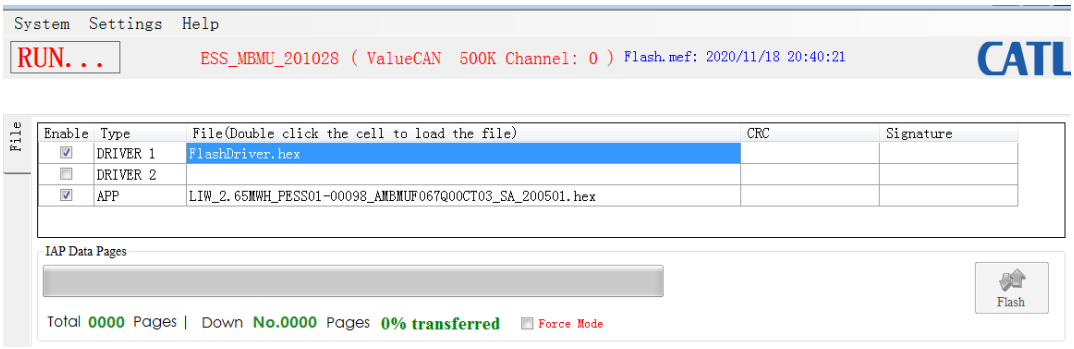
Step	Solution

1	Extract CANTEST software in any folder of the computer. 
2	After connecting the ZLG, open CANTEST.EXE. 
3	Choose 500kbps， click ‘ok and start CAN’. 

6.4 Software configuration

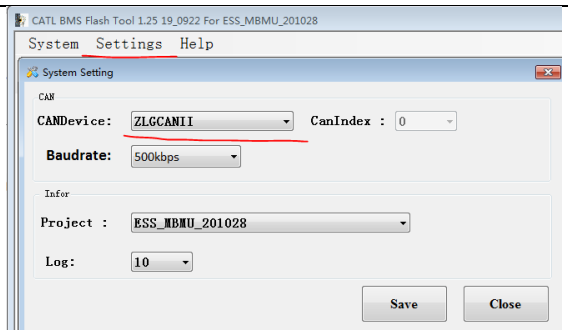
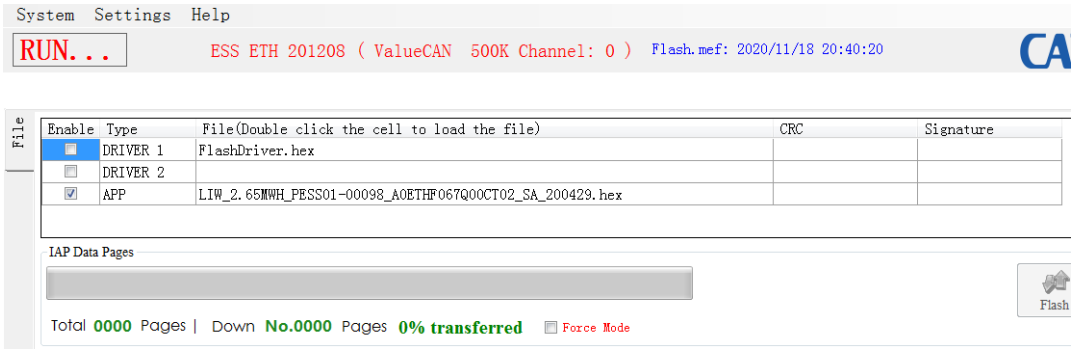
Switch on aux power supply, if the green indicator of master control box lights up, it means the 24V power supply of MBMU, ETH and fiber conversion module is ok, then, use CANTest software to verify the MCAN log. After getting normal log, start verification and flashing MBMU and ETH software, and then configuring ETH IP according to following steps:

1) MBMU software flashing

Step	Description
1	Open MBMU/ETH flash tool CATL BMS Flash Tool.exe
2	Select 'setting', 'ZLGCAN II', and click 'save' 
3	Select driver path in source file configuration \CATL_BMS_Flash_Tool 1.25 For ESS MBMU 201208\Configuration\ESS_MBMU_201028\FlashDriver
4	Select 'APP path', and select MBMU hex file (configured project by project) Such as: AMBMUF067Q00CT03_SA_200501.hex 
5	Select 'system', click 'run'.
6	Click 'flash' and wait until 100% done.

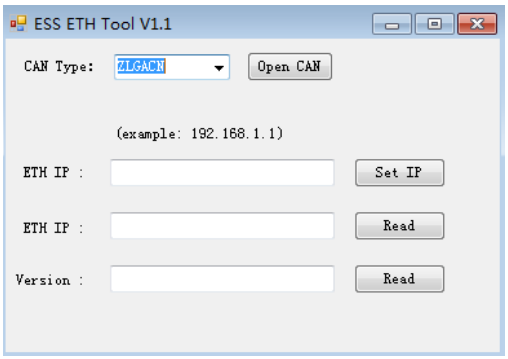
2) ETH software flashing

Step	Description
1	Open MBMU/ETH flash tool CATL BMS Flash Tool.exe
2	Select 'setting', 'ZLGCAN II', and click 'save'

	
3	Select driver path in source file configuration \CATL_BMS_Flash_Tool 1.25 For ESS ETH 201208\Configuration\ESS ETH 201208\FlashDriver
e4	Select 'APP path', and select MBMU hex file (configured project by project) Such as: A0ETHF067Q00CT02_SA_200429.hex 
5	Select 'system', click 'run'.
6	Click 'flash' and wait until 100% done.

3) ETH status verification

a) Open ETH IP setting tool, select ZLGCAN, press open CAN, type in the IP address at ETH IP, press set IP, and then it should show 'successful' after completion. If failed, please check CAN loop and retry. After 'successful' notification appears, Ping IP address and check the connection.



If not able to set IP:

i. Use CANtest to read the log

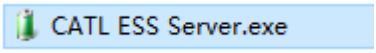
ii. Check ETH power supply and CAN_H/CAN_L loop connection.

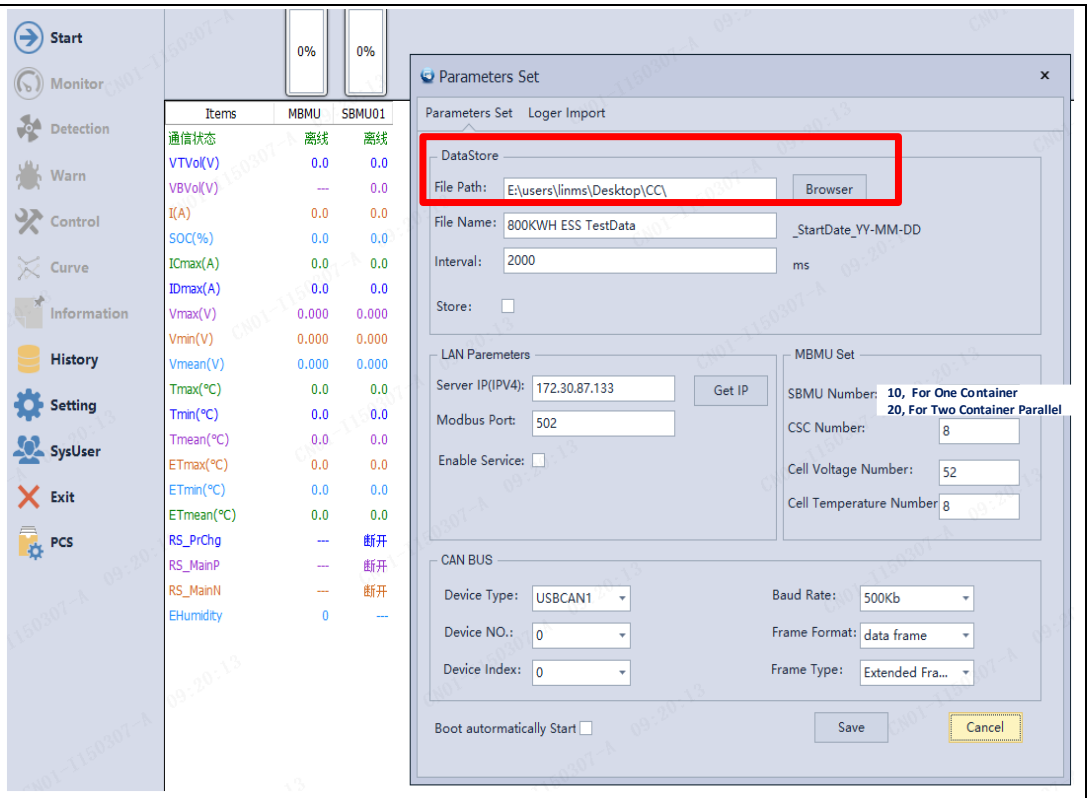
iii. Only turn on the ETH power supply and configure IP.

b) After verifying the version, configure IP using setting tools (if the version is wrong, flash the ETH software first.)

6.5 CATL Real–time Monitoring System

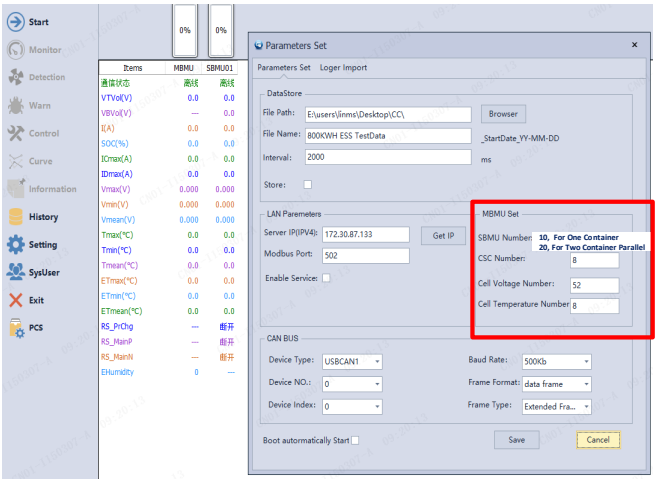
Table 6-2 CATL Real–time Monitoring System Overview

Step	Description
1	**CATL Real–time Monitoring System installation** ● After connecting CAN tools to the computer, open the real-time monitoring system 
2	**Data Store file path setting** ● Set up the real-time monitoring system by choosing the data storage place, check the Store option below, after that, all shown data on the monitoring system will be stored on the path.

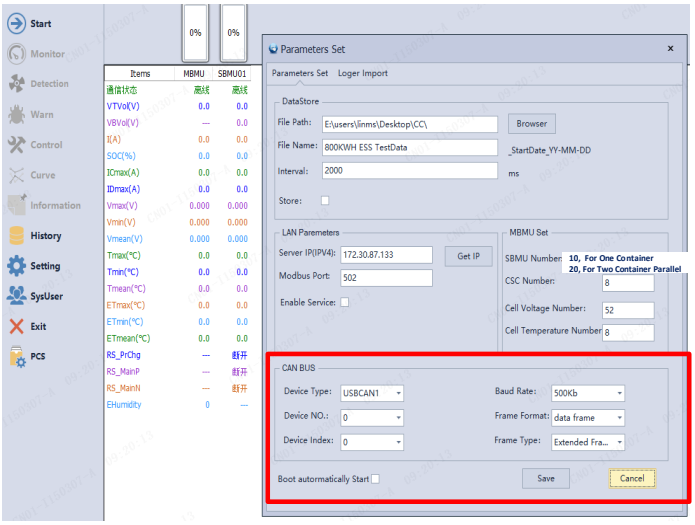
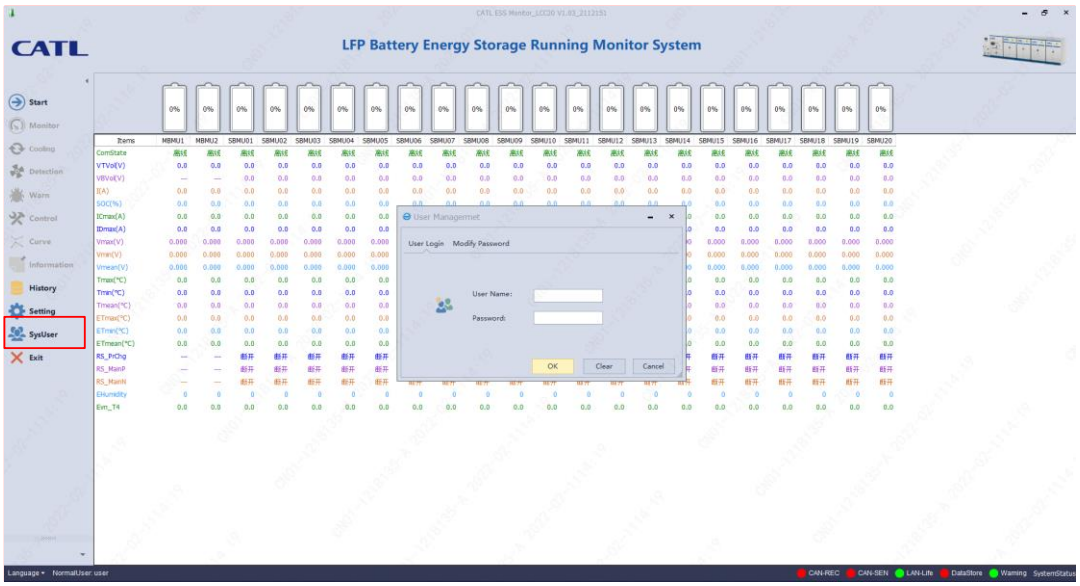


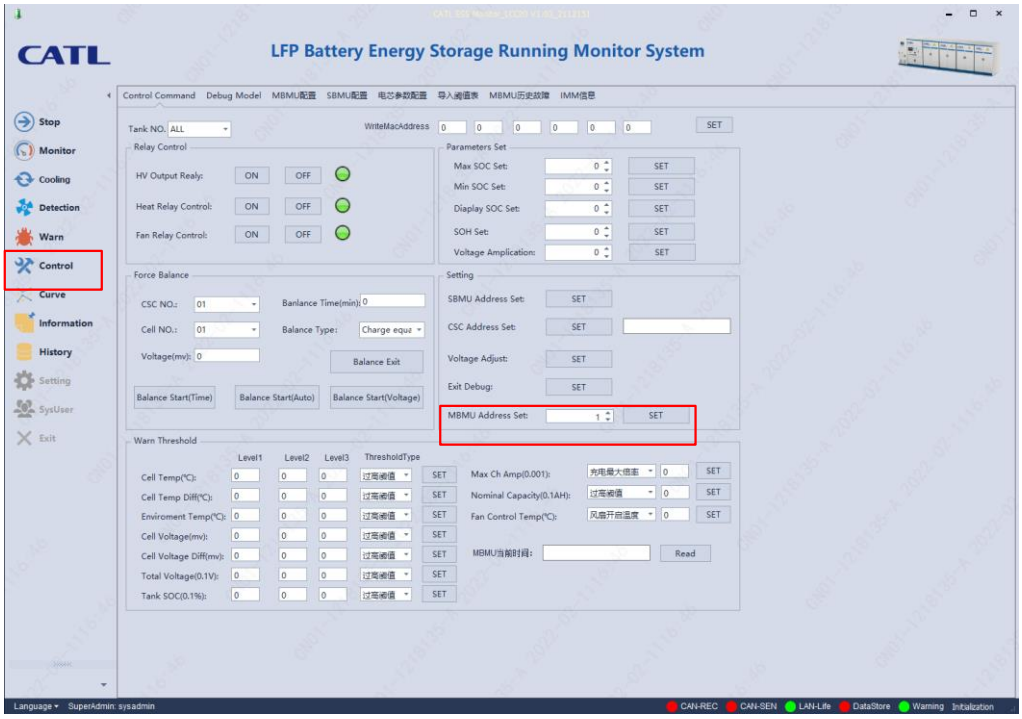
3

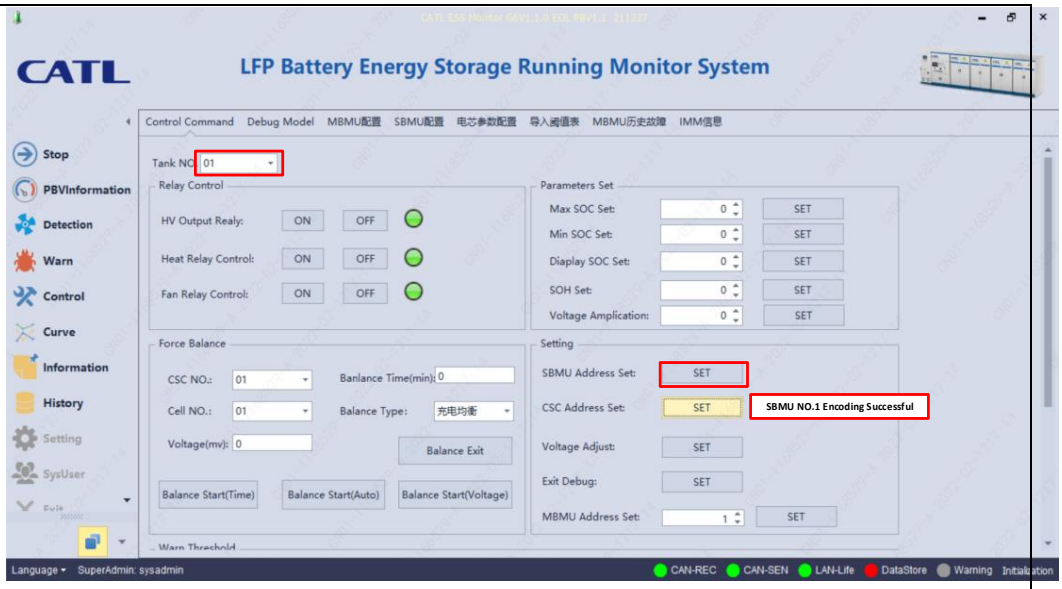
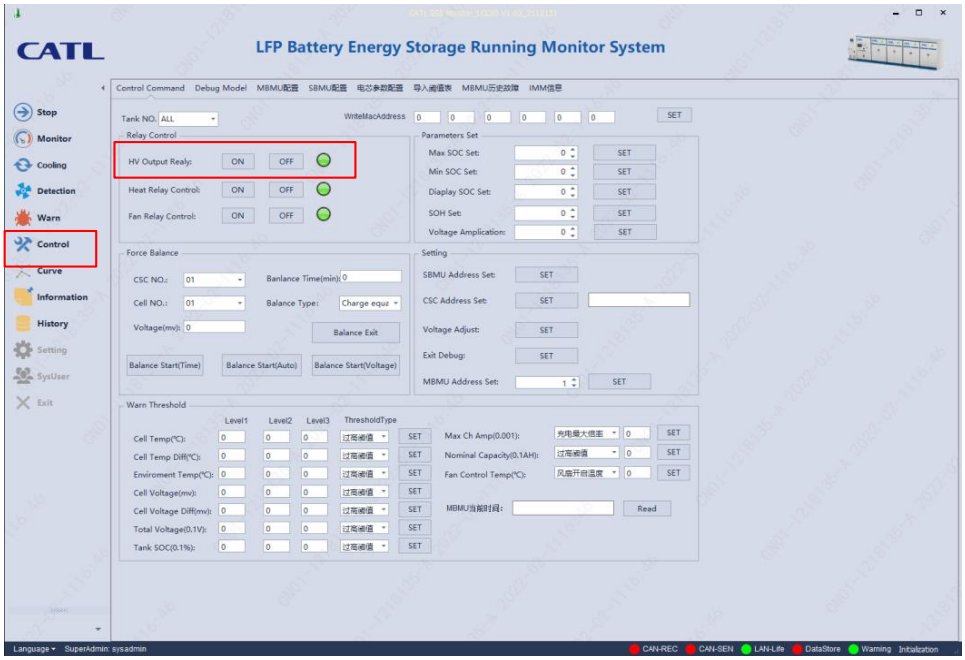
MBMU Setting:

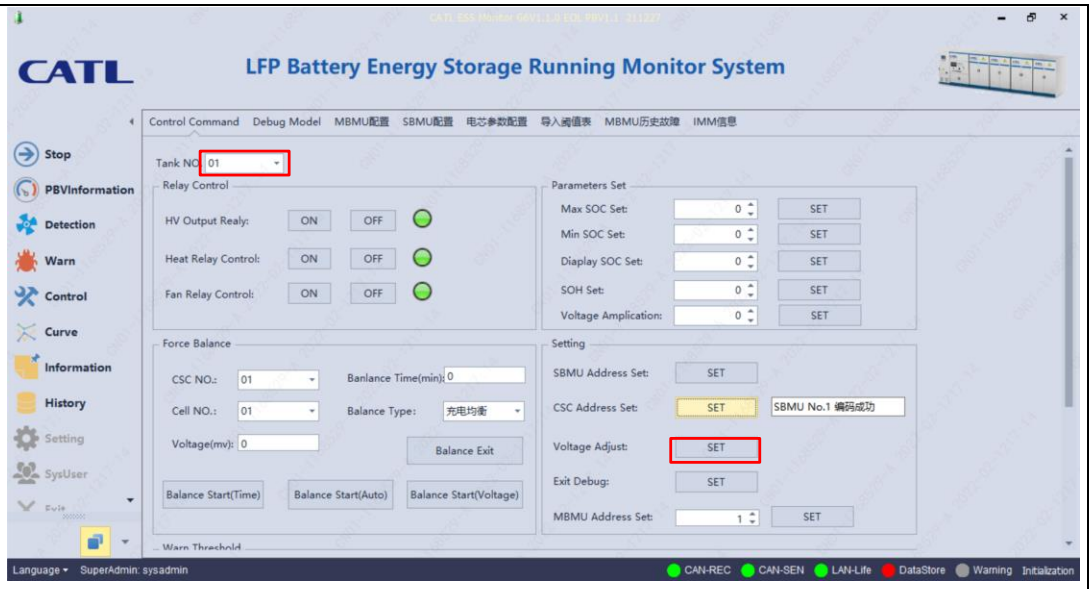
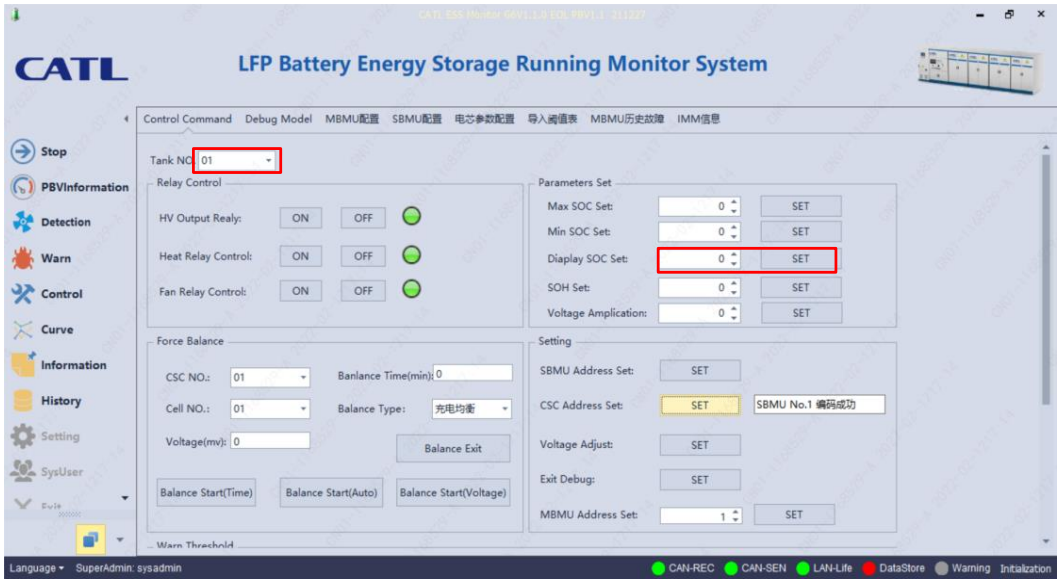


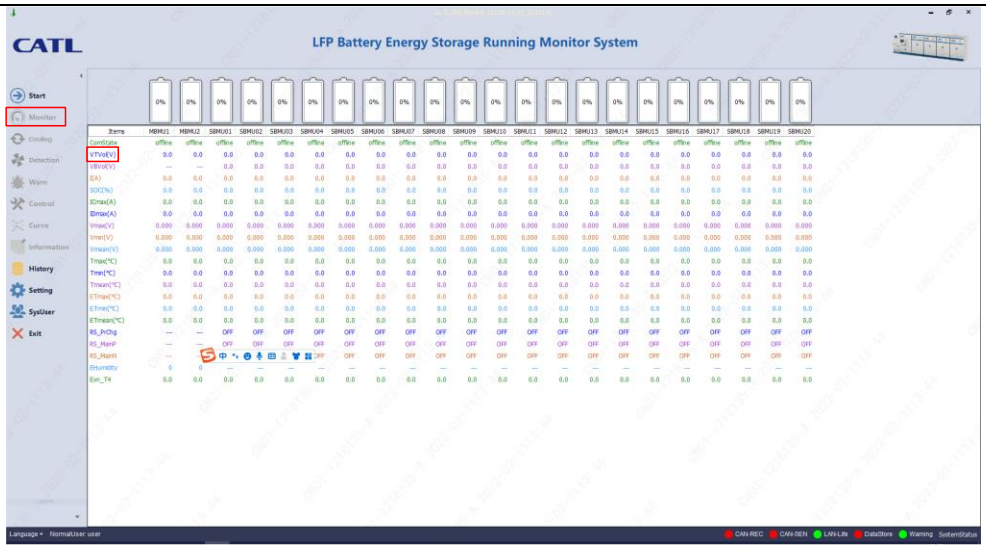
- SBMU number: the number of racks on the same CAN circuit, for single container, SBMU number is 4 for two container parallel connection, the number must be updated to 8;
- CSC number: 8, the number of modules in a single rack;
- Cell voltage number: 52, the number of cell in a single module 104 (2P52S);
- Cell temperature number: 11, the number of temperature test points in a single module.

4	**Interface setting:** ● Regarding device type, usually, choose USBCAN1 if using ZLGCAN (ZLGCAN has two interface, CAN1 and CAN2). If using ValueCAN tool, then choose ValueCAN. ● Regarding Baud Rate and data type, leave them as the default value. Click 'save', and the monitoring system will restart automatically. If others Baud Rate setting is required, the definition is according to the type of CAN, the value of ACAN is 250k, CCAN, MCAN, SCAN need chose 500K. 
5	**User login interface setting** ● Click the menu SysUser， the user login interface will pop up. The User Name is sysadmin, the password is 1234567890111. Then click the OK. 

6	**MBMU Encoding** ● Click the menu 'Control', enter encoding interface. When encoding the first MBMU, the MBMU address must be set to '1'. If have two container parallel connection, the second MBMU address must be set to '2'. 
7	**SBMU&CSC Encoding** ● When encoding the first SBMU, set the Tank NO. to "1", and then click the "SBMU Address Set", after that, click "CSC address set". If encoding successful, following message "SBMU No.1 encoding successful" will be got. ● Others SBMU&CSC encoding follow same process

	
8	**Rack on-off controlling** ● After confirming that the condition for closing High Voltage relays is fulfilled, click ‘ON’. Then all the racks will be powered on. 
9	**internal voltage calibration** ● After closing high voltage relay, BMS will measure system voltage and accumulative voltage of single cell. For limiting these two voltage difference smaller than 2V, the internal voltage calibration need be done. ● Firstly, choose the Tank No. correctly, and then click the ‘set’ in voltage adjust.

<table>
<tr><td></td><td> 
</td></tr>
<tr><td>10</td><td>SOC calibration
● Firstly, choose the Tank No. correctly, and then set the “Display SOC State” to the value you want.
 
</td></tr>
<tr><td>11</td><td>Operating status Monitor
● Select “monitor”， check if all the batteries are on closed state, and check VTVOL to see if there is voltage data.</td></tr>
</table>



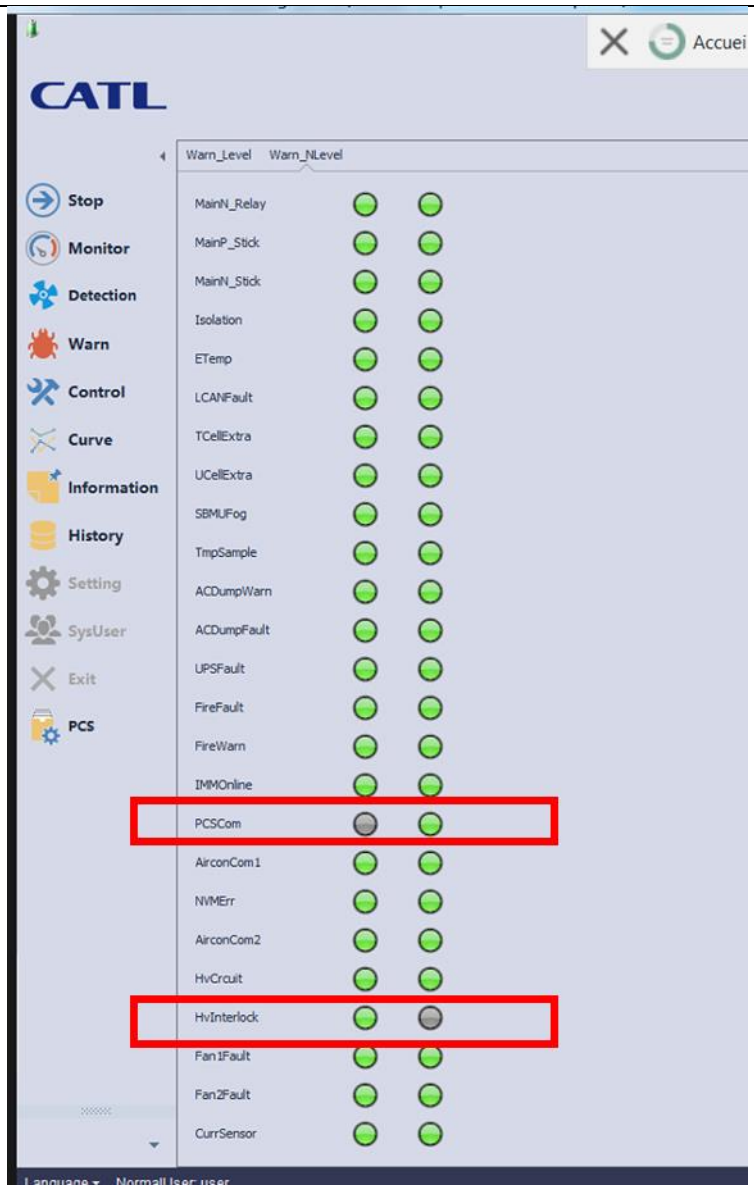
- Check if allowable charging/discharging current appears. If so, it means that the system can charge and discharge normally.

Items	MBMU	SBMU01
ComState	normal	normal
VTVol(V)	---	0.0
VBVol(V)	---	1028.9
I(A)	0.0	0.0
SOC(%)	39.4	39.4
ICmax(A)	0.0	-116.0
IDmax(A)	0.0	181.3
Vmax(V)	3.300	3.300
Vmin(V)	3.297	3.297
Vmean(V)	3.297	3.297
Tmax(°C)	20.0	20.0
Tmin(°C)	19.0	19.0
Tmean(°C)	19.0	19.0
ETmax(°C)	204.0	203.0
ETmin(°C)	204.0	21.0
ETmean(°C)	204.0	203.0
RS_PrChg	---	OFF
RS_MainP	---	OFF
RS_MainN	---	OFF
EHumidity	0	---

12

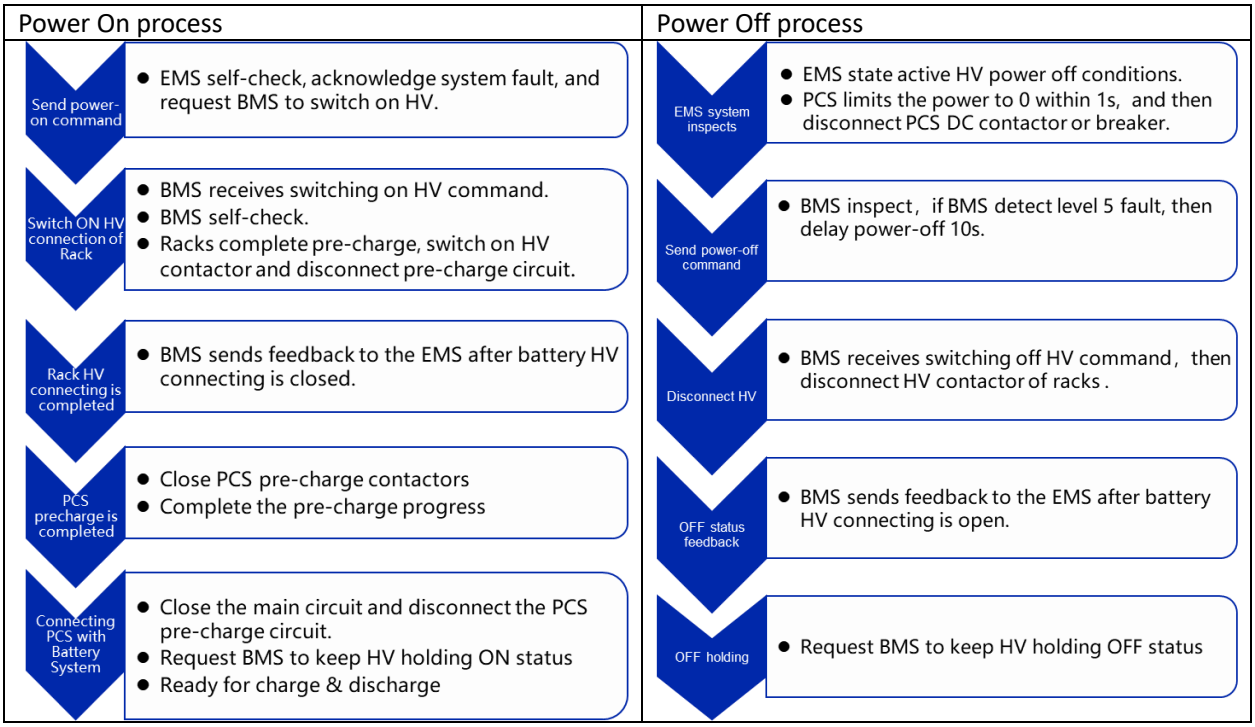
Warning status Monitor

- Select ‘warn’. Alarm status can be found here. Based on the alarm status, figure out the corresponding problems and do the analysis.


Accuei
CATL
Warn_Level
Warn_NLevel
Stop
Monitor
Detection
Warn
Control
Curve
Information
History
Setting
SysUser
Exit
PCS
MainN_Relay
MainP_Stick
MainN_Stick
Isolation
ETemp
LCANFault
TCellExtra
UCellExtra
SBMUFog
TmpSample
ACDumpWarn
ACDumpFault
UPSFault
FireFault
FireWarn
IMMOnline
PCSCom
AirconCom1
NVMErr
AirconCom2
HvCrcuit
HvInterlock
Fan1Fault
Fan2Fault
CurrSensor

7 Commissioning flow chart

7.1 Commissioning flow chart



7.2 System inspection before commissioning

In accordance with the requirements in the system instructions, patrol inspection should be performed for the system and execution and recording should be carried out as per the following table.

Table 7-1 Checklist of system inspection

No	Test item	Description	Result	
1	Appearance Inspection	The appearance of product has no damage and deformation; paint coating has no raise and damage	OK□	NG□
			OK□	NG□
			OK□	NG□
2	Check bolts	Whether bolts get damaged or loosed	OK□	NG□
3	Check HV disconnection	Use the multimeter to test open voltage = 0V;	OK□	NG□
		Use the multimeter to test the resistance	OK□	NG□

		between positive and negative poles is = ∞.		
4	Check LV cable connection	Whether cable connection is correct according to chapter 5.6	OK□	NG□
5	Check AC voltage level of 3AC Auxiliary power supply	Be sure the primary terminals of transformer inside of LV box can match the voltage level 380V…480V of 3AC Auxiliary power supply. Default setting: 3AC 480V.	OK□	NG□

	WARNING
	In the battery system, all power connections must ensure that a sufficient number of protective measures for insulation will be taken, the positive and negative poles of a battery will in no way contact the outer box to lead to leakage of electricity and a short circuit, and the positive and negative poles of the battery system will not be short-circuited in any case; otherwise, a major safety accident and an electric shock might be caused.

7.3 Switch on auxiliary power supply

Connect 3AC 380…480V and 1AC 110…230V auxiliary power and power on according to the following table, make sure the U/V/W/N/PE terminals connection correctly, then check that the green indicator light is on.

Table 7-2 Auxiliary distribution box(UPS configuration)

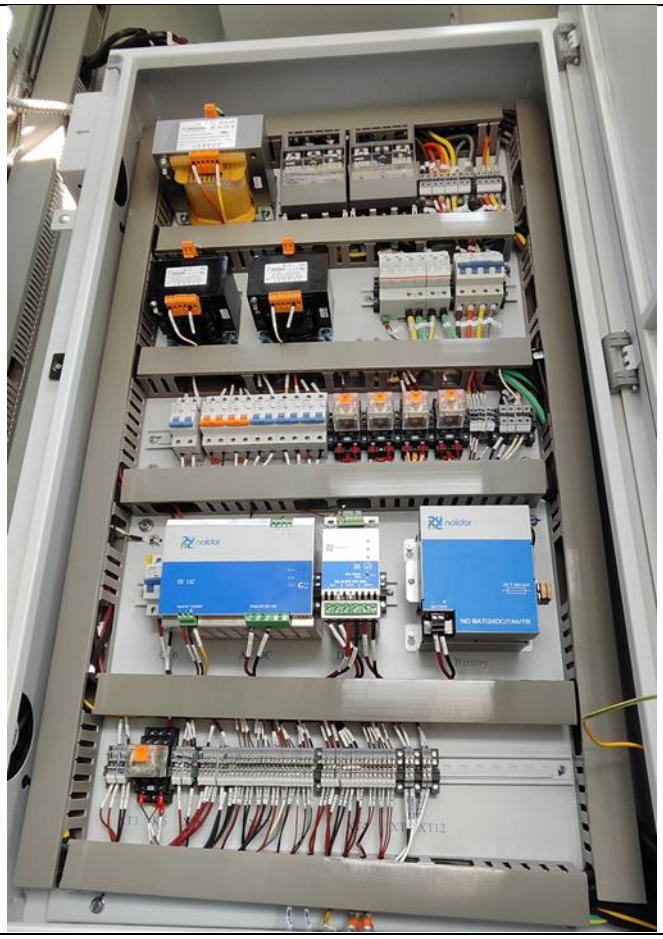
Auxiliary distribution box	**Operating**
	1. Switch on the external 3AC 380V~480V auxiliary power supply and 1AC 120~230V FSS power supply. 2. Close the main circuit breaker QF1 in the 3AC480V power supply. 3. Close the circuit breaker QF2and QF3 in the power supply of the Fire system and Explosion proof . 4. Close the circuit breaker QF4 in the power supply of the cooling unit system. 5. Close the circuit breaker QF5,QF7 & QF8 6. Close the circuit breaker QF6in the UPS battery.. 7. Check the indicator of K1 K2 K3 K5 & K6 relay: **Lighting**

Table 7-3 Auxiliary distribution box(24V power module configuration)

Auxiliary distribution box	**Operating**
	1. Switch on the external 3AC 380V~480V auxiliary power supply and 1AC 120~230V FSS power supply. 2. Close the main circuit breaker QF1 in the 3AC480V power supply. 3. Close the circuit breaker QF2and QF3 in the power supply of the Fire system and Explosion proof . 4. Close the circuit breaker QF4 in the power supply of the cooling unit system. 5. Close the circuit breaker QF5,QF7 & QF8 6. Turn on the QS in the 24V power module. 7. Check the indicator of K1 K2 K3 K5 & K6 relay: **Lighting**

Table 7-3 Definition of indication lights

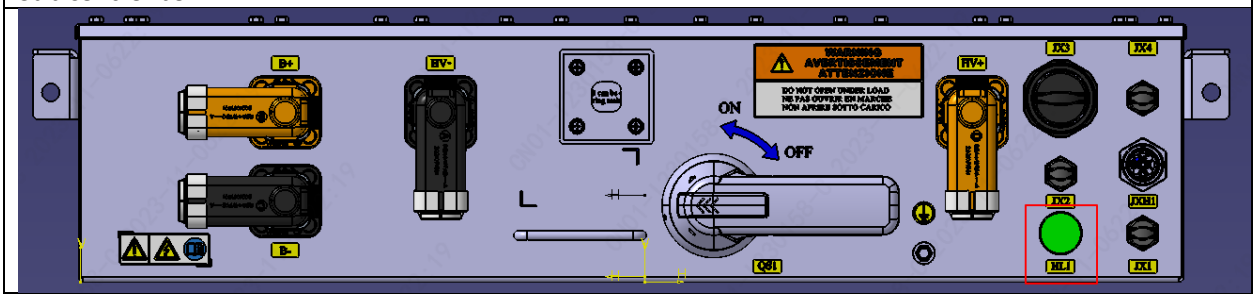
System state	Indicators status for the HV circuit ●	Indicators status for the LV circuit ●	Alarm indicator light ●
Power OFF	Green light is OFF	Red light is OFF	Yellow light is OFF
Failure	Green light is ON	Red light is OFF	Yellow light is ON
Power ON	Green light is ON	Red light is OFF	Yellow light is OFF
Power up of Primary	Green light is ON	Red light is ON	Yellow light is OFF

Circuit			
Charge/Discharge	Green light is ON	Red light is ON	Yellow light is OFF

7.4 Switch on HV relays of battery control box

Switch on insolation switches of four control box.

Table 7-4 Sub control box overview

Sub control box


Switch on HV relays

After the auxiliary power supply is switching on, use the close HV relays command to close the HV relays according to communication protocol. At this moment, the positive and negative output ends of the battery racks will generate about 1040V~1500V DC high voltage. The light will correspond to the following state:

Table 7-5 Indicator light: High voltage power supply

System state	Indicator light for the LV circuit●
low voltage power supply	Green light is on

7.5 Startup PCS and Precharge DC capacitors

Due to PCS include DC capacitors for filter function, the precharging process is always mandatory, it's recommend that PCS precharging is realized by PCS itself instead of DC battery system.

7.6 Switch on the connection between PCS and Container

For EnerX container, high current will be conducted to PCS during charge/discharge process, for line protection and controlling function, a DC breaker with motorized controlling need be used for switching on/off the connection between PCS and EnerX container.

After startup PCS and precharging of DC capacitors, then switch on DC connection.

7.7 EMS send command to PCS to start charge/discharge

7.7.1 Charging of Battery System

When the connection is closed between PCS and EnerX container, enable PCS (EMS) working in constant power control model and start charging, the BMS detects the charging current, and the battery system is charged, at this time, the combination of the on and off of each indicator will correspond to the state as Table 7-5.

7.7.2 Discharging of Battery System

When the battery system is charged at high voltage, if the battery system detects the discharging current, the battery system will enter the discharging state and the battery system will start discharging. At this moment, the combination of lights on and off will correspond to the state as Table 7-5.

7.8 E-Stop procedure

As Figure 7-1 shown, there is an E-stop button on the door, which is used for power off in case of Emergency.

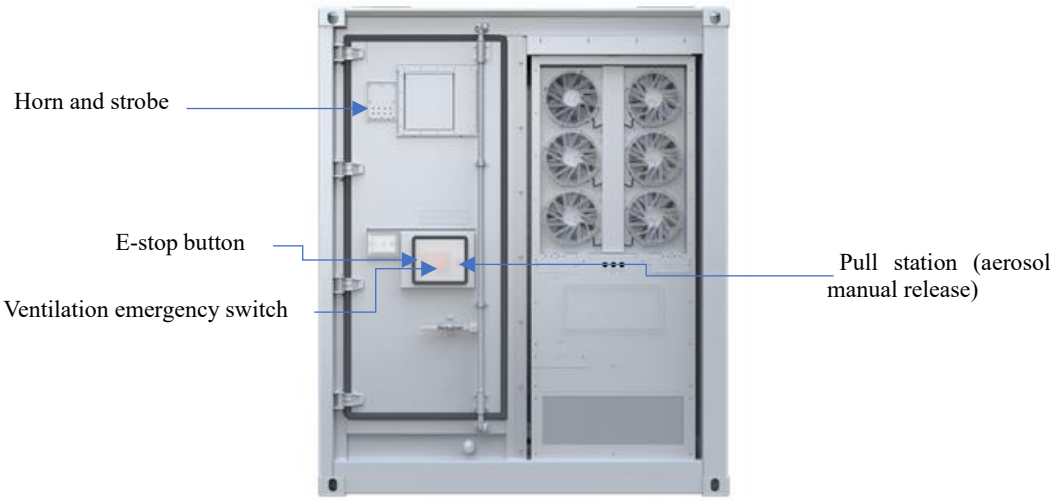


Figure 7-1 E-stop button

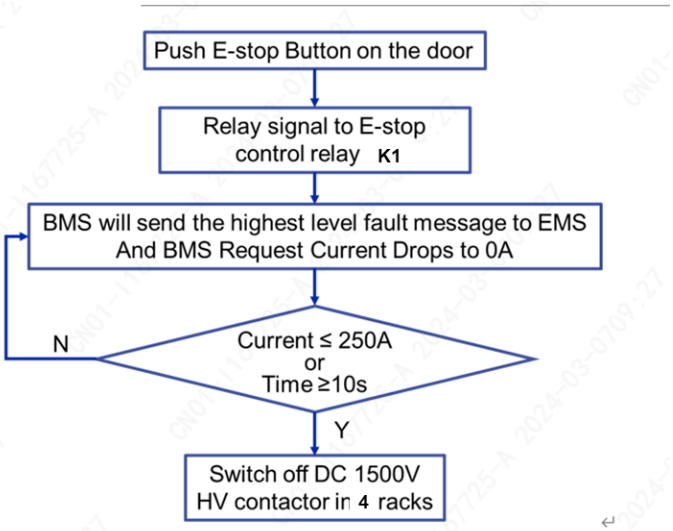


Figure 7-2 E-stop by push button

8 Diagnosis of common abnormal problems

8.1 System status word

The system status can be read by BMS via register address.

Table 6-1 System level fault message

Level	Fault	Register	(Value =0, normal; Value ≠0, abnormal)
MBMU	Single cell overvoltage warning	0x0000	Bit0-Bit2
MBMU	Single cell under voltage warning		Bit3-Bit5
MBMU	Cell extreme over voltage warning		Bit6
MBMU	Cell extreme under voltage warning		Bit7
MBMU	Single cabinet over voltage warning		Bit8-Bit9
MBMU	Single cabinet under voltage warning		Bit10-Bit11
MBMU	Warning for big voltage difference of single cell		Bit12
MBMU	Cell voltage Invalid warning		Bit13
MBMU	Single cell under voltage Report for exchange warning		Bit14
MBMU	Single cell over voltage Report for exchange warning		Bit15
MBMU	Platform Reserved signal	0x0001	Bit0-Bit1
MBMU	Discharge over current warning		Bit2-Bit5
MBMU	Charge over current warning		Bit6-Bit9
MBMU	Current sensor warning		Bit10
MBMU	Platform Reserved signal		Bit11-Bit13
MBMU	Single cell over temperature warning		Bit14-Bit15
MBMU	Single cell over temperature warning	0x0002	Bit0-Bit1
MBMU	Single cell Under temperature warning		Bit2-Bit4

MBMU	Big voltage difference of single cell Warning		Bit5-Bit7
MBMU	SBMU master control box Over temperature warning		Bit8-Bit11
MBMU	SBMU master control box under temperature warning		Bit12-Bit14
MBMU	Single temperature sampling abnormal warning		Bit15
MBMU	Multiple temperature sampling abnormal warning	0x0003	Bit0
MBMU	Platform Reserved signal		Bit1-Bit4
MBMU	Main positive relay drive Short power supply warning		Bit5
MBMU	Main positive relay drive Short Ground warning		Bit6
MBMU	Main negative relay drive Short power supply warning		Bit7
MBMU	Main negative relay drive Short Ground warning		Bit8
MBMU	Pre-charge relay drive Short power supply warning		Bit9
MBMU	Pre-charge relay drive Short Ground warning		Bit10
MBMU	CSC Power Supply Drive Short Power Supply warning		Bit11
MBMU	CSC Power Supply Drive Short Ground warning		Bit12
MBMU	CSC Coded Drive Short Power Supply warning		Bit13
MBMU	Platform Reserved signal		Bit14
MBMU	SBMU Coded Drive Short Power Supply warning		Bit15
MBMU	SBMU Coded Drive Short Ground warning	0x0004	

8.2 Countermeasures of system alarm

If system failure mode is detected, the abnormal status will be divided into 5 level to distinguish the severity of failure, and then the system will automatically switching to a safety operating model according to following definition.

Table 8-2 Treatment measures of failure at different levels

Failure level	Severity degree	Alarm to EMS	BMS failure dry contact	HV Contactor response
CAT 1	Very Low	Report	close	No action
CAT 2	Low	Report	close	No action
CAT 3	Low	Report	close	No action
CAT 4	Medium	Report	close	Outage of failure single rack after 10s
CAT 5	High	Report	close	Outage of failure single rack immediately
CAT 6	High	Report	open	Outage of all battery racks after 10s
CAT 7	Very High	Report	open	Outage of all battery racks immediately

8.3 Countermeasures of abnormal conditions

When enable the battery rack, if it cannot work normally, please check the potential cause according to

Table 8-3. At the same time, pay attention to check whether it is caused by external environment, such as temperature, noncompliant humidity or load overload. If the maintenance or replacement of spare parts is involved, the after-sales service procedure should be followed. Meanwhile, the disassembly and installation are not allowed without authorization.

This chapter contains only a few simple failure diagnosis procedures. If the answer to the diagnosis is not very unequivocal, or the information obtained is not enough to settle the problem, please contact the local office or distributor of the CATL.

Table 8-3 List of Failure diagnosis procedures

S/N	Failure or alarm phenomena	Possible cause of failure	Troubleshooting scheme
1	The green indicator light of the battery rack is not on	1. Poor contact of wiring harness	Check indicator light wiring harness
		2. SBMU failure	Replacement of SBMU
		3. Breakdown of indicator	Replacement of indicator light
2	The yellow indicator light of the battery rack is not on	1. Poor contact of wiring harness	Check indicator light wiring harness
		2. SBMU failure	Replacement of SBMU
		3. Breakdown of indicator	Replacement of indicator light
3	The red indicator light of the battery rack is not on	1. Poor contact of wiring harness	Check indicator light wiring harness
		2. SBMU failure	Replacement of SBMU
		3. Breakdown of indicator	Replacement of indicator light
4	Pre-charge relay cannot be closed	1. Poor connection of relay wiring harness	Check wiring harness connection
		2. Relay failure	Replacement of pre-charge relay
		3. SBMU failure	Replacement of SBMU
5	Main positive DC-contactor cannot be closed	1.Poor connection of main positive DC-contactor wiring harness	Check wiring harness connection
		2. Main DC-contactor failure	Replacement of main DC-contactor
		3. SBMU failure	Replacement of SBMU
6	Main negative DC-contactor cannot be closed	1. Poor connection of main negative DC-contactor wiring harness	Check wiring harness connection
		2. Main negative DC-contactor failure	Replacement of main negative DC-contactor

S/N	Failure or alarm phenomena	Possible cause of failure	Troubleshooting scheme
		3. SBMU failure	Replacement of SBMU
7	Adhesion of main positive DC-contactor	1. Damage of main positive DC-contactor	Replacement of main positive DC-contactor
8	Adhesion of main negative DC-contactor	1. Damage of main negative DC-contactor	Replacement of main negative DC-contactor
9	Abnormal power down of CSC	1. Abnormal CSC power supply wiring harness	Check CSC power supply wiring harness
		2. CSC failure	Replacement of CSC
10	Abnormal cell voltage detection	1. Poor connection of voltage detection wiring harness	Check wiring harness connection
		2. CSC failure	Replacement of CSC
11	Abnormal NTC temperature detection	1. Poor connection of temperature detection wiring harness	Check wiring harness connection
		2. Temperature sensor failure	Replacement of temperature sensor
		3. CSC failure	Replacement of CSC
12	Abnormal total voltage detection	1. Poor connection of total voltage detection wiring harness	Check wiring harness connection
		2. SBMU failure	Replacement of SBMU
13	Internal communication anomaly	1. Poor connection of internal CAN wires	Check CAN connecting wires by pluck and insertion
14	Anomaly caused by unconfigured system parameters	1. Unconfigured battery system parameters	Configure system parameters
15	Current sensor anomaly	1. Poor connection of 12V power harness wiring	Check wiring harness
		2. Poor connection of SCAN communication wires	Check wiring harness
		3. SBMU power generation anomaly	Replacement of SBMU
16	SBMU automatic shutdown	1. Poor connection of MBMU wake-up signal wires	Check wiring harness
		2. MBMU failure	Replacement of MBMU
17	cell over-voltage alarm	1. Poor equalization	Stop charging and standby equalization
		2. System overcharge	Stop charging
18	cell under-voltage alarm	1. Poor equalization	Stop discharge and standby equalization
		2. System over-discharge	Stop discharge

S/N	Failure or alarm phenomena	Possible cause of failure	Troubleshooting scheme
19	NTC over-temperature alarm	1. Excessive temperature of individual NTC	Check whether the air conditioner is in operation
		Excessive charging-discharge current	Appropriately reduce charging and discharge current
20	NTC under-temperature alarm	1. Lower temperature of individual cores	Check whether the heating function is on (if the equipment cabinet has heating function)
		2. Lower ambient temperature	No charging
21	Charging over-current alarm	1. Excessive current of system charging	Reduce charging power
22	Discharge over-current alarm	1.Excessive current of system discharge	Reduce system load
23	Alarm of higher SOC	1.The system power is full (overcharged)	Stop system charging
24	Alarm of lower SOC	1.The system power is too low (over-discharge)	Stop system discharge
25	Alarm of higher monomer temperature difference	1.Non-uniform heat dissipation of equipment cabinet	Check whether the air conditioner is on
		2. Temperature sensor failure	Replacement of temperature sensor
26	Alarm of higher monomer voltage difference	1.Excessive difference of cell capacity	Battery system can be charged to over 80% SOC, with standby equalization
27	SOC difference alarm	1. The electric quantity difference of different battery racks is too large	—— ——
28	Abnormal alarm of equalization circuit	1. Equalization abnormal CSC board	Replacement of CSC board

8.4 After-sales Service

CATL will provide clients with a full range of technical support and after-sales service. Users can gain services by dialing our service number. Service Number: 86 **400-918-0889**

Please refer to the contract for the free warranty service information.

- The following circumstances are not within the scope of our free warranty service:

1. System damage or failure caused by not following the user manual.

2. Damage or failure caused by not following the relevant electrical safety specifications for wiring and power supply or caused by poor site environment.

3. System damage or failure caused by users' private modification.

4. System damage or failure caused by irresistible natural factors, such as typhoon, earthquake, flood, fire or harsh environment (high temperature, low temperature, high humidity, acid rain, etc.).

After the failure occurs, the user fails to maintain the initial failure state, fails to timely notify the manufacturer and handles without authorization, thus causing it is unable to make a practical fault identification of the failure causes.

9 Product Maintenance

During whole product lifecycle, abnormal operating must be avoid, regular maintenance in Table 8-1 is mandatory to ensure safe and reliable operation and acquire an optimal performance for system.

Table 8-1 Product maintenance category

No.	Components	Checking items	Description	Frequency
1	Container	Coating （*）	Check whether the surface coating of the container is warped, cracked, peeled, rusted, etc.	Annual
2		Label & nameplate	Check whether the labels and nameplates have abnormal phenomena such as falling off, blurring and tilting.	Annual
3		Water traces	Check whether there is obvious water ingress or water ingress in the container.	Semi-Annual
4		Biological invasion	Check whether there are any living things (rodents) in the air conditioner, water-cooled unit compartment, electrical compartment, and battery compartment.	Semi-Annual

5		Battery compartment	Check the dust situation inside the container. If the pollution is particularly serious, it is necessary to find the location from where the dust enters.	Semi-Annual
6		Abnormal odor （*）	Check whether there is a pungent odor or burning paste odor in the container (short cycle inspection does not require opening the container door).	Semi-Annual
7		Battery compartment door	Check whether the battery compartment door limit lever functions normally and whether there is any deformation damage.	Annual
8		Corrosion of parts	Check whether there is corrosion of structural parts, frames, etc. caused by water accumulation inside the container.	Semi-Annual
9		Floor drain	Check whether the floor drain function is normal.	Semi-Annual
10		Abnormal sounds （*）	Check whether there is a crackling sound during system operation (short cycle inspection does not require opening the container door).	Semi-Annual
11		Internal identification	Check whether labels such as master control box, subcontrol box, ditribution box have any abnormal phenomena such as falling off, not being able to see clearly, and cocking.	Annual
12		Door seals	Check whether the sealing strip of each door of the container is dirty, broken, falling off, or not installed in place.	Annual

13		Ambient temperature and humidity	Check whether the ambient temperature and humidity record and check whether the temperature and humidity is within the allowable range.	Semi-Annual
14		Indicator （*）	Check whether the indicators are normal or not.	Semi-Annual
15	Fire suppression system	Gas detector	Check whether the gas detectors are normal or not.	Annual (or refer to local rules)
16		Smoke detector	Check whether the smoke detectors are normal or not.	Annual (or refer to local rules)
17		Temperature detector	Check whether the temperature detectors are normal or not.	Annual (or refer to local rules)
18		Smoke&gas trigger	Check whether the alarm function is normal when the smoke and gas detector triggered at the same time.	Annual (or refer to local rules)
19		Temperature&smoke trigger	Check whether the alarm function is normal when the temperature and smoke detector triggered at the same time.	Annual (or refer to local rules)
20		Connectors	Check whether the smoke and temperature sense are installed and tightened, and the wiring harness connection is normal.	Annual (or refer to local rules)
21		Aerosol	Check whether the aerosol starting line is damaged, the aerosol is installed firmly, the appearance is damaged, the aerosol reaches the service life.	Annual (or refer to local rules)

22	Chiller	Filter	Check whether the air inlet filter is blocked	Semi-Annual
23		Ventilation hood	Check whether there is dust in the ventilation hood.	Semi-Annual
24		Heating mode function	Check whether the heating mode function is normal.	Semi-Annual
25		Cooling mode function	Check whether the cooling mode function is normal.	Semi-Annual
26		Sleeping mode function	Check whether the sleeping mode function is normal.	Semi-Annual
27		Interface	Check whether there are obvious liquid leakage marks at each interface position of the unit and water cooling pipe.	Semi-Annual
28		Abnormal sounds （*）	Check whether the chiller has abnormal noise during operation (mechanical impact sound/whistle sound).	Semi-Annual
29		Operational status monitoring	1. Check the operation process. Judged by the operation status TMS_RunState in the Cooling interface of the BMS monitor, Cooling is refrigeration, Hot is heating, Cycling is self-circulation, and Stop is shutdown. 2. Check the TMS outlet pressure and return pressure in Cooling interface when the unit is running for 5 minutes without shutdown, and meet the pressure value ≥x bar.	Semi-Annual
30		Fault monitoring	Check the chiller's working condition based on BMS.	Semi-Annual

31		Water pressure and temperature monitoring	The BMS monitor reads the inlet and outlet temperature and water pressure to check whether it is within the normal range.	Semi-Annual
32	High and low voltage wiring harnesses	Harness appearance	Check whether the wiring harness is damaged, ablated or aged.	Semi-Annual
33	High and low voltage connectors	Connector appearance	Check whether the connector is yellowing, blacking or even ablated.	Semi-Annual
34		Connector connection reliability	Shake the connector plug to see if the connector interface is loose.	Semi-Annual
35	Energy storage system	Common-mode voltage troubleshooting--spot check, one for each project	The waveforms of DC-to GND and DC +to GND under five working conditions (standby/shutdown, zero-power floating charge, full-power charge, full-power discharge, standby-to-charge) were collected and analyzed by oscilloscope. PCS terminal AC A-to-ground, B-to-ground waveform.	Annual
36		Equipotential connecting wire	Check whether the equipotential connecting wire of the electric cabinet is complete.	Semi-Annual
37		Equipotential detection	Measure the resistance of the electric box shell to the equipotential site of the electric cabinet.	Semi-Annual
38		Insulation test	Insulation detection with a multimeter.	Semi-Annual
39		BMS monitor inspection	Read voltage difference by BMS monitor.	Semi-Annual
40		Historical data collection	Collect local 6-month operation data for analysis.	Semi-Annual

41		SOH statue analysis	Refer to the collected data, analyze the SOC consistency, historical failure, voltage difference and other information of the battery.	Semi-Annual

Note:

1.This is a general about CATL preventive maintenance services, for details, please contact CATL service email: S-CustomerCenter@catl.com

2.CATL provide paid preventive maintenance services during warranty period.

3.Service call center：GSS-CustomerCenter@catl.com

3.Maintenance items with asterisks (*）mean that the customer can perform them themselves and will not be counted into the preventive maintenance hours.

4.It is the minimum requirement that an overall annual preventive maintenance shall be carried out to the ESS.

5.It is recommended that ESS preventive maintenance be conducted twice a year, one basic semi-annual inspection and one overall annual checklist.

6.Preventive Maintenance shall be scheduled and carried out as required by CATL ESS User Manuals. Where laws and regulations provide otherwise provisions on the preventive maintenance, such provisions shall prevail.

9.1 Battery System Maintenance

9.1.1 Maintenance instructions for normal operating system

Perform battery maintenance according to following plan on the system every twelve months to prevent battery damage.

1) **Plan 1（This plan is applicable when SOC of the battery system is low）**

- Discharge the battery system to the cut-off condition (the lowest voltage<2.5V), then stop discharging, standing for 1 hour.
- Full charging automatically to the battery system (The highest voltage>3.65V), after charging, standing for 1 hour.
- Discharge the battery system to 23% and stop.

2) Plan 2 （This plan is applicable when SOC of the battery system is high）

- Full charging automatically to the battery system (The highest voltage>3.65V), after charging,

standing for 1 hour.

- Discharge the battery system to the cut-off condition (the lowest voltage<2.5V), then stop discharging, standing for 1 hour.
- Charge the battery system to 23% and stop.

	CAUTION
	1. Check to ensure environmental safety, system safety, no alarm, no fault before performing maintenance operations. 2. After the battery maintenance of ESS is completed, it's suggested to notify CATL after-sales engineer to perform data analysis for free.

9.1.2 Maintenance instructions for long duration idle mode after COD date

- Suggested SOC range of battery storage: 30%~60%.
- If the battery system keep on idle mode more than 90 days, the battery is suggested to have SOC equal or above 50%. 3.21V shall in any case be considered as a minimum voltage level for per cell, in case that this voltage level is reached, battery system must be recharged immediately.
- Battery capacity test about 100% SOC charge and 0% SOC discharge must be conducted every 12 months.
- When recover the system from idle mode over 90 days to discharge/charge mode, the battery system must perform SOC calibration applying one of the possible methods, including:
  - Static Calibration
  - Dynamic Calibration
  - High Voltage Calibration

	CAUTION
	If the energy storage system keep on idle mode for a long time, it will cause irreversible damage to the battery. Please perform regular maintenance. 1. The minimum cell voltage (Static voltage) should not be less than 3.21 V for a long idle state; 2. The minimum cell voltage (Static voltage) should not be less than 2.5 V in any case; otherwise, the warranty will be invalid. 3. The minimum cell voltage (Static voltage)should not be less than 2.0 V in any case; otherwise, the battery will be over-discharged and may not be able to be repaired.

Spare Batteries are shipped out from CATL at SOC=23%

- The initial maintenance of the spare battery needs to be conducted after 12 months period. Charge the battery to 50% SOC (Equipment used: Pack-level charge and discharge machine)
- After the initial recharge, charge the battery once a year. Charge the battery to 50% SOC. (Equipment used: Pack-level charge and discharge machine)
- The spare parts should be maintained as follows before use.

  First discharge the battery until the minimum cell voltage is 2.5V; evaluate the battery consistency according to the OCV curve table, if the SOC imbalance (that is, the SOC corresponded to average voltage – the SOC corresponded to the lowest cell voltage)> 5%, you need to perform balanced maintenance first. (Equipment used: Pack-level charge and discharge machine、Equalization equipment)

  Remark:

  Charging duration (h) = (target SOC - current SOC)*nominated capacity (Ah)/machine constant charging current (A)

  Discharging duration (h) = (current SOC - target SOC)*nominated capacity (Ah)/machine constant discharging current (A)

9.1.3 Battery system inspection

Conduct an inspection of ESS every 12 months and make inspection record.

9.2 Container enclosure maintenance

	CAUTION
	The enclosure is not allowed to have rust, bend structure during whole product lifecycle

Conduct an inspection of Container every twelve months and make inspection record, if the paint on the surface have following damage scenarios, repaint it according to the following steps.

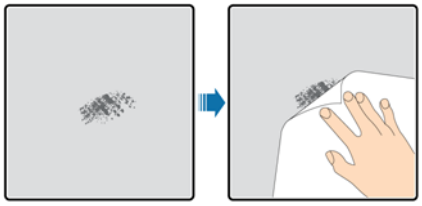
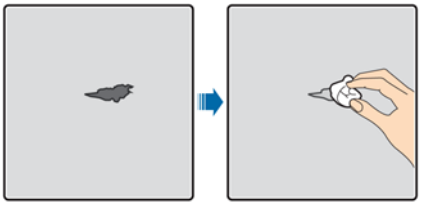
- Shallow scratch (not exposed steel substrate)
- A stain or rust that cannot be wiped
- Deep scratch (damage of primer, exposure of steel substrate)

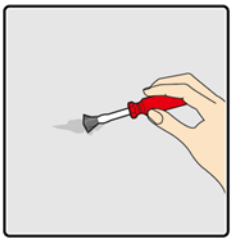
➢ **Precondition**

- In the outdoor environment without shelter, it is strictly forbidden to repaint in bad weather。

- Prepare the corresponding paint with the same color of the container surface.
- Visually inspect the severity of the surface paint damage of the container, prepare corresponding tools and materials, and evaluate the quantity of materials on site based on the repainting situation.
- Paint that meets requirements has been prepared based on the paint surface color number RAL7042 of containers.
- The exterior of the container should be intact. If the paint on the surface of the container is damaged or broken, repaint it immediately.
- Tools and Materials: Hand spray paint or paint, brush (for painting a small area), fine sand paper, anhydrous ethanol, cotton cloth, and spray gun

➢ **Procedure**

Step	Procedure
1	Gently polish the damaged area with fine sandpaper to remove dirt or rust. 
2	Moisten the cotton cloth with anhydrous ethanol, wipe the polished area or area to be repaired, remove dirt and dust, and wipe dry with a clean cotton cloth. 
4	According to the damage degree of the paint, evenly apply paint to the damaged coating by using one of the following methods until no damage is visible: 1. A small number of scratches and small area of stains, rust recommended to use hand spray paint or brush paint. 2. A large number of scratches and large areas of stains and rust should be sprayed with a paint spray gun.

	
5	Leave the paint on for 30 minutes, and then observe whether the repainting area meets requirements.

	CAUTION
	If the substrate is exposed in the area to be repaired, paint primer until the substrate is not exposed after the paint dries, and then apply middle layer paint and polyurethane topcoat. Use primer or polyurethane top coat of the corresponding color.

	CAUTION
	Note that the paint film should be as thin and even as possible. The paint film should not be droplet shape and the surface should be smooth. If there are different colors on the box body pattern, use adhesive tape and white paper to cover the parts of other colors except the damaged paint before painting, so as to avoid contamination of the parts of other colors during painting repair.

	CAUTION
	The paint patch area should be consistent with the color of the surrounding area, without obvious boundaries, obvious bumps, damage marks, and paint peeling phenomenon. If the user want to spray paint, it's advised to spray it three times and then check whether it meets the requirements. If not, repeat until the requirements are met.

9.3 Maintenance requirements for Thermal Management System

9.3.1 Instructions of Chiller Maintenance:

- It is strictly forbidden to let the unit work when there is no coolant in the waterway;
- It is strictly forbidden to operate the unit under the condition of soaking in water;

- It is strictly forbidden for personnel to touch the unit while the unit is running;
- It is strictly forbidden to disassemble by non-professionals
- It is strictly forbidden for the unit to be squeezed by heavy objects
- Use a vacuum cleaner to clean the condenser, radiator and air inlet and outlet of the unit every three months (no water).

9.3.2 Instructions of Coolant Maintenance:

Replace the coolant every five years or the coolant is degraded below any of the following levels.

- PH value < 6.5 or PH value > 9.5
- Chloride concentration > 60ppm
- Appearance: turbid coolant with impurities such as precipitated particles or flocculent impurities that are easily seen as shown below:

Turbid coolant:	Normal coolant:

If coolant has not degraded below any of the conditions described above by YAE, existing coolant can be used until the next scheduled inspection (every 5 years).

The coolant element is EC-45, only following approved supplier & type can be used

Table 8-2 Coolant element

Coolant	Supplier	Supplier type	Mark
EC-45	BASF	G30-45	
	SINOPEC	CNSH OEVC-45	
	Lopal Tech	**JSLP L70-45**	**Default type**

	CAUTION
	Mixed coolant from different supplier or type is not allowed, otherwise, the cooling capacity will be lost.

	CAUTION
	Any damage to the relevant parts of the battery compartment caused by using other coolants which are not recommended or approved by CATL is not covered by the warranty.

9.4 Spare parts

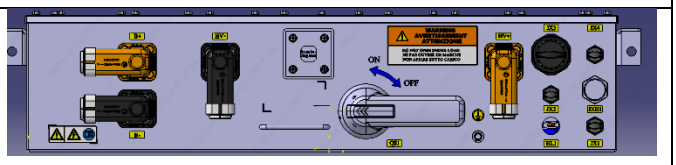
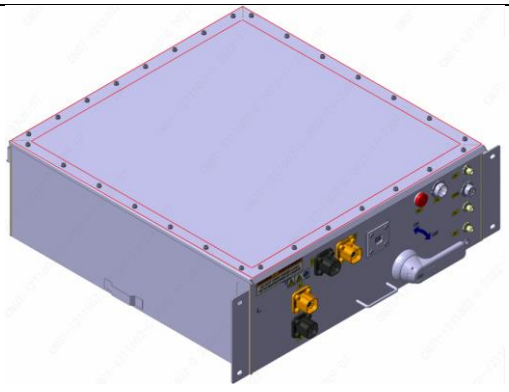
The detail spare parts list can be provided order by order, the range of spare parts is pre-defined as following：

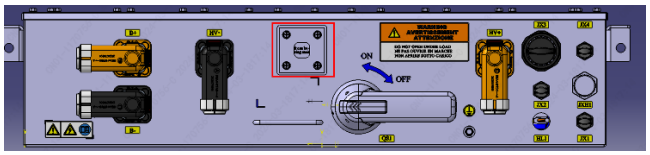
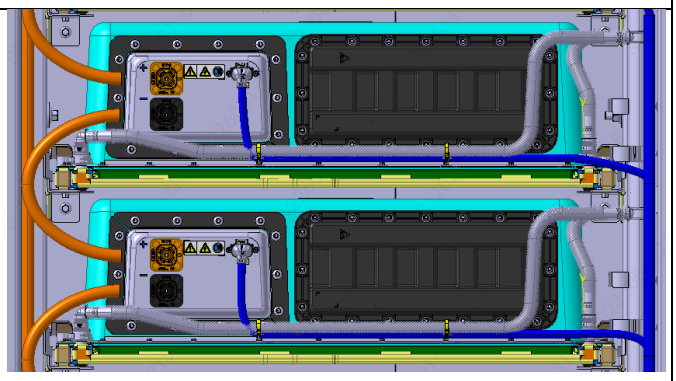
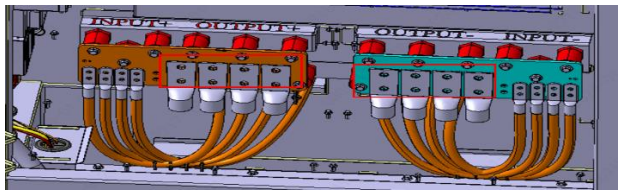
- Master control box and its sub components
- Sub control box and its sub components
- Battery module and CSC module
- Fire Suppression System components
- Thermal Management System components
- LV components of distribution box
- Enclosure

9.5 Fastener type and torque requirement

Any assembly and disassembly maintenance, following fastener type and torque requirement must be followed.

Table 8-3 Fastener type and torque requirement

Module	Screw type	Torque	Fixed point
Sub control box	M6x16, Hexagon bolt with flange	8N.m	
Cover plate of Sub control box	M5x17, Hexagon bolt with flange	5N.m	

Module	Screw type	Torque	Fixed point
Cover Plate of air tightness test in sub control box	M5x17, Hexagon bolt with flange	5N.m	
Battery module	M8x20, Hexagon bolt with flange	25N.m	
HV Connection of DC Combiner	M12x35, Combination Hexagon bolt	50N.m	
Earthing point	M12x35, Combination Hexagon bolt	50N.m	

Module	Screw type	Torque	Fixed point
Cover Plate of Master control box	M4x12, Cross recessed hexagon bolt	2N.m	

10 System Decommissioning & Removal

Contact CATL Service before attempting to decommission or remove a system. CATL equipment is designed for end-of-life management through recycling and materials reclamation, tasks which are normally handled by CATL-qualified partners. CATL Energy Storage can supply a list of qualified partners in your area to help ensure proper disposal of retired equipment.

11 Emergency Plan

After anomalies and accidents occur in battery system, correct and effective treatment measures shall be taken in time to deal with the problems in order to eliminate further damage and enlarged losses. The detail emergency plan can be separated provided.

Appendix 1：Inspection Checklist

No.	Inspection Items	Inspection Methods and Criteria	Tools	Type of Inspection	Inspection Results
1	Common-mode voltage check	Collect the DC- to GND and DC+ to GND waveforms under five operating conditions (standby/shutdown, zero-power floating charge, full power charge, full power discharge, and standby to charge) with an oscilloscope for analysis. Refer to the SOP for Common-Mode Voltage Check Oscilloscope for ESS Products.	Oscilloscope/isolating probe/multimeter, etc.	First maintenance	
2	Historical data collection	Collect local operating data in the last one month and upload it to the cloud storage; name the folder as assembly PN + collection time.	USB flash drive	First maintenance	
3	Rack tightness check	Visually check whether the sealing strip of the rack door comes off or is damaged.	Visual check	Routine inspection	
4	Inspection of the labels and nameplates	Visually check whether the label and the nameplate come off and take photos.	Visual check	Routine inspection	
5	Condensate check	Check whether there are traces of condensate and water flow on the inner wall, the top and other visible areas of the container, and take photos if any.	Visual check	Routine inspection	
6	Cabinet body check	Check whether the surface of the electrical cabinet is deformed, rusted, damaged or peeling off.	Visual check	Routine inspection	

7	Cabinet insulation test	Test the insulation resistance of the DC terminal with PCS, ≥10MΩ; Test condition: test the insulation under 1,500V DC voltage and check whether the stable insulation resistance is ≥20MΩ.	Insulating meter	In-depth inspection	
8	Confirmation of equipotential bonding and grounding of the system	1. Visually check whether the equipotential bonding wire and grounding wire of the system are intact. 2. In the container/cabinet, measure the resistance of the pack housing to the equipotential point of the cabinet, with the value <0.1 Ω as the acceptable one;	Visual check/multimeter	Routine inspection	
9	Fixing bolts of the pack	Check whether the bolts are loose or fall off, and tighten or reinstall them if yes.	Visual check/wrench	Routine inspection	
10	Spill check	Check whether there is any irritating smell in the cabinet.	Smelling	Routine inspection	
11	Harness (HV connector/HV harness in the control cabinet)	1. No missing parts, interference, damage or dirt 2. No looseness, with reliable connection and installation 3. No ablation or damages caused by squeezing 4. Consistency of the line markings, without damage or falling off.	Visual check	Routine inspection	
12	Harness (HV connector/HV harness in the control cabinet)	With the system in operation, use a handheld thermal imaging camera to measure the temperature of the first three cabinets of the system and take photos; check whether the temperature rise exceeds 50°C (temperature measured by the thermal imaging camera minus the room temperature);	Thermal images	In-depth inspection	
13	Electrical parts check	Check whether there is any crackle or burning smell during the operation of the system	Visual check/smelling/listening	Routine inspection	
14	Water cooling pipes	Whether the water cooling pipes are damaged.	Visual check	Routine inspection	
15	BMS monitor inspection	1. Read the software version 2. Check whether there is any alarm in the system. 3. Check whether the cell voltage difference is ≤300 mV (dynamic, full range) or the cell voltage difference is ≤100 mV (dynamic, 30%-80% SOC) 4. Read the net outlet temperature and	BMS monitor	Routine inspection	

		pressure with the BMS monitor to confirm whether they are within the normal ranges. 5. Check whether the disk space of the IPC is full, and back up the data of the past year.			
16	Historical data collection and analysis	Collect local operating data in the last. Upload the data to the cloud storage if no portable servicer is available; name the folder as assembly PN + collection time. Carry out the local analysis with a portable servicer if it is available.	USB flash drive, portable servicer	In-depth inspection	
17	Capacity testing	By project, perform the capacity testing using the capacity test method provided by SC (capacity test requirements in the acceptance report).	/	In-depth inspection	
18	Ambient environment	1. Ensure the channels/pipes are not blocked2. Check whether the plant and the container leak and check the humidity	Visual check	Routine inspection	
19	Fire protection system	1. Obtain a list of firefighting facilities from the energy storage power station and confirm whether the firefighting facilities are complete 2. Confirm whether there is a third-party fire safety inspection record	Visual check	Routine inspection	
20	Fire protection system	Check whether a third party has performed a professional inspection over the fire protection system and maintained an inspection record.	/	In-depth inspection	
21	UPS power supply	Check whether the UPS indicator and the UPS battery work.	Visual check	Routine inspection	

Appendix 2：Maintenance Tools and Equipment List

Number	Name	Photo	Specification	Recommend Brand
1	Insulated gloves		Insulation grade ≥1500V	Tianjin ShuangAn
2	Insulated shoes		Insulation grade ≥1500V	Shida
3	Protective mask or glasses		S200A-普通型 L ordinary typeL	Honeywell

			(GB14866-2006)	
4	Insulated socket wrench		Insulation grade ≥1500V 09267-20 pieces 12.5MM series VDE Insulating sleeve kit	Shida
5	Auto repair full set of special tools		120+1 pieces 6.3*10*12.5MM series	Shida
6	ZLG		ZLG-USBCAN-II	ZLG
7	ValueCAN4		2Can FD channel 64 bit timestamp accuracy reaches 25 nanoseconds	Intrepid
8	Lifting forklift	TBD	**TBD**	TBD
9	数显扭力扳手 Digital torque wrench		examination range 1.5N.M-30N.M accuracy 4% Recommended model: WE2-030	WIZTANK
10	Multimeter		DC voltage range can reach 1500V Recommended model: HD-160C	Fluke
11	Insulation meter/megger		Insulation test voltage level 2500V Recommended model: F1535	Fluke

12	Clamp flow meter		DC current range 600A Accuracy 1%+4 Recommended model: Fluke-317	Fluke
13	Portable airtight tester		Detecting pressure: 0～500Kpa Balance time: 0～999.9s Differential pressure measurement range: -990Pa～+990Pa testing time: 0～999.9s Leakage measurement range: 0～999.9mL/h Resolution: 1Pa	Gu Heng
14	Pack-level charge and discharge machine		Charge/discharge voltage: 2-260V Charge/discharge current: 0~80A Recommended model:FCF-651CT	Fu Guang
15	Equalization equipment		Balanced constant current: 0~5A; Current control accuracy: ±0.1A; Current acquisition accuracy: ±3mA; 2 channels and 12 channels Recommended model: ACTM-5201	Fu Guang

16	Coolant injection and discharge tool		It consists of control panel, air exhaust tool ,coolant injection tool and coolant discharge tool.	Air-internat ional Schlemmer

Appendix I

Condensed Aerosol Fire Extinguishing System JAD300-U01

Condensed Aerosol Fire Extinguishing System

Model: JAD300-U01

DESIGN, INSTALLATION, OPERATION AND MAINTENANCE MANUAL

Hubei Jiandun Fire Technology Co., Ltd.

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1 Forward

This manual is a guiding document for the design, installation and maintenance of condensed aerosol fire extinguishing system, which should be strictly followed in the process of design, installation and maintenance. This manual is written by the designers of Hubei Jiandun Fire Technology Co., Ltd. (hereinafter referred to as JAD). It contains basic information about the design, installation, operation and maintenance of condensed aerosol fire extinguishing system.

Important tips

JAD assumes no responsibility for application of any systems other than those addressed in this manual. The technical data in this manual is limited strictly for information purposes only. JAD believes this data to be accurate, but it is published and presented without any guarantee or warranty whatsoever, JAD disclaims any liability for any use that may be made of the data and information contained herein by any and all other parties.

JAD300-U01 condensed aerosol fire extinguishing system is to be designed, installed, inspected, maintained, and tested by qualified and trained personnel in accordance with the following:

- NFPA 2010 Standard for Fixed Aerosol Fire Extinguishing Systems and the National Fire Code of Canada; and any other applicable NFPA Standards.
- EN15276-2 Fixed firefighting systems - Condensed aerosol extinguishing systems Part 2: Design, installation and maintenance.
- All instructions, limitations, etc. contained in this manual.
- Storage, handling, and transportation shall be performed by qualified and trained personnel in accordance with DOT requirements.

Questions about the information provided in this manual or more detailed information presented in this manual should be addressed to:

Hubei Jiandun Fire Technology Co., Ltd.

No.199 Huaxi Road, Biological Industrial Park, China (Hubei) Free Trade Zone Yichang Area，Yichang City, Hubei Province, China

Tel: 0717-6741877 Mail: development@jad119.com

2 Introduction

JAD300-U01 condensed aerosol fire extinguishing system is designed for total flooding fire extinguishing application based on established design criteria. Application methods, design criteria, and limitations are contained in this manual. In any situation not specifically covered by this manual, the application and installation of the system must be

in accordance with the appropriate and/or applicable standards. All installations must meet the requirements of the local authority having jurisdiction.

JAD300-U01 Condensed Aerosol Fire Extinguishing System with ultra-high extinguishing efficiency and reliability is one of the company's innovative products. The system is small-sized and zero-pressure stored. It generates rapid extinguishing system with safe and reliable, non-toxic , harmless and environmentally friendly materials. It has been widely used in electrical cabinets, cold chain cabinets, communication rooms, battery boxes, energy storage cabinets, engine compartments or other similar enclosure space.

Since differences still exist between this fire extinguishing system and other fire extinguishing systems, the system designer must become thoroughly familiar with the design criteria contained in this manual in order to properly input design data and parameters. There are a number of limitations, which must be considered in entering parameters for accurate results. Users and operators must thoroughly read and understand the design standards and parameters in this manual, and they must be well trained before operation, so as to achieve the maximum utilization rate and the highest fire extinguishing ability to reduce property damage.

3 System Description

3.1 General

JAD300-U01 aerosol fire extinguishing system is total flooding application system, suitable for extinguishing the fire in protected enclosures. It is designed for Fires listed in table 3.1,

Table 3.1 Classification of fires

Classification of fires			
NFPA 10		Europe: CEN Standard EN2	
CLASS "A"	Fire in ordinary combustible materials such as wood, cloth, paper, rubber and many plastics.	CLASS "A"	Fire involving solid materials, usually of an organic nature (such as paper, wood, plastics and so on), in which combustion normally takes place with the formation of glowing embers.

CLASS "B"	Fires in flammable liquids, oil, greases, tars, oilbase paints, lacquers and flam mable gases.	CLASS "B"	Fires involving flammable liquids or liquefiable solids such as paraffin, petrol, oil and so on.
CLASS "C"	Fire which involve energized electrical, non-conductivity of the extinguishing media is of importance. (When electric al equipment is de-energized, extinguishers for Class "A" or "B"fires may be used safely).	CLASS "C"	Fire involving flammable gases such as propane,butane,methane and so on.
CLASS "D"	Fires in combustible metals such as magnesium, titanium, zirconium, sodium, lithium and potassium.	CLASS "D"	Fire involving metals such as aluminium, magnesium, titanium and so on.
CLASS "K"	Fire involving cooking grease, fats and oils.	CLASS "E"	Fires involving electrical apparatus
		CLASS "F"	Fire involving cooking oils and fat and such like.

Note：Class K,Class E, Class F fires are not tested.

JAD300-U01 aerosol fire extinguishing system can be used in the following fields,

Electric power industry: cable tunnel(including underground), cable well, control room, computer room, relay room, transformer distribution room, switchgear, high-voltage switchgear, low-voltage switchgear, fully sealed high-voltage box-type substations etc.;
Transportation industry: diesel locomotives, electric locomotives, railway engineering vehicles etc.;
New energy industry: wind turbines, wind power transformers, electrical cabinets, power distribution cabinets, cold chain cabinets, energy storage boxes, photovoltaic power generation transformers, electrical equipment rooms, electrical cabinets ,etc.;
Manufacturing industry: machining equipment, hydraulic equipment, CNC machine tools , etc.
Communication industry: communication equipment room, signal base station,etc.

JAD300-U01 aerosol fire extinguishing system shall not be used on fires involving the following materials,

a)Certain chemicals or mixtures of chemicals,such as cellulose nitrate and gunpowder, that are capable of rapid oxidation with a combination of air;
b) Reactive metals such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium;
c) Self-decomposition compounds, such as certain peroxides, hydrazine, etc;
d) Metal hydrides, such as potassium hydride, sodium hydride;
e) Spontaneously combustible substances, such as phosphorus;
f) Strong oxidants, such as nitrogen oxides, fluorine;
g) Deep-seated fires in Class A materials.

The extinguishing generators are **not suitable** for the following places:
Commercial, catering services, entertainment and other normally occupied spaces.

The generator is also not for use in hazardous (classified) locations.

3.2 Fire Extinguishing Agent

JAD300-U01 aerosol fire extinguishing system produces a large number of fire extinguishing media, which are mainly composed of ultra-fine potassium salt particles and inert gas. After a long period of continuous verification and application, potassium salt has been recognized as one of the most effective fire extinguishing agents. Its main fire-fighting mechanisms can be divided into four categories: isolation, suffocation, cooling and chemical suppression. Several fire-fighting mechanisms interact and combine to suppress the fire, without any negative impact on the environment. Both the Ozone Depletion Potential (ODP) and Global WarmingPotential (GWP) are zero. Because of the ultra-fine particle size（≤2μm）there is a dramatic increase in the surface area interaction between the agent and the fire. Aerosol has been shown to be a highly effective alternative to other extinguishing agents.

Different from other conventional fire extinguishing agents, aerosol will not decompose in case of fire and will not be extinguished due to the lack of oxygen. Therefore, it is especially suitable for normally unoccupied places .

When used at the normal design concentration required to extinguish most types of fires, aerosol is non-toxic to human body; However, when applying and handling the generator, there is a high shielding coefficient, and some safety restrictions and related standards and specifications should be observed. Exposure to aerosols should be minimized and unnecessary particle contact should be avoided.

Toxicity: The extinguishing agent discharged by JAD300-U01 aerosol fire extinguishing system can be suspended for a long time (up to one hour), providing excellent protection against re-ignition and minimizing cleaning work. When used at the normal design concentration required to put out most fires, aerosol is considered to be non-toxic to human body; Although the components of aerosol are not considered toxic at normal concentration level, ingestion of ultrafine particles may cause short-term

discomfort, therefore unnecessary contact should be avoided.

Corrosiveness: Extensive tests show that JAD300-U01 aerosol fire extinguishing system is non-corrosive and harmless to various materials, including structural metals, plastics, electrical components, complex materials used in aviation, films and tapes. If the system is not cleaned in time after discharging, aerosol may cause slight surface discoloration to some metal alloys, but this is a non-progressive event and will not affect the function.

Conductivity: Residue not cleaned after discharging will absorb moisture. If left untreated, caking may absorb moisture and may lead to non-progressive surface discoloration of unprotected metal surfaces. If agglomerated mass is formed on the PCB, it may lead to short circuit of electronic components on the PCB due to the moisture and metal particles contained in the agglomerated mass.

Cleanliness: The fire extinguishing agent discharged by condensed aerosol fire extinguishing system can remain suspended for a long time and can be easily discharged by fan or air treatment; A small amount of aerosol deposited on the floor or other horizontal surfaces can be cleaned by vacuuming, blowing, brushing or washing . Small amounts of residue or agglomerated mass that have not been removed during the ventilation process must be cleaned with contact cleaner spray thoroughly.

The above cleaning work should be completed within 24 hours after discharging.

Other safety considerations: The temperature of aerosol discharged into the hazard area after actuating the generator is relatively low. However, the aerosol flow leaving the generator is higher than 100℃ within a short distance from the generator discharge port. JAD300-U01 aerosol fire extinguishing system has a required installation clearance distance. Measures must be taken to ensure the generator placement meets this installation requirement.

The temperature of the generator casing after discharging will not exceed 150℃. The generators will remain quite warm to the touch for a time after actuation. When treating the generator after discharging before it is cooled to ambient temperature, be careful ! Aerosol generators must be mounted in such a way as to have an unobstructed discharge path and must not discharge at close range onto walls, ceiling, or equipment.

Storage: Temperature range (-40℃ ~+54℃) and humidity (maximum 95% relative humidity) have been evaluated. The accelerated aging test shows that JAD300-U01 aerosol fire extinguishing system has a 15 years' useful time.

3.3 Component Description

3.3.1 Component Composition

JAD Aerosol Fire Extinguishing system with self-generated aerosol fire extinguishing agent, is one of the most efficient Halon Alternative products. The condensed aerosol extinguishing generator is composed of stainless steel casing, initiator, aerosol-forming compound ,coolant ,mounting bracket and other elements. The coolant is used to cool the

aerosol fire extinguishing agent before it is discharging. The initiator is electrically activated with a secure two-wire connector.

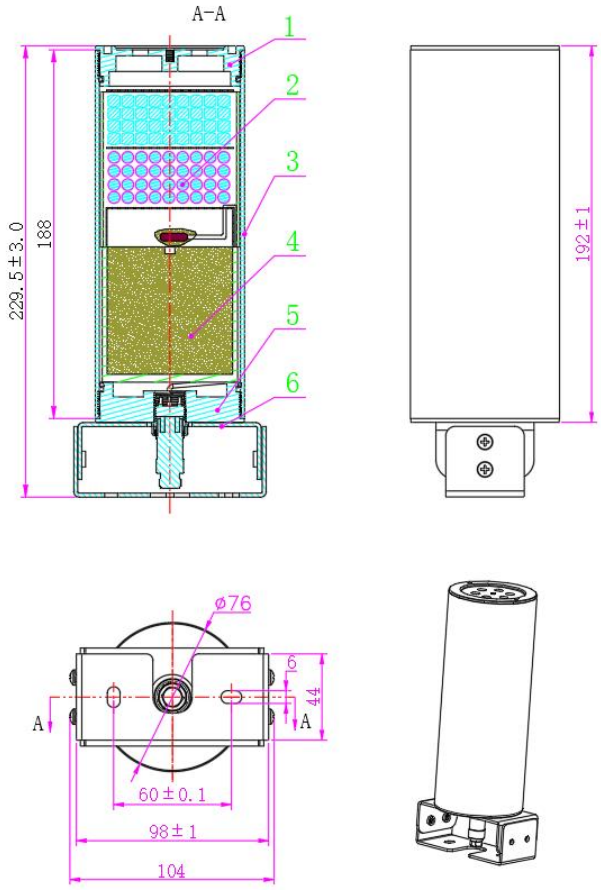

Figure 3.1 Drawing of JAD300-U01 aerosol fire extinguishing generator.

1. Front cover
2. Coolant
3. Casing
4. Aerosol-forming Compound
5. Back Cover
6. Mounting Bracket.

3.3.2 Technical Parameters

3.3.2.1 End-use: Total Flooding , normally unoccupied areas

3.3.2.2 Size: φ76mm(±0.2mm)×192mm (±1mm)(without bracket)

3.3.2.3 Weight: 2320g（±2%）

3.3.2.4 Discharge Time: 12.5S (±2.5S)

3.3.2.5 Thermal Clearance (discharge port)

a)The aerosol agent discharge temperature shall not exceed 75°C (167°F) at the minimum safe distance between the aerosol generator discharge ports and personnel. The minimum distance is130cm.

b)The aerosol agent discharge temperature shall not exceed 200°C (392°F) at the minimum safe distance between the aerosol generator discharge ports and combustible materials. The minimum distance is 70cm.

3.3.2.6 Thermal Clearance (generator casing)

a)The temperature shall not exceed 75°C (167°F) during and after discharge at the minimum safe distance between the generator casing and personnel. The minimum distance is 2cm.

b)The temperature shall not exceed 200° C (392° F) during and after discharge at the minimum safe distance between the generator casing and combustible materials. Since the temperature of the generator casing will not exceed 150℃(302° F), it is not applicable(N/A).

3.3.2.7 Operating temperature range: -40℃~+54℃

3.3.2.8 Mass of aerosol-forming compound: 300g(±6g)

3.3.2.9 Actuation method: Electrical

3.3.2.10 Initiator safe current: 600mA(±2mA) ,300s no action

3.3.2.11 Initiator rated current: 2A/5ms

3.3.2.12 Class of Fires and Density: see Table 3.2

Table 3.2 Class of Fires and Density

UL/ULC2775	
Class of Fire	Minimum design application density
Class“A”	105.3 g/m³
Class“B”	78 g/m³
Fuel combination:	105.3 g/m³
Class of Fire	Minimum design application density
EN15276	
Class“A”	105.3 g/m³
Class“B”	78 g/m³
Class“C”	105.3 g/m³
Fuel combination:	105.3 g/m³

3.3.2.13 Useful Time: 15 years

3.3.3 Electric Initiator

Electric Initiation: The JAD300-U01 aerosol fire extinguishing system is designed to be actuated by double-bridge electric initiator.

The specification of the electric initiator,

Initiator Model: WS-XPSS201

Initiator resistance: 1.0Ω ±0.2Ω

Initiator Minimum rated current: 900mA, It can be actuated 100% instantaneously. (it is normal when the current is between safe current to 900mA the initiator is actuated.)

Initiator Safe current: 600mA（±2mA）,300s no action

Initiator Rated current: 2A/5ms

Working voltage: 24V DC

For series connected generators below data should be noted,

power supply :24Vdc

maximum 10 JAD300-U01 generators connect in series

the maximum line resistance is 1Ω

4 System Design and Limitations

4.1 General

System design is based on the applicable requirements of the National Fire Protection Association (NFPA) Standard 2010, the EN15276-2 Fixed firefighting systems - Condensed aerosol extinguishing systems Part 2: Design, installation and maintenance, manufacturer's design data, and the authority having jurisdiction.

4.2 Application

The following steps must be taken to design and calculate the application of JAD300-U01 aerosol fire extinguishing system,

Determine how the protected area is used and whether the floor, ceiling and walls are fire-proof.

Determine the classification of hazard fires.

Determine the appropriate design density according to the fire classification.

Determine the geometric dimensions (volume, total area, height) of the protected area (the volume of protected equipment is not deducted from the total volume).

Determine whether there are any big obstacles in the hazard.

4.2.1 Calculate the total mass of aerosol-forming compound required to protect the hazard.

4.2.1.1 Protected area

Protected areas should be divided into fixed single closed spaces. The area and volume of a protected area should not be greater than 500m^2 and 2000m^3 respectively.

The area of unclosable openings in the protected area enclosure shall be kept to a minimum.If a protect area enclosure is designed with openings that cannot be closed, the non-sealing degree of the protected area should not be greater than 0.6%. Before the fire extinguishing system is actuated, the ventilation and ventilation facilities in the protected

area should be automatically closed, and the production operations that may affect the fire extinguishing effect should be stopped.

4.2.1.2 Protected Volume

When calculating the mass of aerosol-forming compound, the protection volume should be subtracted from the volume of permanently existing substances in the protection area that cannot be penetrated by the fire extinguishing agent.

$$W=K_1 \cdot K_2 \cdot C_1 \cdot V$$

where

W =design total mass of aerosol-forming compound (kg)

K_1=the compensation coefficient based on the non-uniformity of aerosol distribution and the height of the protected area.

When the height of the protected area is ≤2.4 m, K_1 = 1.00；

Consult Manufacturer for height of enclosure > 2.4m.

K_2=the leakage rate based on the calculated protected volume, that is, the ratio of the total opening to the total area of the outer surface of the protected area.

When the leakage rate of the protected area is< 0.3%, K_2 = 1.00；

When the leakage rate of the protected area is 0.3% ~ 0.6%, K_2 = 1.10；

Consult Manufacturer for the leakage rate of enclosure > 0.6%.

C_1=design application density (g/m³), the minimum mass of the designated aerosol generator in the unit enclosed space volume required for the design of the total flooding system, multiplied by a safety factor of 1.3.

V = protected volume (m³)

Consult Manufacturer for the volume of enclosure> 5m^3 .

4.2.2 Calculate the number of aerosol generators required.

The following formula is used to calculate the number of aerosol generators required for fire extinguishing systems:

N = W/m (when only one size generator is used)

where:

N= the number of generators required. If the value of N is a decimal, it is rounded to an integer.

W= the total mass of aerosol-forming compound required.

m= mass of aerosol-forming compound of a single aerosol generator.

4.2.3 Precautions for other facilities/systems

4.2.3.1 Obstacles affecting the distribution of chemicals

If the fixed equipment accounts for a large proportion of the total volume, or the position of the protected equipment hinders the free flow and distribution of aerosol in the whole area, which will affect the total flooding fire extinguishing ability of JAD300-U01 aerosol fire extinguishing system. It is better to use more small aerosol generators in hazard areas. If general mass is ≤500g, it will allow the strategic layout of aerosol generators and improve the distribution characteristics of the whole area. Resulting in the achievement of higher fire extinguishing energy efficiency.

4.2.3.2 Total flooding fire extinguishing in normally unoccupied areas where personnel may be present.

Note: For total flooding installations in normally unoccupied spaces where personnel may be present, a 30 second time delay shall be reserved to ensure egress time in prior to system discharge. In occupied and normally unoccupied areas, a system isolate switch shall be installed outside the hazard area to ensure that activation of the system is “manual only” when personnel are present.

4.2.3.3 Shutdown of Air Handling and Power Supply

After fire is detected by the system, the ventilation system and all openings (such as fire doors, cooling vents, air conditioning outlets, etc.) in the protected area must be closed to ensure the required application density, because the fire will be aggravated when the oxygen concentration in the protected area increases. Besides that, the power supply of the protected equipment must be turned off, in order to avoid short circuit of equipment and aggravate the fire.

4.2.4 Placement of JAD300-U01 aerosol fire extinguishing system

4.2.4.1 Installation

JAD300-U01 aerosol fire extinguishing system is suitable to be installed on the side wall and center of the protected area. It can be installed on walls, beams and structural columns, where the unit can be firmly fixed. It’s suggested to be installed on its unobstructed discharge path, which will not affect the positions of personnel, equipment and combustible materials located in the protected area. See Table 4.1 for aerosol streams characteristics. The position of the generator must also leave enough clearance between the structural material and the generator casing. See Table 4.2 generator casing clearance.

Table 4.1 Characteristics and Installation Limitations of Aerosol Discharge Flow

model	Distance at 75℃ of discharge port (m)	Installation Height (m)	Maximum Area Coverage (m^2)	Minimum Area Coverage height (m)	Maximum Area Coverage height (m)	Maximum volume(m^3)
300g	1.3	0~2.4	2.24*2.24	1	2.4	5

Distance at 75°C of discharge port: refers to the distance where the instantaneous peak temperature of blowout will not exceed 75 °C The generator must also be equipped with a clear discharge path as long as possible to reduce the possibility of caking with the consumption of fire extinguishing agent.

Table 4.2 Generator Casing Clearance

model	Required Clearance from Combustible and Structural Materials	
	mm	Inch
300g	13	0.50

4.2.4.2 Installation Height

Generally , JAD300-U01 aerosol fire extinguishing system should be installed at the bottom of the protected area or in a room close to the bottom of the protected area, and installed horizontally in the center of the bottom of the protected area to ensure the three-dimensional distribution of aerosol. The installation angles of systems with different installation heights are different, so it is only necessary to ensure that the discharge port of the system keeps an angle of 45 with the bottom of the protection area. In a large volume (≥100m^3), the installation method of aerosol generator must have a clear discharge path, and it must not be discharged to obstacles or equipment, which will lead to agglomeration and reduce efficiency, and it will also affect the fluidity and dispersity of aerosol fire extinguishing agent. The generators used for total flooding must be set on multiple levels.

When multiple fire extinguishing generators are installed in a unified protected area or the protected space is large (generally 30m^3-100m^3), their installation positions should be at multiple levels (tiers), and each level (tier) should meet the installation height limit and the maximum area coverage limit. This will ensure that the aerosol is completely evenly distributed throughout the hazard area.

JAD300-U01 aerosol fire extinguishing system generally used underfloor should be installed horizontally. For the same reason, aerosol fire extinguishing systems with less mass should be used for underfloor applications (generally, the generator of the system is ≤ 500g).

4.2.4.3 Aerosol Stream

The aerosol fire extinguishing agent should be distributed as evenly as possible around the hazard area to ensure that fire extinguishing agent can quickly flow and disperse to the fire source in the protected space. To ensure the fire extinguishing effect of

the fire extinguishing system. JAD300-U01 aerosol fire extinguishing system shall not be placed in the position where they are directly discharged from each other, leading to the aggregation of aerosol particles, reducing the fluidity and dispersion of fire extinguishing media and thus reducing the fire extinguishing effect. The location of the aerosol generator in total flooding application should also ensure that the aerosol flow does not directly hit the side of obstacles or protected equipment.

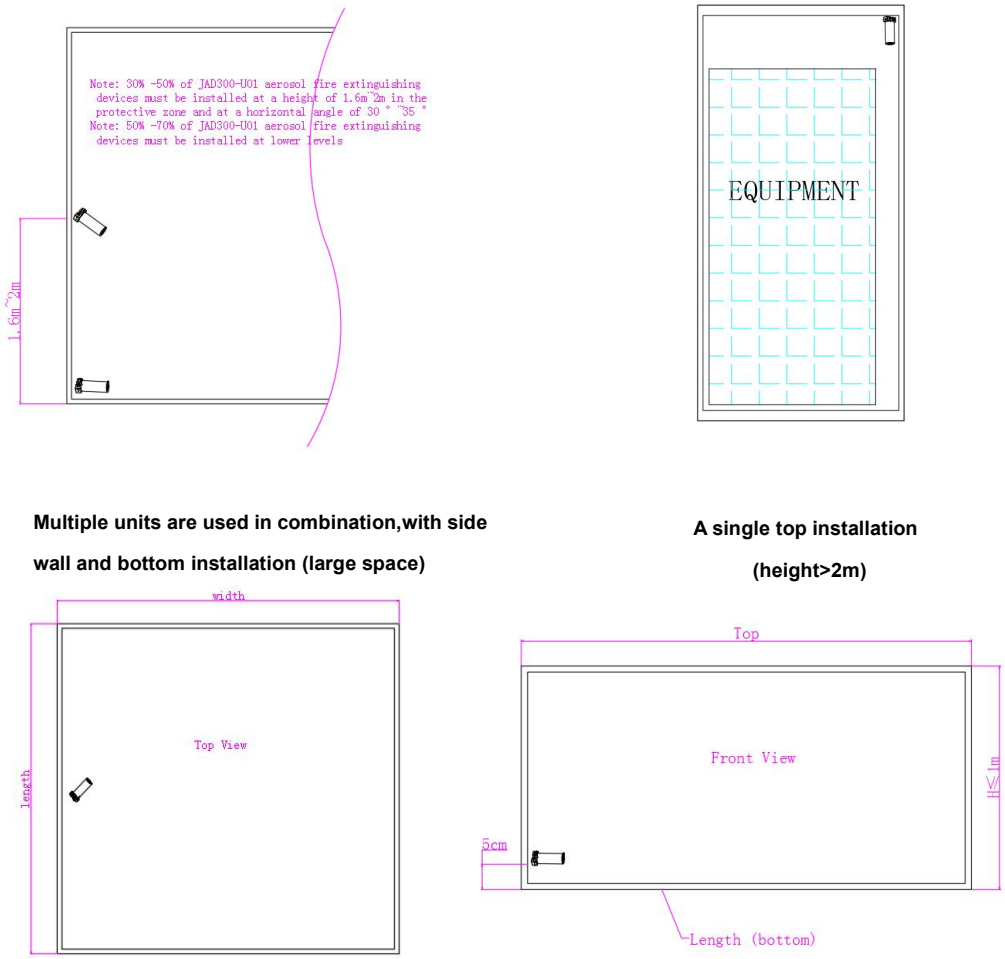

Figure 4.1 Placement of JAD300-U01 aerosol fire extinguishing system.

Note: 30% -50% of JAD300-U01 aerosol fire extinguishing systems must be installed at a height of 1.6m~2m in the protective zone and at a horizontal angle of 30 °~35 °

Note: 50% -70% of JAD300-U01 aerosol fire extinguishing systems must be installed at lower levels

Note: the space should be even unless there is an obstacle.

4.2.5 Operating/Temperature Range

JAD300-U01 aerosol fire extinguishing system has been evaluated for temperature range(-40℃ ~+54℃) and humidity (maximum 95% relative humidity). The accelerated

aging test shows that JAD300-U01 aerosol fire extinguishingsystemhave a 15 years' useful life.

5 Installation

5.1 General

Please read this manual carefully and be familiar with it before installing the equipment, so as to ensure the correct operation, inspection, testing and any other possible maintenance. During the installation, the equipment shall not be damaged by any mechanical, chemical or other damage that may cause operation failure. Equipment must be installed in strict accordance with all applicable standards and manuals.

WARNING

WHEN HANDLING, INSTALLING AND MAINTAINING THE EQUIPMENT, THE OPERATION MUST BE CARRIED OUT IN STRICT ACCORDANCE WITH THE INSTRUCTIONS IN THIS MANUAL. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY LEAD TO FALSE START-UP, WHICH WILL LEAD TO NORMAL POTENTIAL INJURIES AND PROPERTY DAMAGE.

5.2 Installation of Fire Extinguishing system

When installing the fire extinguishing system in the protected area, the installation instructions must be carried out in strict accordance with the following order to prevent potential personal injury or property loss caused by misoperation.

Installation requirements for screws and nuts: 304 stainless steel

The installation tightening force meets the requirements of table 5.1,

Table 5.1

Bolt strength level	yield strength (N/mm^2)	Bolt nominal diameter (mm)							
		6	8	10	12	14	16	18	20
		Tightening torque (N.m)							
4.6	240	4-5	10-12	20-25	36-45	55-70	90-110	120-150	170-210
5.6	300	5-7	12-15	25-32	45-55	70-90	110-140	150-190	210-270
6.8	480	7-9	17-23	33-45	58-78	93-124	145-193	199-264	282-376
8.8	640	9-12	22-30	45-59	78-104	124-165	193-257	264-354	376-502
10.9	900	13-16	30-36	65-78	110-130	180-201	280-330	380-450	540-650
12.9	1080	16-21	38-51	75-100	131-175	209-278	326-434	448-597	635-847

WARNING

TO PREVENT POTENTIAL PERSONAL INJURY, PLEASE DE-ENERGIZE ALL ELECTRICAL CONNECTIONS PRIOR TO GENERATOR INSTALLATION. THE

DESIGN AND INSTALLATION OF AEROSOL GENERATOR SHOULD BE CARRIED OUT BY QUALIFIED PERSONNEL IN FIRE EXTINGUISHING SYSTEM TECHNOLOGY.

5.2.1 Installation of Single Generator System

1. Take JAD300-U01 aerosol fire extinguishing system out of the shipping container and check the integrity it. If the system is damaged or parts are missing, please do not install it. Use ohmmeter to check the completeness of initiator. Adjust the gear of the ohmmeter to 200Ω, and connect the two wires of the initiator of the system with the wires of the ohmmeter. If the figure exceeds the range of 1.0±0.2 Ω, do not install it.

2. To determine the installation location, it is necessary to ensure that the JAD300-U01 aerosol fire extinguishing system is discharged and released unimpededly when it is actuated. Attention must be paid to prevent the fire extinguishing system from directly discharging near the vertical surface of equipment ceiling in the hazard area, and to ensure that the fire extinguishing system will not be accidentally damaged. After the position is selected, locate and fix the mounting bracket 1.

3. Connect JAD300-U01 aerosol fire extinguishing system firmly to the mounting bracket 1, and make sure that there is no risk of actuation during the installation process, and all bolts are firmly screwed in place.

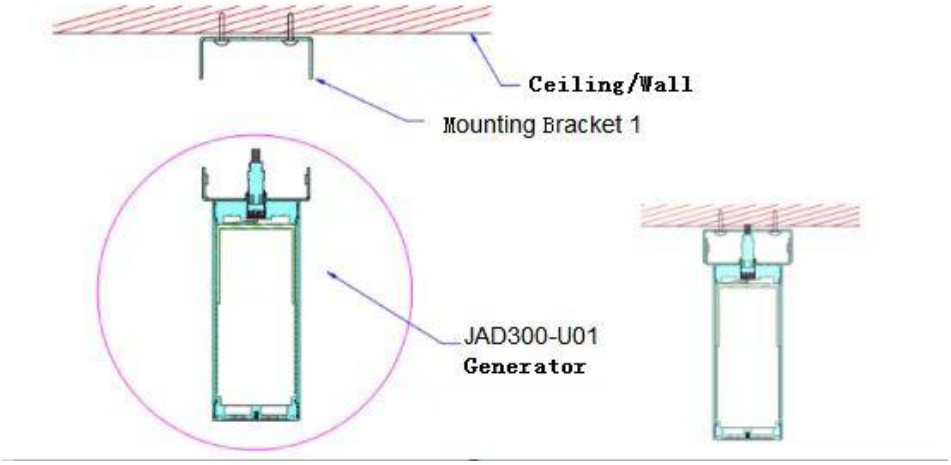

Figure 5.1 Single Generator System Installation

Attention: Ensure that the power supply is turned off, and connect the wire to the initiator connector at the bottom of the fire extinguishing system.

WARNING

TO PREVENT PERSONNEL INJURY, DE-ENERGIZE ALL ELECTRICAL CONNECTIONS PRIOR TO GENERATOR INSTALLATION. MAKE SURE THAT NO BODY PART IS PLACED DIRECTLY IN FRONT OF THE GENERATOR EXIT PORTS DURING INSTALLATION.

5.2.2 Installation of Multiple Generator System

1. Take JAD300-U01 aerosol fire extinguishing system out of the shipping container and check the integrity . If the system is damaged or parts are missing, please do not install it. Use ohmmeter to check the completeness of initiator. Adjust the gear of the ohmmeter to 200Ω, and connect the two wires of the initiator of JAD300-U01 aerosol fire extinguishing system with the wires of the ohmmeter. If the figure exceeds the range of 1.0±0.2Ω, do not install it.

2. To determine the installation location, it is necessary to ensure that the JAD300-U01 aerosol fire extinguishing system is discharged and released unimpeded when it is actuated. Attention must be paid to avoid direct discharging of fire extinguishing systems near the vertical surface of the equipment ceiling in the hazard area, and to ensure that the fire extinguishing systems will not be accidentally damaged. The location of the fire extinguishing systems must promote the circulating flow and mixing of aerosols from multiple fire extinguishing systems. Fire extinguishing systems shall not be placed in the position where they are directly discharged from each other, which will lead to the accumulation of aerosol fire extinguishing media and reduce the fire extinguishing effect of aerosol. After the position is selected according to the above principles, locate and fix the mounting bracket 1.

3. Connect JAD300-U01 aerosol fire extinguishing system firmly to the mounting bracket 1, and pay attention to ensure that there is no risk of actuation during the installation process, and all bolts are firmly screwed in place.

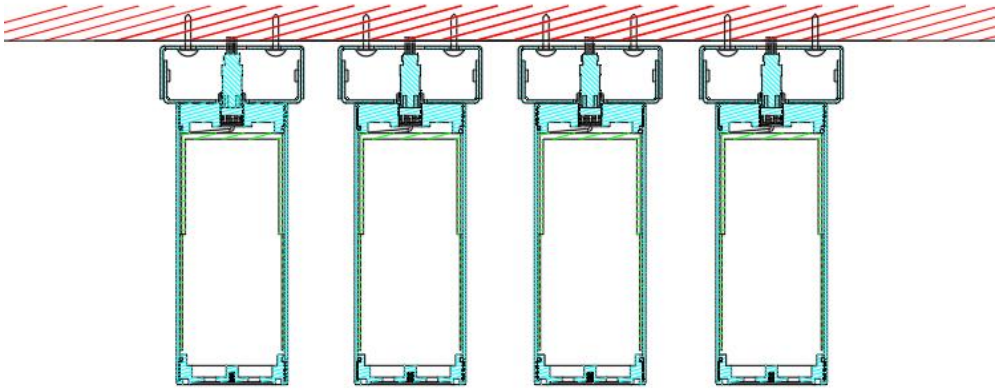

Figure 5.2 Multiple Generator System Installation

Attention: Ensure that the power supply is turned off, and connect the wire to the initiator connector at the bottom of the fire extinguishing system.

5.3 Post Installation Checkout

After installing the JAD300-U01 aerosol fire extinguishing system and connecting it to the detection/control system, perform the following inspections and tests.

1. Confirm that the fire extinguishing system with the correct size and model is installed as required.
2. Verify that the fire extinguishing system mounting bracket is correctly installed and all accessories are fastened.
3. Confirm that all electrical connections have been completed, and use an ohmmeter (electrical only) to test electrical continuity.
4. Verify that the positions of all fire extinguishing systems are correct. Check whether there are obstacles in the path of aerosol discharge flow. Fire extinguishing systems must be installed to ensure that they will not cause personal injury when they are actuated. The aerosol discharge flow shall not impact the ceiling or the vertical surface of the equipment at close range.
5. The isolation lighting must be installed correctly, easily accessible and clearly marked.
6. Verify the delay function and integrity.
7. All acceptance testing shall be in accordance with this manual, any applicable standards, and the authority having jurisdiction.

6 Operation

6.1 General

When the fire detection system detects a fire, the fire detection system transmits a actuation signal to the initiator of JAD300-U01 aerosol fire extinguishing system and actuate the aerosol generator. After the generator being actuated, a large amount of fire extinguishing media is generated, which is discharged into the protected area from the port of the system after passing through the coolant to extinguish the fire.

6.2 Operating Procedures

JAD300-U01 aerosol fire extinguishing system can be used with both automatic and manual control systems.

Note: If it is intended to be operated with automatic control system. All components must be UL/ULC listed as compatible with the aerosol generators under the UL Listing.

6.2.1 Automatic Control of Fire Extinguishing Process

For automatic aerosol fire extinguishing system, the fire extinguishing control mode of the protected area is fully automatic. In this state, when the system receives the fire signal

detected by two or more detectors in the same protected area, the controller in the protected area will send a signal to actuate the JAD300-U01 fire extinguishing system, and then the fire extinguishing system will perform the following procedures and operations,

a) According to the program setting, the controller of the protected area firstly sends out audible and visual alarm in the area, and simultaneously sends out the emergency evacuation signal of personnel;

b) After the above operations are completed, the countdown will be performed according to the delay time set by the program (the delay time can be adjusted according to the actual application scene and place);

c) During the delay period, all openings, fire doors, heat dissipation vents, air conditioning outlets and other openings that may affect the fire extinguishing effect will be automatically closed according to the design requirements and program settings;

d) Sending a feedback signal to the fire control system or monitoring system to monitor whether all programs or actions are running normally ;

e) After the delay period is over, immediately issue a fire extinguishing actuation command to the aerosol fire extinguishing generator;

f) After the generator being actuated, a large amount of fire extinguishing media (aerosol agent) will be generated and discharged into the protected area to extinguishing the fire;

g) At the same time, the aerosol-forming compound reacts, in the meantime a feedback signal will be transmitted to the fire control system. The controller sends a linkage signal to light up the gas discharge indicator light set at the entrance of the protection area, warning the personnel not to enter the area;

h) After the fire in the protected area is extinguished, the enclosure is to be quickly ventilated and the protected area shall be cleaned up.

The generator can be separately connected back to the control equipment or connected in series in a loop(see Figure 6.1 and Figure 6.2).

Control Process of JAD300-U01 Fire Extinguishing (single generator)

a)The current is directly input from the gaseous controller panel (see Figure 6.1)

b)The minimum actuation current of the aerosol fire extinguishing system is 900mA, and the minimum actuation voltage is 1.5Vdc. Attention should be paid to observing the maximum current required and the voltage drop from the power supply of the aerosol fire extinguishing system.

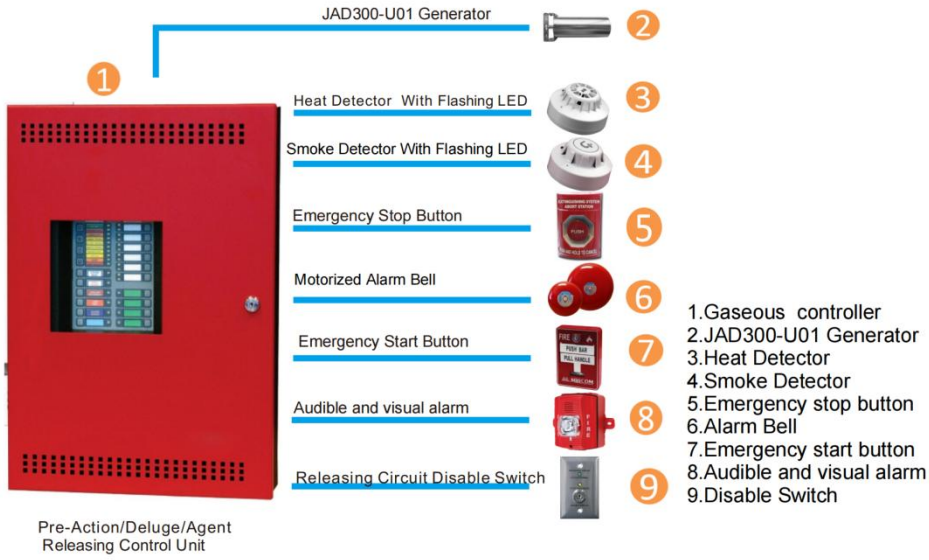

Figure 6.1 Single JAD300-U01 generator control progress

Control of Fire Extinguishing Process (series connected generators)

a)Automatic actuation mode achieved through fire detection systems (heat, smoke, or gas detectors). Connect to Gaseous fire suppression controller through heat, smoke or gas detector(see Fig6.2).

b)The minimum actuation current of the aerosol fire extinguishing system is 900mA, and the minimum actuation voltage is 1.5Vdc. Attention should be paid to observing the maximum current required and the voltage drop from the power supply to the aerosol fire extinguishing system.

c)Automatically connected to fire detection and control panels through heat, smoke, or gas detectors.

d)When the rated actuation voltage is DC24V, 10 series connected aerosol fire extinguishing generators can be actuated.

e)At a rated actuation voltage of DC24V (15.6V) of 65%, 10 series connected aerosol fire extinguishing generators can be actuated.

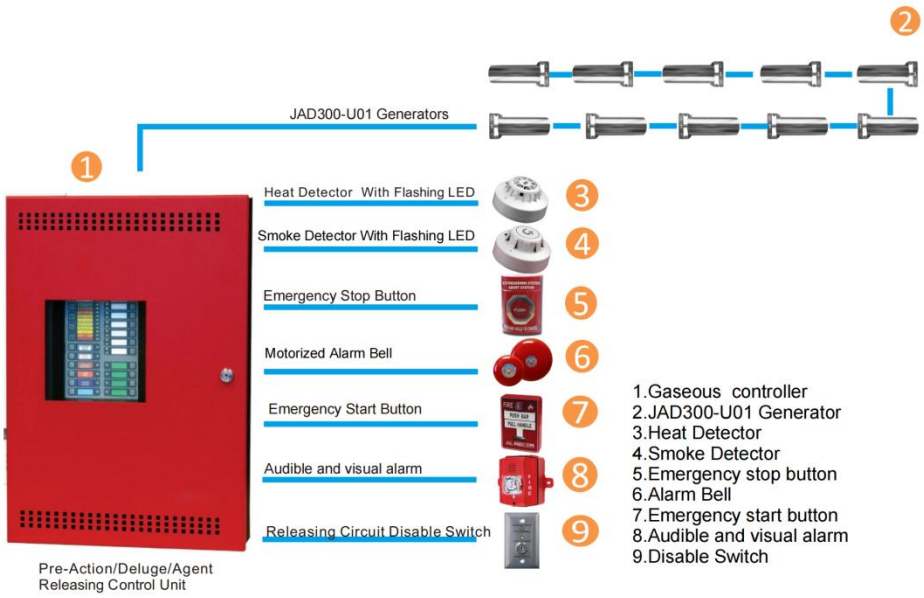

Figure 6.2 Series Connected JAD300-U01 generators control progress

Note：Fire Alarm Control Panels must be UL/ULC Listed as compatible with the aerosol generators under the UL Listing.

6.2.2 Manual Control of Fire Extinguishing Process

a) For manual aerosol fire extinguishing system, the fire control system only receives the fire signal detected by the fire detector, according to the program setting, the controller of the protected area first sends out audible and visual alarm in the area, and simultaneously sends out the emergency rescue signal of personnel.

b) In this state, even if the fire signal detected by two or more detectors in the same protected area is received, the fire extinguishing linkage signal will not be sent to the aerosol generator.

c) When it is necessary to actuate the JAD300-U01 aerosol generator in this state, the on-site operator can manually press the isolate switch set at the entrance of the protected area.

d) After the aerosol generator is actuated manually, fire extinguishing will be conducted as the same progress of autonomic aerosol fire extinguishing system.

e) This manual operation method is also effective when the fire extinguishing control mode is in the automatic state even if the fire detector has not detected the fire in the protected area. The control subsystem satisfies "manual override".

6.2.3 System Isolate Switch

The automatic operation of the system shall be prevented by means of a system isolate switch (located outside the protected area) when personnel are present in the hazard area. The operation of the system shall be manual only when personnel are present. While the system isolate switch is active the automatic activation of the system is inhibited but the fire detection and alarm system shall remain functional. The system shall return to full automatic control when the switch is reactivated.

The operation of the system isolate switch shall be electrically isolated and each conductor of the generators wires and initiate a visual indicator of status at the Control Station.

6.2.4 Flow Chart of Fire Extinguishing Control

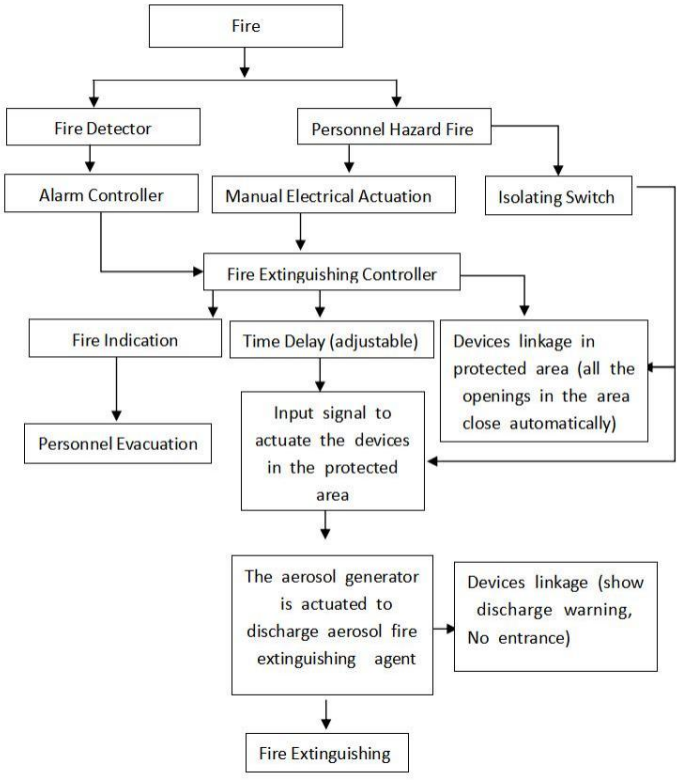

Figure 6.3 Flow chart of fire extinguishing control

6.3 Post Fire Operation

After the JAD300-U01 aerosol fire extinguishing system is discharged, trained professionals must carry out post-fire maintenance, post-treatment of the system and equipment must be performed according to the relevant provisions of this manual, and strictly abide by all warnings in this manual and relevant standards and specifications during operation and maintenance. Especially when entering the dangerous area, relevant safety technical disclosure and strict maintenance and treatment scheme must be specified.

WARNING

DO NOT ENTER A HAZARD AREA WITH AN OPEN FLAME OR LIGHTED CIGARETTE. THE POSSIBLE PRESENCE OF FLAMMABLE VAPORS MAY CAUSE RE-IGNITION OR EXPLOSION.

WARNING

ENSURE FIRE IS COMPLETELY EXTINGUISHED BEFORE VENTILATING AREA. BEFORE PERMITTING ANYONE TO ENTER THE HAZARD AREA, VENTILATE AREA THOROUGHLY OR USE SELF-CONTAINED BREATHING APPARATUS.

6.4 Post Fire Maintenance

The following operation procedures must be followed to maintain and re-commission the fire extinguishing system:

1. After JAD300-U01 aerosol fire extinguishing system is discharged, allow a minimum holding time of 10 minutes, during which ventilation or opening of relevant openings (doors, windows, fire doors, etc.) is not allowed in the protected area.

2. Ensure that there is a spare portable fire extinguisher in hand for use in case of re-ignition during the whole operation process.

3. Vent the area thoroughly by operating the ventilation system, by fan extraction, or by opening doors and windows. To avoid unwanted inhalation of fire by-products and aerosol, a protective breathing apparatus or mask should be worn if it is necessary to enter prior to complete ventilation of the hazard area.

4. Inspect the area to insure the fire is completely extinguished and that there are no localized hot spots or other sources of re-ignition present.

5. Clean any minor amounts of residue, which may have not been removed during ventilation, by thoroughly vacuuming, blowing, brushing, or washing away (with a water alcohol mixture) as appropriate. Check to make sure that there is no agglomeration due to discharge too close to equipment, walls etc. Any agglomeration exists must be wiped or washed clean.

6. If the residue after discharge is not treated, it may absorb moisture and may lead to non-gradual surface discoloration of unprotected metal surface. If caking is formed on the PCB, it may lead to short circuit of electronic components on the PCB due to the moisture and metal particles contained in the caking. The change of room temperature during a fire event or discharge will affect the humidity, so it is very important to reduce the humidity of the casing as soon as possible after discharge.

7. Remove the spent JAD300-U01 aerosol fire extinguishing system. The casing temperature of the fire extinguishing system after discharge is high. Be sure to wear gloves or take other hand protection measures when removing the spent system.

8. Dispose of spent systems according to applicable federal, state, and local

regulations.

9. Contact your distributor to replace the system immediately.

WARNING

BEFORE PERFORMING POST FIRE MAINTENANCE PROCEDURES, REFER TO THE MATERIAL SAFETY DATA SHEETS AND SAFETY BULLETINS IN THE APPENDIX OF THIS MANUAL.

NOTE

Aerosol fire extinguishing agent refers to a kind of gaseous colloidal mixed substance (particle size reaches 10^{-5}μm ∽ 10^{-1}μm) formed by physical or chemical action. The substance with gas fluidity, which can be spread around obstacles and has certain fire extinguishing function is aerosol fire extinguishing agent.

The extinguishingmedia and particles produced after JAD300-U01 aerosol fire extinguishing system is actuated are very easy to float and suspend in the protected area. Due to the characteristics of aerosol fire extinguishing agent, it can be suspended for a long time (up to one hour) and will not start to settle in a short time, so aerosol gas and particles are very easy to be discharged from the protected area, and only a very small amount of particles may be deposited on the equipment. Usually, there is almost nothing to do except extracting air from the protected area through fans or air handling systems. Then purge with compressed air. Because the particle size of aerosol deposited on the horizontal plane is 10^{-5} μm-10^{-1} μm, and no continuous layer will be formed, the gap between particles is also large, so the problem of conductivity will not occur.

However, as a preventive measure, it is always important to thoroughly inspect and clean the site after discharge. Although the aerosol itself is very "clean", environmental factors are also worthy of consideration. The actual fire is unknown and may produce harmful by-products, which may also expose great risks to sensitive equipment.

Because of the possible unknowns after the fire and the unreliable factors of the environment, we suggest thoroughly cleaning the impurities in the protected area to ensure the elimination of harmful substances in the protected space and avoid secondary injuries and economic losses. For example, on-site maintenance and housekeeping may be lax, resulting in dust accumulation in the protected area. During the discharge process, any dirt in the protected area will be blown to the surrounding area, and any dirt will be deposited in the protected area. Therefore, it is necessary to maintain the protected area and carry out subsequent ventilation and clean after the fire.

In addition, in rare cases, the discharging direction and equipment position of JAD300-U01 aerosol fire extinguishing system may be changed, resulting in the system being directly discharged onto the wall or equipment surface incorrectly. This may lead to the deposition of small, localized and highly concentrated particles on the surface. If left

untreated, caking may absorb moisture and may lead to non-progressive surface discoloration of unprotected metal surfaces. Therefore, it is very important to clean any agglomerated particles with contact cleaner spray within 24 hours after discharge.

Figure 6.4 Recommended contact cleaner spray

7 Maintenance

WARNING

BEFORE PERFORMING MAINTENANCE PROCEDURES, REFER TO THE MATERIAL SAFETY DATA SHEETS AND SAFETY BULLETINS IN THE APPENDIX OF THIS MANUAL.

7.1 General

Although JAD300-U01 aerosol fire extinguishing system needs much less maintenance than other fire extinguishing systems operating under pressure, it is necessary to establish a detailed regular maintenance plan for the system to ensure the continuous and correct operation of JAD300-U01 aerosol fire extinguishing system.

At a minimum, the log must record:

1.inspection interval,

2.inspection procedure performed,

3.maintenance performed, if any, as a result of inspection, and

4.the name of the responsible person performing the operation.

7.2 Preventive Maintenance

Perform preventive maintenance according to the preventive maintenance/replacement schedule in Table 7.1.

Table 7.1 Preventive Maintenance/Replacement Schedule

Schedule	Requirement
Monthly	Visual examination of the operating condition of the generators.
	Visual inspection of components
Annual	Check/test all system components.
	Test electrical continuity
	Check the bracket & position of the generators.
15 years	Remove from service

7.3 Inspection Procedures

7.3.1Monthly

1. Check all electrical connections to ensure that JAD300-U01 aerosol fire extinguishing system can operate normally in case of fire.

2. Conduct a comprehensive visual inspection of all JAD300-U01 aerosol fire extinguishing systems to see if there are any damaged or missing parts.

3. Ensure that JAD300-U01 aerosol fire extinguishing system is not obstructed and meets the required clearance.

7.3.2 Annual

1. Make a general visual inspection of all JAD300-U01 aerosol fire extinguishing systems for damaged or missing parts.

2. Ensure that the access to hazard areas and exits is unobstructed and the isolate switch is normal, and there are no obstacles that inhibit the normal operation of fire extinguishing systems or aerosol distribution in case of fire.

3. Inspect whether JAD300-U01 aerosol fire extinguishing system has physical damage, such as cracks, dents, deformation or corrosion. If damage is found, please replace it in time and re-install and debug it according to the operation instructions in this manual.

4. Inspect the mounting bracket and related hardware for loose, damaged or broken parts. Replace damaged parts and tighten all loose hardware.

5. Inspect whether the isolate switch outside the protection area is damaged, broken, dirty or deformed. Replace if necessary.

6. Inspect all electrical connections and conduct the electrical continuity test with an ohmmeter. Repair or replace the connections if necessary.

7. Ensure that the generator is not obstructed and the required clearance has been met.

7.3.3 Replacement/Removal from Service

JAD300-U01 aerosol fire extinguishing system has an installed useful life of 15 years. The production date and expiration date will be indicated on the product label. If the expiration date is exceeded, please contact the supplier for replacement.

8 System Components

Table 8.2 JAD300-U01 Aerosol Generator Assembly

Model	Capacity	P/N	Remarks
JAD300-U01	300g	JAD300-U01-C-00	The system is an integral structure that cannot be disassembled, and there are no spare parts.

Table 8.3 JAD300-U01 Mounting Brackets

Model	P/N
300g mounting bracket	JAD300-U01-C-0005

9 Limited Warranty Statement

Hubei Jiandun Fire Technology Co., Ltd. represents that this product is free from defects in materials and workmanship, and any products or parts proved to be defective in workmanship or materials can be repaired or replaced within 18 months from the first delivery date of our factory. Please return the defective products to the factory:

Manufacturer: Hubei Jiandun Fire Technology Co., Ltd.

Address: No.199 Huaxi Road, Biological Industrial Park, China (Hubei) Free Trade Zone Yichang Area，Yichang City, Hubei Province, China

Tel: 0717-6741877

E-mail:development@jad119.com

Delivery expenses caused by return the products with defects shall be borne by Hubei Jiandun Fire Technology Co., Ltd.

10.Limitation of Liability

This warranty does not cover systems damaged during transportation or caused by misuse, accident or negligence, or systems that have been repaired or changed by others. In any case, JAD will not be liable for special or indirect damages, such as damage or loss of systems, loss of profits or income, cost of capital, cost of purchasing or replacing goods, or claims made by customers of the original buyers. In this agreement, the remedies of the original buyer and all other buyers shall not exceed the price of the provided systems.

This warranty completely and explicitly replaces all other warranties, whether express or implied, including the warranties of merchantability or fitness.

Appendix

Appendix A Safety/Information Bulletins

JAD300-U01 aerosol fire extinguishing system uses pyrotechnic technology. Personnel responsible for the installation and maintenance of JAD300-U01 aerosol fire extinguishing system must be aware of the potential hazards associated with improper handling, installation or maintenance of this equipment.

Maintenance personnel of JAD300-U01 aerosol fire extinguishing system must be fully trained in proper handling, installation and maintenance, and the hardware of JAD300-U01 fire extinguishing system, and follow the instructions in this manual and the safety bulletin contained in this appendix. And JAD has provided appropriate warnings and precautions in the full text of this manual. These warnings and precautions must always be observed. Failure to do so may result in potential injury to personnel.

Safety Bulletin 1

Environmental Issues

Both Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) are zero. There are no environmental issues associated with the use of JAD300-U01 aerosol fire extinguishing system.

Toxicity and Health Issues

Condensed aerosol fire extinguishing agent is non-corrosive and harmless to various materials, and JAD300-U01 aerosol fire extinguishing system will not do harm to health in its benign state, because the constituent chemicals are pressed into a very stable solid form, even when the working temperature rises. The stored chemicals will not cause harm to the environment or health.

Different fire extinguishing agents have different fire extinguishing mechanisms.The fire extinguishing mechanisms of general fire extinguishing agents mainly include isolation method, suffocation method, cooling method and chemical inhibition method. The fire extinguishing mechanism of condensed aerosol is mainly reflected in two aspects: on the one hand, it is the cooling effect of endothermic decomposition, on the other hand, it is the chemical inhibition effect of gas phase and solid phase, which play a synergistic role with each other. In addition, the gas phase components in aerosol fire extinguishing agent products also played a certain auxiliary role.

Aerosol extinguishing agent itself is composed of solid and gas combustion products. The solid phase is composed of highly dispersed alkali metal salts and oxide particles, which is not harmful to human health at normal design concentration. The gas phase may contain a small amount of carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx) and ammonia (NH_3). The amount of these gases is very small due to the pharmaceutical formula, pharmaceutical raw materials and processing flow.

Under the limited accidental exposure of normal design concentration, aerosol will not

cause harm to health. Exposure to aerosols is usually less than exposure to decomposition products of fire. Accidental exposure within five minutes is usually considered safe. However, certain safety restrictions should always be observed. Contact with aerosols should be avoided, as ingestion of ultra-fine particles may cause short-term discomfort. Aerosol emission also has a high shielding coefficient. Therefore, the following installation requirements must be observed.

System Installation Requirements:

The total flooding fire extinguishing of JAD300-U01 aerosol fire extinguishing system can only be used in normally unoccupied areas. The system needs to be equipped with an isolate switch to ensure the evacuation of personnel before the system is discharged, and it is only actuated manually when personnel may present in the protected area.

Safety Bulletin 2

Subject: Safety Handling Procedure of JAD300-U01 Aerosol Fire Extinguishing System

Personnel must be trained in proper handling, installation and maintenance before handling the JAD300-U01 aerosol fire extinguishing systems.

The instructions in this manual and the safety bulletin contained in this appendix must be strictly followed.

JAD has provided appropriate warnings and precautions in the full text of this manual. These warnings and precautions must be strictly observed. Failure to do so may result in potential injury to personnel.

Before dealing with JAD300-U01 aerosol fire extinguishing system, all personnel must be fully trained to know how to operate the fire extinguishing system safely and be familiar with the correct procedures of installation, disassembly, transportation and disposal.

Read, understand and always follow the operation and maintenance manuals, user manuals, etc. attached to each system.

The following safety procedures must always be observed:

Moving the systems: The fire extinguishing system shall be compactly transported in an upright manner in the provided packaging. They must be properly fixed in place and are not allowed to roll or fall off the tailgate of the vehicles. **Dropped systems are not to be installed.**

Rough handling: the fire extinguishing system shall not fall or be violently strook. **Dropped and Strook systems are not to be installed.**

Storage: Containers must be stored standing upright where they are not exposed to extreme environmental conditions or are subject to being knocked over.

Safety Bulletin 3

Subject: Post Fire Disposal of JAD300-U01 aerosol fire extinguishing system.

Recycling of JAD300-U01 aerosol fire extinguishing system after discharge

In most cases, the discharged JAD300-U01 aerosol fire extinguishing system can be disposed of in any landfill that treats industrial wastes. However, relevant local laws and regulations must be researched and observed. Each discharged JAD300-U01 aerosol fire extinguishing system will contain the following materials:

1. All stainless steel casings and front and back covers.
2.All installation mounting brackets.
3. Stainless steel aviation plug.
3. Ignition wristband and gasket inside the fire extinguishing system.
4. Silica and alumina (ceramic balls): 125g
5. Teflon wire: ø0.8mm×400mm
6. Thermal insulation silicone rubber
8. Trace chemicals: potassium carbonate (water-soluble particles remaining in the system during discharge).

If you have any questions about the above contents, please contact us.

Manufacturer: Hubei Jiandun Fire Technology Co., Ltd.

Address: No.199 Huaxi Road, Biological Industrial Park, China (Hubei) Free Trade Zone Yichang Area，Yichang City, Hubei Province, China.

Tel: 0717-6741877

E-mail:development@jad119.com

Safety Bulletin 4

Equipment Exposure Issues of JAD300-U01 Aerosol Fire Extinguishing system

JAD300-U01 aerosol fire extinguishing system has made relevant tests and strict material selection for the structure, including the structure, aviation composite materials and materials commonly used in electronics and circuit boards. In the case of this research and test, it is shown that JAD300-U01 aerosol fire extinguishing system has no harmful effect on the operation of the equipment.

Fire extinguishing mechanism:

Generation of aerosol fire extinguishing agent;

Chemical reaction to produce aerosol fire extinguishing agent

$K_{0.692}C_{1.197}N_{1.55}O_{2.188}H_{1.53} \rightarrow 0.346K_2O + 0.775N_2 + 1.197CO_2 + 0.765H_2O$

① Aerosol fire extinguishing agent generator: KNO_3 and O_2 are oxidants, $C_3H_6N_6$ is reductant/combustible agent, and C48H42O7 is adhesive/combustible agent.

② Aerosol fire extinguishing agent: K_2O provides potassium free radicals to play the main fire extinguishing role (endothermic decomposition and cooling, chemical inhibition), while N_2 and CO_2 dilute oxygen on the surface of combustible materials (oxygen dilution).

Note: The above reaction formula is theoretical. Because the formula is negative oxygen balance and the reaction is incomplete, the actual product is different from it. When the oxidant is insufficient, gas products such as CO and NH_3 may be produced. K_2O in the product may also be further reacted to generate carbonate/bicarbonate, etc.

Table A.1 Composition Table of Aerosol Fire Extinguishing Agent

	Gas composition（%）							Solid composition（%）			
ingredient	CO_2	N_2	NO_2	H_2O	O_2	CO	other	K_2CO_3	C	$KHCO_3$	other
content	30.79	47.96	7.38	6.44	6.37	0.28	0.78	81.61	15.28	0.25	2.86

Combustion reaction inhibition process:

The fire extinguishing process includes three stages:

（1）The fire spreads through the combustion reaction groups (O, H, OH) in the flame chain; （2）The tiny particles generated by aerosol have great surface area and surface energy, which attract the combustion reaction groups and have chemical action;（3）After the tiny particles enter the fire, they dissociate the potassium free radical (K) at the high temperature of the fire, participate in the combustion chain reaction, and have many chain reactions, which inhibit or interrupt the combination of combustion reaction groups and oxygen.

$K_2O+2\cdot H \rightarrow 2KOH$

$KOH+\cdot OH \rightarrow KO\cdot+H_2O$

$KO\cdot+\cdot H \rightarrow KOH$

$K\cdot+\cdot OH \rightarrow KOH$

$K\cdot+\cdot O \rightarrow KO\cdot$

$KOH+\cdot OH \rightarrow KO\cdot+H_2O$

$2K\cdot+\cdot O \rightarrow K_2O$

The combustion reaction groups react chemically with fine particles, which inhibits the

combustion reaction. The tiny particles dissociate at the high temperature of the fire, and the dissociated potassium radical (K) reacts with OH and O to generate KOH and KO, which further consumes H and OH, and finally generates KOH, K_2O and other products. As KOH and K_2O further react with CO_2 and H_2O in the air, substances such as K_2CO_3 and $KHCO_3$ are generated.

Aerosol characteristics:

Aerosol fire extinguishing agent refers to a kind of gaseous colloidal mixed substance (particle size reaches 10^{-5} μm~10^{-1} μm) formed by physical or chemical action. The substance with gas fluidity, which can spread around obstacles and has certain fire extinguishing function is aerosol fire extinguishing agent.

The extinguishingmedia and particles produced after JAD300-U01 aerosol fire extinguishing system is actuated are very easy to float and suspend in the protected area. Because of the characteristics of aerosol fire extinguishing agent, it can be suspended for a long time (up to one hour) and will not start to settle in a short time, so aerosol gas and particles are very easy to be discharged from the protected area, and only a very small amount of particles may be deposited on the equipment. Usually, there is almost no need to do anything except to extract air from the protected area through fans or air handling systems. Then purge with compressed air. Because the particle size of aerosol deposited on the horizontal plane is 10^{-5} μm~10^{-1} μm, and no continuous layer will be formed, the gap between particles is also large, so the problem of conductivity will not occur.

However, as a preventive measure, it is always important to thoroughly inspect and clean the site after discharge. Although the aerosol itself is very "clean", environmental factors are also a factor worthy of consideration. The actual fire is unknown and may produce harmful by-products, which may also pose great risks to sensitive equipment.

Due to the possible unknowns after the fire and the unreliable factors of the environment, we suggest thoroughly cleaning the impurities in the protected area to ensure the elimination of harmful substances in the protected space and avoid secondary injuries and economic losses. For example, on-site maintenance and housekeeping may be lax, resulting in dust accumulation in the protected area. During the discharge process, any dirt in the protected area will be blown to the surrounding area, and any dirt will be deposited in the protected area. Therefore, we think it is necessary to maintain the protected area and carry out subsequent ventilation and cleaning after the fire.

In addition, in rare cases, the spraying direction and equipment position of JAD300-U01 aerosol fire extinguishing system may be changed incorrectly, resulting in the JAD300-U01 aerosol fire extinguishing system being directly discharged onto the wall or equipment surface incorrectly. This may lead to the deposition of small, localized and highly concentrated particles on the surface. If left untreated, caking may absorb moisture and may lead to non-progressive surface discoloration of unprotected metal surface. If caking is formed on PCB, it may lead to short circuit of electronic components on PCB due to moisture and metal particles contained in caking.

The extinguishing agent discharged by JAD300-U01 aerosol fire extinguishing system can remain suspended for a long time and can be easily discharged by fan or air treatment. A small amount of aerosol deposited on the floor or other horizontal surfaces

can be cleaned by vacuuming, blowing, brushing or washing . Small amounts of residue or agglomerated mass that have not been removed during the ventilation process must be cleaned up with contact cleaner spray thoroughly.

The above cleaning work should be completed within 24 hours.

Summary

Combined with the study of aerosol characteristics and chemical composition of JAD300-U01 aerosol fire extinguishing system, it is shown that the correctly installed JAD300-U01 aerosol fire extinguishing system will not damage electronic equipment, nor will it adversely affect the effective life of equipment exposed to the fire extinguishing system protection area.

Generally speaking, JAD300-U01 aerosol fire extinguishing system should be installed at the bottom of the protected area or in a room close to the bottom of the protected area, and installed horizontally in the center of the bottom of the protected area to ensure the three-dimensional distribution of aerosol. The installation angles of systems with different installation heights are different, so it is only necessary to keep the angle of 45°（±5°）between the discharge port of JAD300-U01 aerosol fire extinguishing system and the bottom of the protected area. In a large volume (≥100m^3), the installation method of JAD300-U01 aerosol fire extinguishing system must have a clear discharge path, and it must not be discharged to obstacles or equipment, because it will lead to agglomeration, reduce efficiency and affect the liquidity of aerosol fire extinguishingmedia. The aerosol fire extinguishing system used for total flooding must put the fire extinguishing system on multiple levels.

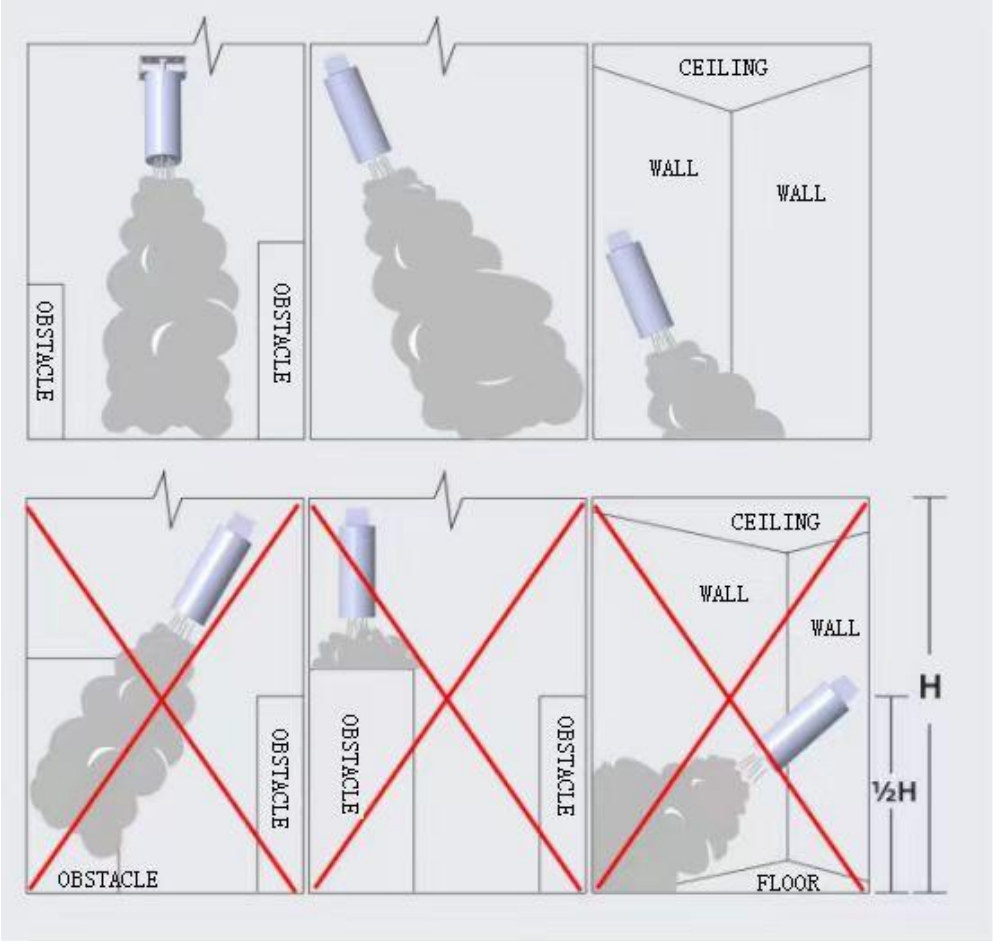

Figure A.1 Schematic Diagram of Discharge

It is very important to install JAD300-U01 aerosol fire extinguishing system to ensure proper aerosol flow and distribution. The aerosol fire extinguishing agent should be distributed as evenly as possible around the hazard area to ensure that the aerosol fire extinguishing agent can quickly flow and disperse to the fire source in the protective space. Ensure the fire extinguishing effect of the fire extinguishingsystemJAD300-U01 aerosol fire extinguishing system shall not be placed in the position where they are directly discharged from each other, which will lead to the aggregation of aerosol particles, reduce the fluidity and dispersion of fire extinguishing media and thus reduce the fire extinguishing effect of aerosol. For the same reason, the location of the aerosol generator in total flooding application should also ensure that the aerosol flow does not directly hit the side of obstacles or protected equipment. Always check whether there are obstacles in the path of aerosol discharge flow. The installation of JAD300-U01 aerosol fire extinguishing systems must ensure that they will not cause personal injury when actuating.

Appendix B

Material Safety Data Sheet

Material Safety Data Sheet

For reference only: Please contact us for details.No.199 Huaxi Road, Biological Industrial Park, China (Hubei) Free Trade Zone Yichang Area，Yichang City, Hubei Province, China.Tel: 0717-6741877 E-mail:development@jad119.com

Section1 Identification of the Substance/Company

Commodity	JAD300-U01 Aerosol Fire Extinguishing System Agent
Manufacturer	Hubei Jiandun Fire Technology Co., Ltd.
Address	No.199 Huaxi Road, Biological Industrial Park, China (Hubei) Free Trade Zone Yichang Area，Yichang City, Hubei Province, China.
Tel:	+86-717-6741877
Fax:	+86-717-6211484
Website/E-mail	development@jad119.com

Section 2 Component/ Information on Ingredients

Component	CAS#	Notes:
potassium nitrate	7757-79-1	The related raw materials are mixed and pressed into a highly stable and consistent grain. The grain is coated with silica gel and then assembled into a sealed stainless steel casing-it will not be exposed to the environment.
Melamine	108-78-1	
Phenolic resin	9003-35-4	
Appearance and smell:	Beige to white, no odor.	
Spontaneous combustion temperature:	350℃	
Water solubility:	Slightly Soluble	

Section 3 Hazard identification

Aerosol Generating Compound	Aerosol Fire Extinguishing Agent
flammable	Possible exposure to aerosol extinguishing agent if system is actuated. May cause temporary, very mild irritation of mucous membrane.

Section 4 First Aid Measures

Contact Method	Aerosol-Generating Compound	Aerosol Extinguishing Agent
Inhalation	N/A	Remove to fresh air
Eye Contact	Hold eyes open and flush with water	Remove to fresh air and flush with water.
Skin contact	Change clothing and shoes, wash with soap and water.	Wash with soap and water.

Section 5 Fire Fighting Measures

Aerosol-Generating Compound	Aerosol Extinguishing Agent
In the event of a fire, evacuate the area and inform emergency services. Ignition of JAD300-U01 aerosol fire extinguishing system to produces a fire extinguishing aerosol. Water may be used as an additional extinguishing agent.	N/A

Section 6 Accidental Release Measures

Aerosol-Generating Compound	Aerosol Fire Extinguishing Agent
N/A	Keep ventilate till aerosol drop away, clean up the discharge residue.

Section 7 Handling and Storage

Handing Precautions	Keep away from combustion source, high temperature and keep ventilate and dry.
Storage Precautions	Keep away from combustion source, high temperature and keep ventilate and dry.
Storage Class	9

Section8 Exposure Controls and Personal Protection

Exposure	Keep ventilate during manufacture and operation.
Personal Protection	Protective gloves, goggles and anti-static clothing should be worn during a production and spilled material clean up procedure. Fire proof and heat insulation clothing ,helmeted and shoe cover shall be worn during fire extinguishing procedure.

Section 9 Physical and Chemical Properties

Appearance	Steel Cylinder length:Φ76×192mm (excluding mounting bracket)

Section10 Stability and Reactivity

Stability	The system is extremely stable under normal temperature conditions
Conditions to Avoid	Avoid sources of fire, sources of electrical power, shock, and high temperatures
Hazardous Reaction Products	Combustion products potentially infinitesimal hazardous carbon monoxide CO and nitrogen oxides NOx
The agent in the system is extremely stable below 125℃	

Section 11 Toxicological Information

The TLV's (Threshold Limit Values) of the chemicals released in the aerosol phase are applicable only in case of long, as long as a complete professional life, exposure. This is not the case of a real life situation.		
Product		
The potential damage is not caused by the product mixture composition, but by the fact that it can be inhaled. The TLV's apply in case of long exposure over many years, contrasted to this application where exposure would be once only and short (in case of accidental discharge when evacuation does not take place on time).		
Components		
Potassium Nitrate	Toxicity	Acute oral toxicity(LD50):901mg/kg(rabbit)750mg/kg(rat)
Melamine	Toxicity	Toxic Dose LD50:3248mg/kg(oral,rat)
Phenolic resin	Toxicity	Not available

Section12 Ecological information

Present no ecological hazards, ODP(Ozone depletion potential)=0 GWP(Global warming potential)=0 ALT(Atmospheric life time)=Low

Section 13 Disposal Considerations

Comply with all local, state, and federal/international regulations.

Section 14 Transport Information

Proper shipping name	Safety systems
Hazard Class or Division	9
UN No.	3268
Packing Introduction	NULL

Division 9 articles present no significant hazard as packaged for transport.

Section 15 Regulatory Information

For the Following Components: The EU classification and R&S phrases, referred to the components of the Solid bound compound related only to the single components considered as separate chemical entities. Once mixed in the production of the solid bound compound, the risk sentences of the single components are not applicable being the solid bound compound a separate chemical entity.			
Potassium Nitrate	EU Classification	Oxidizer	
	R Phrase S Phrase	8 16 41	Contact with combustible material may cause fire Keep away from sources of ignition-No smoking in case of fire and /or explosion, do not breathe fumes.
Melamine	EU Classification	Oxidizer	
	R Phrase S Phrase	22 36 37	Harmful if swallowed Wear suitable protective clothing Wear suitable gloves

Phenolic resin	EU Classification R Phrase	No available 24/25 34	Toxic in contact with skin and if swallowed Causes burns
Limit Value for Exposure EINECS Status Restrictions on Marking and Use		None listed All components are included in EINECS inventories None	

Section16 Other Information

Comply with manufacturer’s installation and maintenance procedures.

Disclaimer:
The information contained herein is accurate to the best knowledge and belief of Hubei Jiandun Fire Technology Co., Ltd., and is intended to describe the product for health, safety, and environmental requirements only. It is not intended and should not be construed as a warranty. Consult Hubei Jiandun Fire Technology Co., Ltd.for further information.

Appendix J

ACTI FIRE Certificate of Conformity

CSIRO Verification Services
Clayton, Victoria, Australia
+61 13 0036 3400
https://activfire.csiro.au

Certificate of Conformity

Certificate num.	Registration date	Version Number	Version Issue date	Valid until	Page 1 of 3
afp - 3838	15-Sep-2023	1	15-Sep-2023	30-Apr-2025	

Product designation

Jiandun, Model JAD300-U01, aerosol fire extinguishing system

(Refer to the Schedule/enclosures for further specified details)

Agent/distributor

Hubei Jiandun Fire Technology Co., Ltd.
No. 199, Huaxi Road, Biological Industrial Park, Yichang Free Trade Zone, YICHANG DISTRICT, HUBEI, CHINA

Registrant

Hubei Jiandun Fire Technology Co., Ltd.
No. 199, Huaxi Road, Biological Industrial Park, Yichang Free Trade Zone, YICHANG DISTRICT, HUBEI, CHINA

Producer

Hubei Jiandun Fire Technology Co., Ltd.
No. 199, Huaxi Road, Biological Industrial Park, Yichang Free Trade Zone, YICHANG DISTRICT, HUBEI, CHINA

Conformance criteria and evaluation

The Jiandun, Model JAD300-U01, aerosol fire extinguishing system has been evaluated and verified as conforming with the relevant requirements of the following criteria.

1. CSIRO Technical Specification TS-016, Version 1,15-Sep-2023, 'Conformity verification of condensed aerosol fire extinguishing systems'.
2. Australian Standard AS 4487-2013, 'Condensed aerosol fire extinguishing systems—Requirements for system design, installation and commissioning and test methods for components'.
3. Underwriters Laboratories Standard UL 2775, 'Outline of Investigation for Fixed Condensed Aerosol Extinguishing System Units'.
4. Underwriters Laboratories - Evaluation and listing, 'UL listing'.

This certification is issued within the scope of CSIRO Verification Services – Rules governing ActivFire Scheme and is valid only for the product(s) as submitted for evaluation and verification of conformity, subject to the following conditions.

- Reference to details, limitations and requirements, where documented as a schedule/enclosure with this certificate.
- The Registrant is responsible for their attestation of conformity and ensuring that on-going production complies with the conformance criteria defined in this certificate.
- This certificate will not be valid if any changes or modifications are made to the product which have not been notified and validated by CSIRO Verification Services.
- This certificate is subject to periodical re-validation upon verification that all requirements, as determined by the conformity assessment body, continue to be satisfactorily met by the Registrant.
- This certificate may only be reproduced in its published form, without modification and inclusive of all schedules/enclosures.
- Any changes, errors or omissions, must be submitted in writing and if necessary or requested, substantiated with relevant evidence.
- Any representations, such as advertising or other marketing related activities or articles shall reflect the correct contents of this certificate and conform with all relevant trade practices .and consumer protection legislation and regulations.
- Any terms or conditions of use as applicable to content and documentation as published or accessed through web sites administered by the CSIRO Verification Services.

Issued by

Kai Loh
Executive Officer – ActivFire Scheme

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This certificate remains the property of CSIRO and may be subject to amendment, suspension or withdrawal at any time.
The validity and authenticity of this certificate can be verified by the certification register located at https://activfire.csiro.au

Schedule to
Certificate of Conformity

Certificate num.	Registration date	Version		Valid until	Page **2** of **3**
		Number	Issue date		
afp - 3838	15-Sep-2023	1	15-Sep-2023	30-Apr-2025	

Limitations/conditions of conformance

Limitations/conditions of conformance, where identified on this certificate, are derived from qualifications from evaluation(s) for conformity and/or other related technical documentation. All details with respect to design, assembly and installation instructions and restrictions should be checked against the producer's current technical manual/data sheets and the requirements of the Authority having Jurisdiction.

Specified limitations/conditions, determined from the evaluation for conformity, include the following.

i. Systems, installation and maintenance shall be installed in accordance with Hubei Jiandun Fire Technology Co., Ltd Model JAD300-U01 Aerosol Fire Extinguishing System design, installation, operation and maintenance manual JAD M230507 Version 1, 05-07-2023, including correct usage and maintenance and the requirements of AS 4487 and authorities having jurisdiction.

ii. Detection, actuation and control systems shall be design and installed in accordance with the requirements of AS 4487 and authorities having jurisdiction.

iii. System is not used to extinguish fires arising from:

   a. Chemicals or mixtures of chemicals, such as cellulose nitrate and gunpowder, that are capable of rapid oxidation with a combination of air.
   b. Reactive metals, such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium.
   c. Chemicals capable of undergoing auto thermal decomposition, such as some organic peroxides and hydrazine.
   d. Metal hydrides, such as potassium hydride, sodium hydride.
   e. Spontaneously combustible substances, such as phosphorus.
   f. Strong oxidants, such as nitrogen oxides, fluorine.
   g. Reactive hydrides, or metal amides, some which may react violently with a gaseous extinguishant.
   h. Deep-seated fires in Class A materials
   i. Class “C” fires involving gasses.

iv. System is not installed into marine applications.

v. System is not installed in occupiable areas and environment rated hazardous.

vi. The limiting aerosol characteristics are described in the table below:

Distance at 75 °C of discharge port (m)	Installation height (m)	Maximum area coverage (m)	Minimum area coverage height (m)	Maximum area coverage height (m)	Maximum volume (m^3)
1.3	0 – 2.4	2.24 × 2.24	1	2.4	5

Producer's description

The Jiandun, Model JAD300-U01, aerosol fire extinguishing system is a Halon alternative product. The system is composed of an initiator, aerosol -forming compound, coolant, mountain bracket and sealed casing.

The generators, combined with actuating mechanisms and other accessory equipment (detection, alarm, control equipment etc.), form the aerosol extinguishing system.

During a fire, the detection system transmits the actuation signal to the initiator of the aerosol generator after detecting the fire. The aerosol-forming compound will then be pyrotechnically actuated and produce aerosol extinguishing agent that flows through the coolant within the device prior to exiting through discharge port(s) into the protected space.

Schedule to
Certificate of Conformity

Certificate num.	Registration date	Version		Valid until	Page **3** of **3**
		Number	Issue date		
afp - 3838	15-Sep-2023	1	15-Sep-2023	30-Apr-2025	

Technical specification

The following details are a representative extract of the technical specification for the Jiandun, Model JAD300-U01, aerosol fire extinguishing system and may be subject to change. Complete and current details should be determined from the designated producer's technical manual/data sheets.

Schedule of variant designations

The following is a schedule of validated variant designations of the certified/listed equipment.

Variant		
Type	**Ident.**	**Description**
Model no.	JAD300-U01	300 g condensed aerosol fire extinguishing system

Schedule of properties/characteristics

The following schedule is an extract of physical and operational properties/characteristics of the certified/listed equipment.

Item	**Specifications**
Application density:	
• Class A fuels:	• 105.3 g/m^3
• Class B fuels:	• 78 g/m^3
Discharge time:	12.5 s (± 2.5 s)
Size:	Ø76 mm (±0.2 mm) × 192 mm (±1 mm) (without bracket)
Safe clearance distance to personnel	
• Discharge port	• 75 °C at 1300 mm
• Generator casing	• 75 °C at 20 mm
Safe clearance distance to combustibles	
• Discharge port	• 200 °C at 700 mm
• Generator casing	• N/A (casing does not exceed 150 °C)
Operating temperature:	-40 °C to +54 °C
Mass of aerosol-forming compound:	300 g ± 2%
Actuation method:	Electrical
Initiator safe current:	600 mA ± 2 mA, 300 s no action
Initiator rated current:	2 A

Supplementary information

Schedule of relevant articles

The following schedule is an extract of articles significant and/or related as evidence of conformity.

Reference			Date issued (or date validated)	Source
Ident. type	**Ident.**	**Title / description**		
Report No.	CSBA0056/R1	Verification of Conformity of the Hubei Jiandun Fire Technology Co., Ltd Model JAD300-U01 Aerosol Fire Extinguishing System to AS 4487:2013 in accordance with CSIRO Technical Specification TS-016 v01	15-Sep-2023	CSIRO, Fire Systems Laboratory, AU
Certificate No.	UL-CA-2328906-0	Certificate of Compliance Report reference EX26592-20230814 Date 16-Aug-2023 (EX26592-20230814-CertificateofCompliance.pdf)	15-Sep-2023	Underwriters Laboratories Inc, US
Fire ref.	FWSA.EX26592	Fixed Condensed Aerosol Extinguishing System Units Hubei Jiandun Fire Technology Co., Ltd. Aerosol-generating extinguishing system unit JAD300-U01 (ul_w3_FWSA.EX26592_JAD300-U01_v_20230915.pdf)	15-Sep-2023	Underwriters Laboratories Inc, US; Product IQ™
Manual	JAD M230507	Manual No. JAD M230507 Version 1, 05-07-2023 Condensed Aerosol Fire Extinguishing System Model: JAD300-U01 DESIGN, INSTALLATION, OPERATION MAINTENANCE MANUAL Hubei Jiandun Fire Technology Co., Ltd. (01-JAD300-U01 design, installation, maintenance manual No JAD M230507.pdf)	11-Aug-2023	Hubei Jiandun Fire Technology Co., Ltd., CN

Appendix K

VBB Fire Report of Technical Findings

January 25, 2022

Victorian Big Battery Fire: July 30, 2021

REPORT OF TECHNICAL FINDINGS

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SENIOR FIRE PROTECTION ENGINEER

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Background

The Victorian Big Battery (VBB) is a 300-Megawatt (MW)/450-Megawatt hour (MWh) grid-scale battery storage project in Geelong, Australia. VBB is one of the largest battery installations in the world and can power over one million Victorian homes for 30 minutes during critical peak load situations.[1] It is designed to support the renewable energy industry by charging during times of excess renewable generation. The VBB is fitted with 212 Tesla Megapacks to provide the 300-MW/450-MWh of energy storage. The Megapack is a lithium-ion battery energy storage system (BESS) consisting of battery modules, power electronics, a thermal management system, and control systems all pre-manufactured within a single cabinet that is approximately 7.2 meters (m) in length, 1.6 m deep and 2.5 m in height (23.5 feet [ft] x 5.4 ft x 8.3 ft).

On Friday, July 30th, 2021, a single Megapack at VBB caught fire and spread to a neighboring Megapack during the initial installation and commissioning of the Megapacks. The fire did not spread beyond these two Megapacks and they burned themselves out over the course of approximately six hours. There were no injuries to the general public, to site personnel or to emergency first responders as the Megapacks failed safely (i.e., slowly burned themselves out with no explosions or deflagrations), as they are designed to do in the event of a fire. Per the guidance in Tesla's Lithium-Ion Battery Emergency Response Guide[2] (ERG), emergency responders permitted the Megapack to burn and consume itself while nearby exposures were being monitored at a safe distance. The total impact to the site was two out of the 212 Megapacks were fire damaged, or less than 1% of the BESS.

Following the emergency response, a detailed, multi-entity fire investigation commenced on August 3, 2021. The investigation process included local regulatory entities, Tesla, outside third-party engineers and subject matter experts. The investigation process involved analyzing both the fire origin and cause as well as the root cause of the fire propagation to the neighbor Megapack. In addition, given this is the first fire event in a Megapack installation to date, a review of the emergency response has been performed to identify any lessons learned from this fire event.

This report summarizes those investigations and analyses and has been prepared by Fisher Engineering, Inc. (FEI) and Energy Safety Response Group (ESRG), two independent engineering and energy storage fire safety consulting firms. In addition, this report provides a list of lessons learned from the fire and also highlights the procedural, software and hardware changes that have been implemented based on those lessons learned.

Incident Timeline

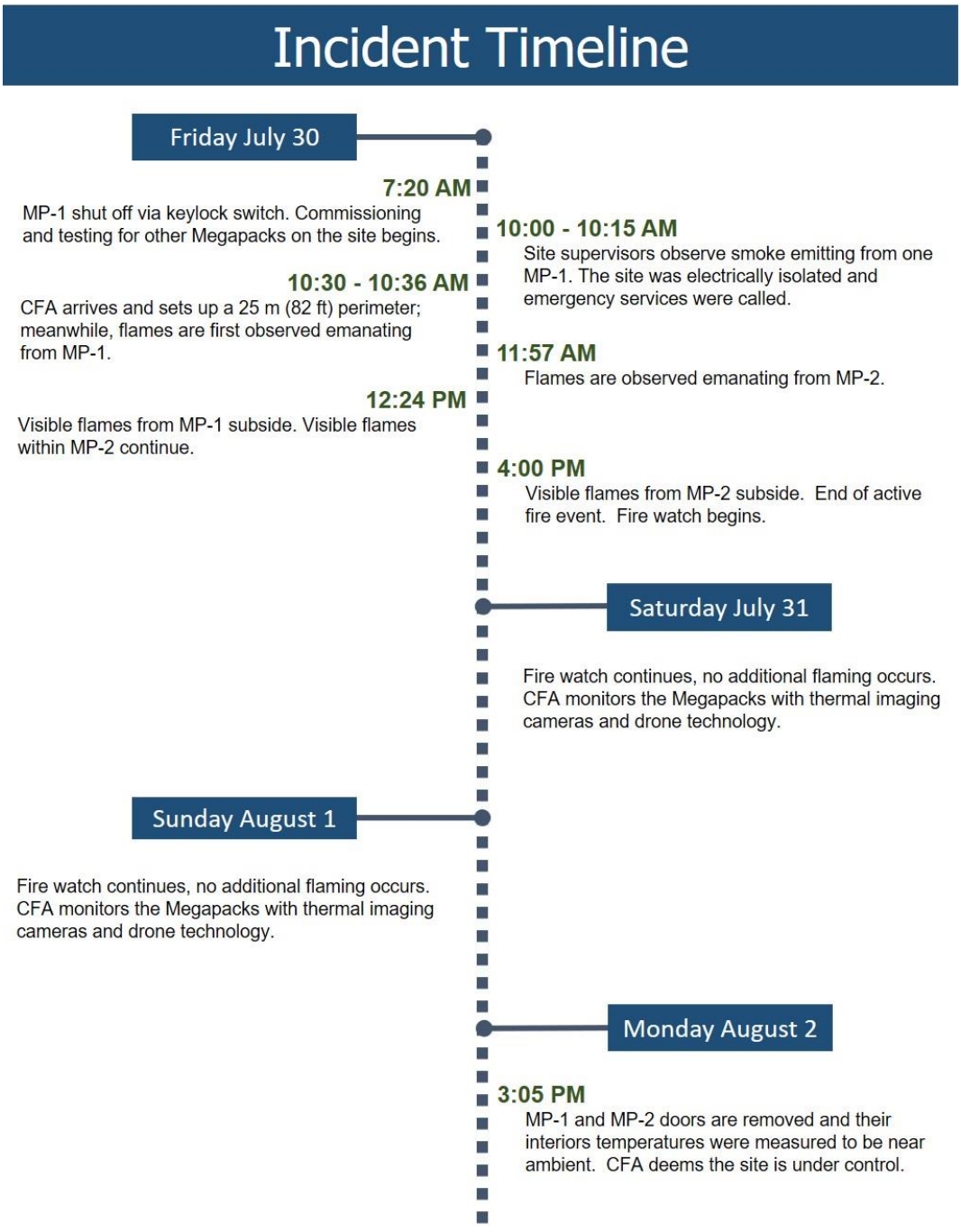
At the time of the fire, the VBB was fitted with approximately one-half of the 212 total Megapacks intended for the site. The Megapacks that were installed at VBB were undergoing routine testing and commissioning on the day of the fire. At 7:20 AM Australian Eastern Standard Time (AEST) on the morning of July 30, 2021, commissioning and testing of a number of Megapacks commenced. One such Megapack (denoted herein as MP-1), was not going to be tested that day and was therefore shut off manually by means of the keylock switch.[3] At the time MP-1 was shut down via the keylock switch, the unit displayed no abnormal conditions to site personnel. Around 10:00 AM, smoke was observed emitting from MP-1 by site personnel. Site personnel

[1] https://victorianbigbattery.com.au/

[2] https://www.tesla.com/sites/default/files/downloads/Lithium-Ion_Battery_Emergency_Response_Guide_en.pdf

[3] The keylock switch is a type of "lock out tag out" switch on the front of the Megapack that safely powers down the unit for servicing.

electrically isolated all the Megapacks on-site and called emergency services: Country Fire Authority (CFA). The CFA arrived shortly thereafter and set up a 25 m (82 ft) perimeter around MP-1. They also began applying cooling water to nearby exposures as recommended in Tesla's ERG. The fire eventually spread into a neighbor Megapack (MP-2) installed 15 centimeters (cm), or 6 inches (in), behind MP-1. The CFA permitted MP-1 and MP-2 to burn themselves out and did not directly apply water into or onto either Megapack, as recommended in Tesla's ERG. By 4:00 PM (approximately six hours after the start of the event), visible fire had subdued and a fire watch was instituted. The CFA monitored the site for the next three days before deeming it under control on August 2, 2021, at which time, the CFA handed the site over for the fire investigation to begin.



Note: The time stamp is AEST (UTC+10) which is 19 hours ahead of USA PDT (UTC-7)

Investigation

A multi-entity fire investigation commenced on August 3, 2021. The VBB fire investigation process involved analyzing both the root cause of the initial fire in MP-1 as well as the root cause of the fire propagation into MP-2. The investigations included on-site inspections of MP-1 and MP-2 by the CFA, Energy Safe Victoria[4] (ESV), Work Safety Victoria[5] (WSV), local Tesla engineering/service teams and a local third-party independent engineering firm. In addition to the on-site work immediately after the incident, the root cause investigations also included data analysis, thermal modeling and physical testing (electrical and fire) performed by Tesla at their headquarters in California, USA and their fire test facility in Nevada, USA.

Fire Cause Investigation

On-site inspections commenced on August 3, 2021 and concluded on August 12, 2021. MP-1 and MP-2 were documented, inspected and preserved for future examinations, if necessary. Concurrently, all available telemetry data (such as internal temperatures and fault alarms) from MP-1 and MP-2 were analyzed and a series of electrical fault and fire tests were performed. The on-site investigation findings, the telemetry data analysis, electrical fault tests and fire tests, when combined, identified a very specific series of fault conditions present on July 30, 2021 that could lead to a fire event.

Fire Origin and Cause Determination

The origin of the fire was MP-1 and the most likely root cause of the fire was a leak within the liquid cooling system of MP-1 causing arcing in the power electronics of the Megapack's battery modules. This resulted in heating of the battery module's lithium-ion cells that led to a propagating thermal runaway event and the fire.

Other possible fire causes were considered during the fire cause investigation; however, the above sequence of events was the only fire cause scenario that fits all the evidence collected and analyzed to date.

Contributory Factors

A number of factors contributed to this incident. Had these contributory factors not been present, the initial fault condition would likely have been identified and interrupted (either manually or automatically) before it escalated into a fire event. These contributory factors include:

1. The supervisory control and data acquisition (SCADA) system for a Megapack required 24 hours to setup a connection for new equipment (i.e., a new Megapack) to provide full telemetry data functionality and remote monitoring by Tesla operators. Since VBB was still in the installation and commissioning phase of the project (i.e., not in operation), MP-1 had only been in service for 13 hours prior to being switched off via the keylock switch on the morning of the fire. As such, MP-1 had not been on-line for the required 24 hours, which prevented this unit from transmitting telemetry data (internal temperatures, fault alarms, etc.) to Tesla's off-site control facility on the morning of the fire.
2. The keylock switch for MP-1 was operated correctly on the morning of the fire to turn MP-1 off as the unit was not required for commissioning and testing that morning; however, this action caused telemetry systems, fault monitoring, and electrical fault safety devices[6] to be disabled or operate with

[4] Victoria's energy safety regulator

[5] Victoria's health and safety regulator

[6] These elements include, among other devices, fuses at the cell and module level for localized fault current interruption and a battery module pyro disconnect that severs the electrical connection of the battery module when a fault current is passing through the battery module.

only limited functionality. This prevented some of the safety features of MP-1 from actively monitoring and interrupting the electrical fault conditions before escalating into a fire event.

3. The exposure of liquid coolant onto the battery modules likely disabled the power supply to the circuit that actuates the pyro disconnect.[7] With a power supply failure, the pyro disconnect would not receive a signal to sever and would not be able to interrupt a fault current passing through the battery module prior to it escalating into a fire event.

Fire Propagation Investigation

The VBB fire investigation process involved analyzing not only the root cause of the initial fire in MP-1 but also the root cause of the fire propagation into MP-2. The Megapack has been designed to be installed in close proximity to each other without fire propagating to adjacent units. The design objective of the Megapack in terms of limiting fire propagation was mainly reliant on the thermal insulation of the Megapack's exterior vertical steel panels and the sheer mass of the battery modules acting as a heat sink (i.e., they are difficult to heat up). With this thermal insulation, the Megapack spacing can be as close as 15 cm (6 in) to the sides and back of each unit with 2.4 m (8 ft) aisles in front of each Megapack, as shown in Figure 1. This product spacing has been validated in UL9540A unit level tests.[8] Similar to the fire origin and cause investigation, the on-site inspections were supported simultaneously with an analysis of telemetry data (such as internal temperatures) from MP-2 and fire testing. The on-site investigation findings, the telemetry data analysis and fire tests, when combined, identified a scenario where Megapack to Megapack fire propagation can occur.

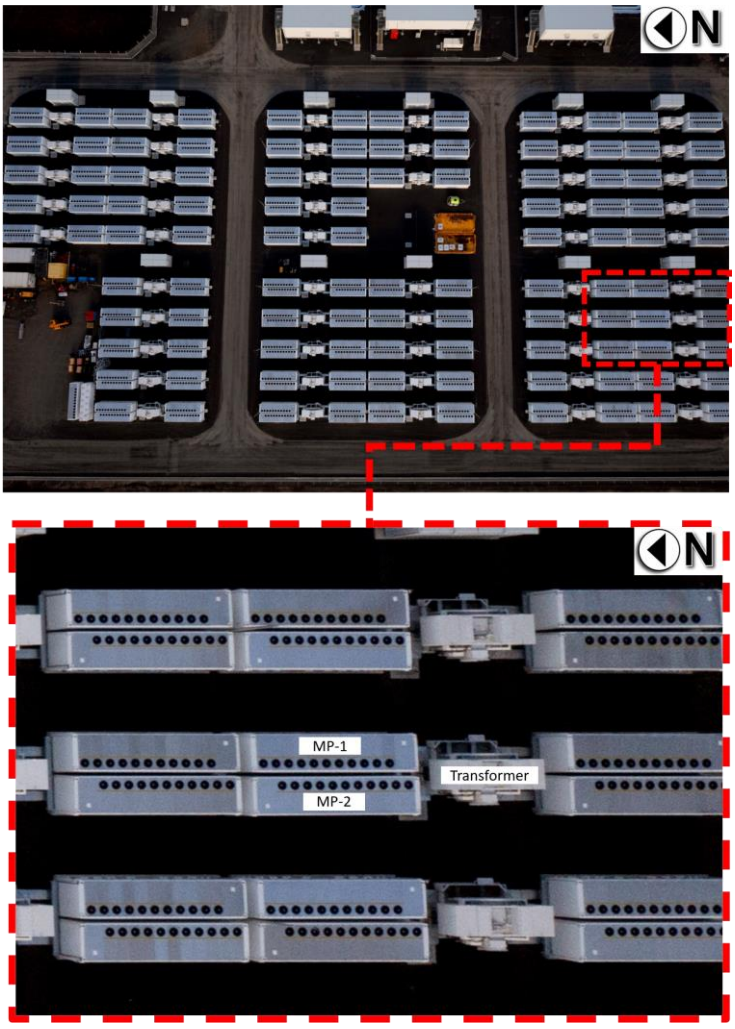


Figure 1 VBB Megapack layout (top) and area of fire origin (bottom)

[7] The pyro disconnect is a Tesla proprietary shunt-controlled pyrotechnic fuse that allows for rapid one-time actuation. There is one pyro disconnect per battery module.

[8] UL9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*. UL9540A is a test method developed by UL to address fire safety concerns with BESS. The test method provides a method to evaluate thermal runaway and fire propagation at the cell level, module level, and unit level. In addition to cell and module level tests, Tesla performed unit level tests to evaluate, among other fire safety characteristics, the potential for fire propagation from Megapack-to-Megapack. During unit level testing, fire propagation did not occur between Megapacks when they were installed with a spacing of 15 cm (6 in) to the sides and back of each unit.

Fire Propagation Determination

Flames exiting the roof of MP-1 were significantly impacted by the wind conditions at the time of the fire. Wind speeds were recorded between 20-30 knots[9] which pushed the flames exiting the roof of MP-1 towards the roof of MP-2. This direct flame impingement on the top of the thermal roof of MP-2 ignited the internal components of MP-2, most notably, the plastic overpressure vents that seal the battery bay[10] from the thermal roof. Once ignited, the overpressure vents provided a direct path for flames and hot gases to enter into the battery bays, thus exposing the battery modules of MP-2 to fire and/or elevated temperatures. Exposed to temperatures above their thermal runaway threshold of 139°C (282°F), the cells within the battery modules eventually failed and became involved in the fire.

Other possible fire propagation root causes were considered during the investigation; however, the above sequence of events was the only fire propagation scenario that fits all the evidence collected and analyzed to date. Of note, at the time when fire was observed within the thermal roof of MP-2, internal cell temperature readings of MP-2 had only increased by 1°C (1.8°F) from 40°C to 41°C (104°F to 105.8°F)[11] Around the same time that fire was observed within the thermal roof of MP-2, around 11:57 AM (approximately 2 hours into the fire event), communication was lost to the unit and no additional telemetry data was transmitted. However, given the internal cell temperatures of MP-2 had only recorded a 1°C (1.8°F) temperature rise 2 hours into the fire event and while the unit's roof was actively on fire, fire propagation across the 15 cm (6 in) gap via heat transfer is not the root cause of the fire propagation. Furthermore, this telemetry data from MP-2 demonstrates that the Megapack's thermal insulation can provide significant thermal protection in the event of a fire within an adjacent Megapack installed only 15 cm (6 in) away.

Contributory Factors

The wind was the dominant contributory factor in the propagation of fire from MP-1 to MP-2. At the time of the fire, a 20-30 knot (37-56 km/hr, 23-35 mph) wind was recorded out of the north. The wind conditions at the time of the fire pushed the flames exiting out of the top of MP-1 towards the top of MP-2 leading to direct flame impingement on the thermal roof of MP-2. This type of flame behavior was not observed during previous product testing or regulatory testing per UL9540A. In UL9540A unit level testing, the maximum wind speed permitted[12] during the test is 10.4 knots (19.3 km/hr, 12.0 mph); whereas, wind conditions during the VBB fire were two to three times greater in magnitude. As such, the wind conditions during the VBB fire appear to have identified a weakness in the Megapack's thermal roof design (unprotected, plastic overpressure vents in the ceiling of the battery bays) that allows Megapack-to-Megapack fire propagation. This weakness was not identified previously during product or regulatory testing and does not invalidate the Megapack's UL9540A certification, as the cause of fire propagation was primarily due to an environmental condition (wind) that is not captured in the UL9540A test method.

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9 This equates to 37-56 kilometers per hour (km/hr) or 23-35 miles per hour (mph).

10 The battery bay is an IP66 enclosure that houses the battery modules. It is distinct from the thermal roof installed above it. Plastic overpressure vents are installed in the ceiling of the battery bay, sealing the two enclosures from one another.

11 As a reference, the Megapack's normal operating cell temperature is between 20-50°C and cell thermal runaway does not occur until 139°C (98°C above cell temperatures of MP-2 before telemetry data was lost).

12 This threshold is necessary for test reliability and reproducibility. If wind conditions are not bounded in some fashion in an outdoor fire test, large variances on product performance could be introduced due to varying wind conditions.

Mitigations

The investigation of the VBB fire identified several gaps in Tesla's commissioning procedures, electrical fault protection devices and thermal roof design. Since the fire, Tesla has implemented a number of procedural, firmware, and hardware mitigations to address these gaps. These mitigations have been applied to all existing and any future Megapack installations and include:

Procedural Mitigations:

- Improved inspection of the coolant system for leaks during Megapack assembly and during end-of-line testing to reduce the likelihood of future coolant leaks.
- Reduce the telemetry setup connection time for new Megapacks from 24 hours to 1 hour to ensure new equipment is transmitting telemetry data (internal temperatures, fault alarms, etc.) to Tesla's off-site control facility for remote monitoring.
- Avoid utilizing the Megapack's keylock switch during commissioning or operation unless the unit is actively being serviced. This procedural mitigation ensures telemetry, fault monitoring, and electrical fault safety devices (such as the pyro disconnect) are active while the Megapack is idle (such as during testing and commissioning).

Firmware Mitigations:

- Added additional alarms to the coolant system's telemetry data to identify and respond (either manually or automatically) to a possible coolant leak.
- Keep all electrical safety protection devices active, regardless of keylock switch position or system state. This firmware mitigation allows electrical safety protection devices (such as the pyro disconnect) to remain in an active mode, capable of actuating when electrical faults occur at the battery modules, no matter what the system status is.
- Active monitoring and control of the pyro disconnect's power supply circuit. In the event of a power supply failure (either through an external event such as a coolant exposure or some other means), the Megapack will automatically actuate the pyro disconnect prior to the loss of its power supply.

Hardware Mitigations

- Installation of newly designed, thermally insulated steel vent shields within the thermal roof of all Megapacks. These vent shields protect the plastic overpressure vents from direct flame impingement or hot gas intrusion, thus keeping the IP66 battery bay enclosures isolated from a fire above in the thermal roof. Their performance was validated through a series of fire tests, including unit level fire testing of entire Megapack units.[13] The vent shields are placed over the top of the overpressure vents and will come standard on all new Megapack installations. For existing Megapacks, the vent shields can be installed in the field (retrofit) with minimal effort or disruption to the unit. At the time of this report, the vent shields are nearing production stage and will be retrofitted to applicable Megapack sites shortly.

[13] The tests confirmed that, even with the entire thermal roof fully involved in fire, the overpressure vents will not ignite and the battery modules below remain relatively unaffected by the fire above. For instance, the cells within the battery modules saw a less than 1°C temperature rise while the entire thermal roof was fully involved in fire.

Emergency Response

Beyond the origin and cause and propagation investigations, another key aspect of the VBB fire was the emergency response. The CFA is the responsible fire service organization for VBB, and the facility is in their initial response jurisdiction. The location of the VBB facility is in a semi-rural location. The nearest fire station is the CFA Lovely Banks, approximately 4 km (2.5 miles) distance from VBB and thus relatively close, though other resources had more extended travel distances.

Upon arrival around 10:30 AM, CFA immediately established incident command (IC) in accordance with their protocols, and the IC worked closely with the facility representatives and subject matter experts (SMEs). This close coordination continued throughout the entire event. The facility was evacuated and all-site personnel accounted-for upon notification of the emergency event and the commencement of fire service operations. A 25 m (82 ft) perimeter was established around MP-1 while water application and cooling strategies were discussed with facility representatives and subject matter experts (SMEs). The decision was made to provide exposure protection to Megapacks and transformers adjacent to MP-1 and MP-2 using water hose lines, as recommended in Tesla's ERG. The fire eventually propagated into MP-2; however, flame spread did not advance any further than MP-1 and MP-2. The two Megapacks were permitted to burn themselves out, during which time the CFA did not directly apply water into or onto either Megapack. By 4:00 PM (approximately six hours after the start of the event), visible flames had subdued and a fire watch was instituted. The CFA continued to monitor the site for the next three days before deeming it under control on August 2, 2021, at which time, the fire investigation began.

Key Takeaways

A thorough review of the VBB fire emergency response yielded the following key takeaways:

- Effective Pre-incident Planning: VBB had both an Emergency Action Plan (EAP) and an Emergency Response Plan (ERP). Both plans were available to emergency responders and were effectively used during the VBB fire. For example, all site employees and contractors followed proper evacuation protocols during the fire and as a result, no injuries occurred to those personnel.
- Coordination with SMEs: VBB had thorough pre-incident plans that clearly identified the SMEs, how to contact them, their role and other key tasks. It was reported that the facility SMEs stayed in close contact with the CFA IC throughout the VBB fire, providing valuable information and expertise for the CFA to draw upon. For example, site representatives and SMEs worked closely with the CFA in determining water application and cooling strategies of adjacent exposures.
- Water Application: A key question regarding water application is the necessary amount and duration for effective fire containment. Tesla's design philosophy is based on inherent passive protection (i.e., thermal insulation), with minimal dependence on active firefighting measures like external hose lines. As such, water was not aimed at suppressing the fire but rather protecting the exposures as directed by Tesla's ERG and the SMEs on site. All available data and visual observations of the fire indicates water had limited effectiveness in terms of reducing or stopping fire propagation from Megapack-to-Megapack. The thermal insulation appears to be the dominant factor in reducing heat transfer between adjacent Megapacks. However, water was effectively used on other exposures

(transformers, electrical equipment, etc.) to protect that equipment, which are not designed with the same level of protection as a Megapack is (i.e., thermal insulation).[14]

- The fire protection design approach of the Megapack has inherent advantages over other BESS designs in terms of safety to emergency responders. The Megapack approach minimizes the likelihood of fire spread using passive compartmentation and separation, eliminates the danger to fire fighters of an overpressure event due to design features and a lack of confinement (e.g., outdoor versus indoor), does not rely on active firefighting measures like external hose lines and minimizes the dangers from stranded electrical energy to those involved with overhaul and de-commissioning with a fire response approach permitting the Megapack to burn itself out.

Environmental Concerns

The Environment Protection Authority Victoria (EPA) deployed two mobile air quality monitors within 2 km (1.2 miles) of the VBB site. Locations were chosen where there was potential to impact the local community. The EPA monitors confirmed "good air quality in the local community" after the incident; however, the measurements were not taken during the peak of the fire event. They were sampled around 6:00 PM, or approximately 2 hours after the fire was out. Therefore, the data cannot be used to understand the airborne hazards during the actual fire event. The data does demonstrate that two hours after the fire event, the air quality in the surrounding area was "good" and no long-lasting air quality concerns arose from the fire event.[15]

During the fire event, the CFA coordinated with site personnel to control the water run-off from fire hoses into a catchment. Water samples, collected by Tesla site personnel under the supervision of CFA, were extracted from the catchment. Laboratory results from those samples indicated that the likelihood of the fire having a material impact on the water was minimal. After the incident, as a precaution, the water was removed from the catchment, via suction trucks, and was transported to a licensed waste facility for treatment and disposal. It is estimated that approximately 900,000 liters of water was disposed of from the site after the event.

Community Concerns

Neoen, the project developer and owner, pro-actively engaged with the local community during and following the VBB fire. These engagements included door-to-door visits, phone calls and emails with the residential and agricultural properties within a 2-3 km (1.2-1.9 mile) radius of the VBB site. Neoen found their prior community outreach during the project planning stages to be invaluable as this outreach provided up-to-date contact information for Neoen when reaching out to the local community during and following the fire. In addition, Neoen formed an executive stakeholder steering committee compromising of key organizations within 24 hours of the incident. With multiple parties involved in the emergency response to the fire event

[14] At the time of this report, final fire department reports were not available for review and inclusion. As that information becomes available, additional information regarding water usage and effectiveness may require inclusion in this report. Although the effectiveness of external water in a Megapack fire may be limited, water should still be made available for exposure protection and other unanticipated events in the future, as required by any applicable regulatory requirements.

[15] It should be noted that prior regulatory testing (UL 9540A module level fire testing) has shown that the products of combustion of a Megapack battery module can include flammable and nonflammable gases. Based on those regulatory tests, the flammable gases were found to be below their lower flammable limit (LFL) and would not pose a deflagration or explosion risk to first responders or the general public. The nonflammable gases were found to be comparable to the smoke you would encounter in a typical Class A structure fire and do not contain any unique, or atypical, gases beyond what you would find in the combustion of modern combustible materials.

actively participating in the steering committee, this helped ensure that from the outset communication was timely, efficient, well-coordinated across different organizations and accurate.

In addition to the community outreach, Neoen and Tesla also briefed multiple industry, State and Federal Government Departments and Agencies immediately following the VBB fire and at the conclusion of the investigation process. These briefings helped ensure the wider energy sector with interests in BESS were able to be kept directly informed as information became available.

Overhaul and Remediation

On July 29, 2021 nearly half of the Megapacks had been installed and the site was in the testing and commissioning stage of the project. Following the fire event on July 30, 2021, fire department personnel, regulatory agencies and other emergency responders remained on-site for precautionary purposes until August 2, 2021. At that time the site was turned over for regulatory fire investigations to begin. On-site fire investigations started on August 3, 2021 and continued until August 12, 2021. During this time, starting on August 6, 2021, the site was permitted to continue the installation of Megapacks while the area around MP-1 remained cordoned off for the investigation. On September 23rd, 2021, less than two months after the fire, VBB was re-energized and testing and commissioning restarted. Remediation of the damaged equipment followed shortly after, and lasted a total of three days. All testing and commissioning efforts were completed without any further incidents and on December 8, 2021, VBB officially opened.

Lessons Learned

The VBB fire exposed a number of unlikely factors that, when combined, contributed to the fire initiation as well as its propagation to a neighboring unit. This collection of factors had never before been encountered during previous Megapack installations, operation and/or regulatory product testing. This section summarizes those factors as well as the emergency response to the fire, discusses the lessons learned from this fire event, and highlights the mitigations Tesla has implemented in response.

1. Commissioning Procedures

Lessons learned related to commissioning procedures include: (1) limited supervision/monitoring of telemetry data during the first 24 hours of commissioning and (2) the use of the keylock switch during commissioning and testing. These two factors prevented MP-1 from transmitting telemetry data (internal temperatures, fault alarms, etc.) to Tesla's control facility and placed critical electrical fault safety devices (such as the pyro disconnect) in a state of limited functionality, reducing the Megapack's ability to actively monitor and interrupt electrical fault conditions prior to them escalating into a fire event.

Since the VBB fire, Tesla has modified their commissioning procedures to reduce the telemetry setup connection time for new Megapacks from 24 hours to 1 hour and to avoid utilizing the Megapack's keylock switch unless the unit is actively being serviced.

2. Electrical Fault Protection Devices

Lessons learned related to electrical fault protection devices include: (1) coolant leak alarms; (2) the pyro disconnect being unable to interrupt fault currents when the Megapack is off via the keylock switch and (3) the pyro disconnect likely being disabled due to a power supply loss to the circuit that actuates it. These three factors prevented the pyro disconnect of MP-1 from actively monitoring and interrupting the electrical fault conditions before escalating into a fire event.

Since the VBB fire, Tesla has implemented a number of firmware mitigations that keep all electrical safety protection devices active, regardless of keylock switch position or system state, and to actively monitor and control the pyro disconnect's power supply circuit. Furthermore, Tesla has added additional alarms to better identify and respond (either manually or automatically) to coolant leaks. Additionally, although this fire event was likely initiated by a coolant leak, unexpected failures of other internal components of the Megapack could create similar damage to the battery modules. These new firmware mitigations do not only address damage from a coolant leak. They also permit the Megapack to better identify, respond, contain and isolate issues within the battery modules due to failures of other internal components, should they occur in the future.

3. Fire Propagation

Lessons learned related to fire propagation include: (1) the significant role external, environmental conditions (such as wind) can have on a Megapack fire and (2) the identification of a weakness in the thermal roof design that permits Megapack-to-Megapack fire propagation. These two factors led to direct flame impingement on the plastic overpressure vents that seal the battery bay from the thermal roof. With a direct path for flames and hot gases to enter into the battery bays, the cells within the battery modules of MP-2 failed and became involved in the fire.

Since the VBB fire, Tesla has devised (and validated through extensive testing) a hardware mitigation that protects the overpressure vents from direct flame impingement or hot gas intrusion via the installation of new, thermally insulated, steel vent shields. The vent shields are placed on top of the overpressure vents and will come standard on all new Megapack installations. For existing Megapacks, the vent shields can be easily installed in the field. At the time of this report, the vent shields are nearing production stage and will be retrofitted to applicable Megapack sites shortly.

4. Megapack Spacing

Lessons learned related to Megapack spacing include: no changes are required to the installation practices of the Megapack with the vent shield mitigation (as described above) in place. Based on an analysis of telemetry data within MP-2 during the VBB fire, the Megapack's thermal insulation can provide significant thermal protection in the event of a fire within an adjacent Megapack installed 15 cm (6 in) away. The internal cell temperatures of MP-2 only increased by 1°C (1.8°F), from 40°C to 41°C (104°F to 105.8°F), before communication was lost to the unit, presumably due to fire, around 11:57 AM (approximately 2 hours into the fire event). Fire propagation was triggered by the weakness in the thermal roof, as described above in #3, and not due to heat transfer via the 15 cm (6 in) gap between Megapacks. With the vent shield mitigation in place, the weakness has been addressed and validated through unit level fire testing (i.e., tests involving the ignition of the Megapack's thermal roof). These tests confirmed that, even with the thermal roof fully involved in a fire, the overpressure vents will not ignite and the battery modules remain relatively unaffected with internal cell temperatures rising less than 1°C.

5. Emergency Response

Lessons learned from the emergency response to the VBB fire include: (1) effective pre-incident planning is invaluable and can reduce the likelihood of injuries; (2) coordination with SMEs, either on site or remotely, can provide critical expertise and system information for emergency responders to draw upon; (3) the effectiveness of applying water directly to adjacent Megapacks appears to provide limited benefits; however, water application to other electrical equipment, with inherently less fire protection built into their designs (such as transformers), can be a useful tactic to protect that equipment; (4) the fire protection design

approach of the Megapack has inherent advantages over other BESS designs in terms of safety to emergency responders; (5) the EPA indicated that there was “good” air quality 2 hours after the fire demonstrating that no long-lasting air quality concerns arose from the fire event; (6) water samples indicated that the likelihood of the fire having a material impact on firefighting water was minimal; (7) prior community engagement during the project planning stages is invaluable as it enabled Neoen to quickly update the local community and address immediate questions and concerns; (8) early, factual and where possible, face-to-face engagement with the local community is essential when a fire event is unfolding to keep the general public informed; (9) an executive stakeholder steering committee from the key organizations involved in the emergency response can help ensure that any pubic communications are timely, efficient, coordinated and accurate; and (10) effective coordination between stakeholders at the site allowed for rapid and thorough handover process after the incident, the swift and safe decommissioning of the damaged units and the site’s quick return to service.

In summary, the VBB fire event proceeded in accordance with its fire protection design and pre-incident planning. It presented no unusual, unexpected, or surprising characteristics (i.e., explosions) or resulted in any injuries to site personnel, the general public or emergency responders. It was isolated to the units directly involved, had minimal environmental impact, did not adversely impact the electrical grid, and had appreciably short mission interruption.

Appendix L

Sungrow Battery Spacing Review Documentation

Prüfbericht-Nr.: *Test Report No.:*	**CN21GYRR 001**	**Auftrags-Nr.:** *Order No.:*	244370534	**Seite 1 von 56** *Page 1 of 56*
Kunden-Referenz-Nr.: *Client Reference No.:*	2182037	**Auftragsdatum:** *Order date.:*	Oct 28, 2021	
Auftraggeber: *Client:*	Sungrow Energy Storage Technology Co.,Ltd. No.788 Mingchuan Road, Boyan Technology Park, Hi-tech Zone, Hefei City, 230088 Anhui, P.R. China			
Prüfgegenstand: *Test item:*	Battery Rack			
Bezeichnung / Typ-Nr.: *Identification / Type No.:*	R287-111, R344-111 R578-111, R688-111			
Auftrags-Inhalt: *Order content:*	Test report			
Prüfgrundlage: *Test specification:*	UL 9540A: 2019 (Fourth Edition)			
Wareneingangsdatum: *Date of receipt:*	Nov 15, 2021			
Prüfmuster-Nr.: *Test sample No.:*	Engineering sample			
Prüfzeitraum: *Testing period:*	Nov 15, 2021 ~ Nov 17, 2021			
Ort der Prüfung: *Place of testing:*	See clause 1.1 of main report			
Prüflaboratorium: *Testing laboratory:*	See clause 1.1 of main report			
Prüfergebnis*: *Test result*:*	See main report			

geprüft von / *tested by:*

December 13, 2021 Marvin Peng&David Zhou / Engineer

Datum *Date*	**Name/Stellung** *Name/Position*	**Unterschrift** *Signature*

kontrolliert von / *reviewed by:*

December 13, 2021 Bowen Dong / Reviewer

Datum *Date*	**Name/Stellung** *Name/Position*	**Unterschrift** *Signature*

Sonstiges / *Other:*

Zustand des Prüfgegenstandes bei Anlieferung: *Condition of the test item at delivery:*

Prüfmuster vollständig und unbeschädigt
Test item complete and undamaged

* Legende:	1 = sehr gut P(ass) = entspricht o.g. Prüfgrundlage(n)	2 = gut	3 = befriedigend F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	4 = ausreichend N/A = nicht anwendbar	5 = mangelhalt N/T = nicht getestet
Legend:	1 = very good P(ass) = passed a.m. test specifications(s)	2 = good	3 = satisfactory F(ail) = failed a.m. test specifications(s)	4 = sufficient N/A = not applicable	5 = poor N/T = not tested

Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht auszugsweise vervielfältigt werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens.

This test report only relates to the a. m. test sample. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.

V04

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 do not 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.

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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 unit level tests of UL 9540A: 2019.

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.

Testing period: Nov 15, 2021 ~ Nov 17, 2021

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

Video records of the test from 4 different directions were provided in .mp4 format. Complete records were provided in 4 separate documents, file number listed as below:

NY202111224-1.mp4

NY202111224-2.mp4

NY202111224-3.mp4

NY202111224-4.mp4

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 as 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 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.

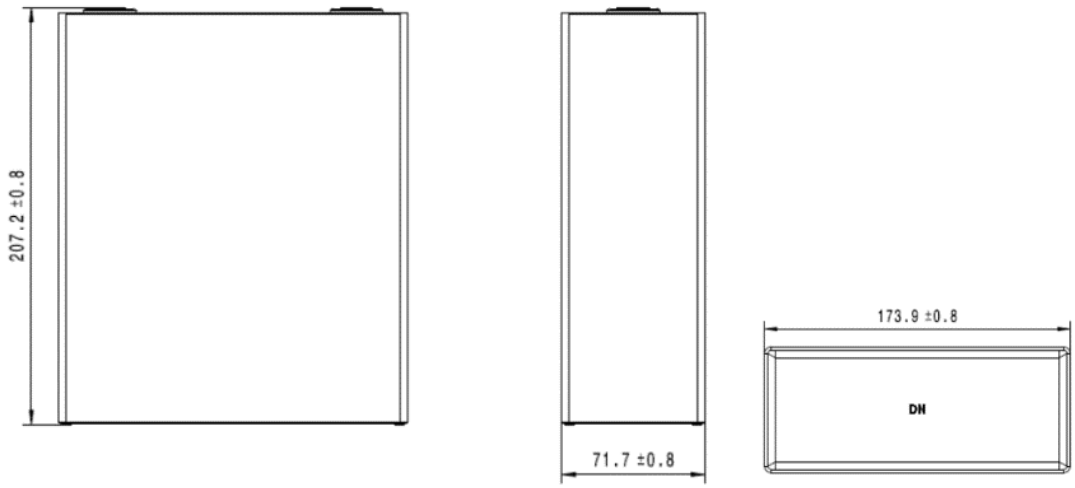
2 General Product Information

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

2.1 Cell

2.1.1 Product information and parameters

Manufacturer .....:	CATL	
Model .....:	CB2W0 CB310	
Chemistry .....:	LiFePO4	
Physical configuration .....:	Prismatic	
	Weight:	5410 ± 300 g
Electrical rating .....:	Rated capacity:	280 Ah
	Nominal voltage:	3.2 V
Standard charge method .....:	Charge current:	280 A
	End of charge voltage:	3.65 V
	Cut off current:	14 A
Standard discharge method .....:	Discharge current:	280 A
	End of discharge voltage:	2.5 V
Diagram with overall dimension		



Model Difference: Cell model CB2W0 is identical to model 001CB310 except for the rated charging/discharging current declared, documented in UL with project No. 4789439215. Models CB2W0 and CB310 are identical to model 001CB310 except for model names, and the declared ratings of pulse charging and discharging current.

2.1.2 Cell level test information

Cell level thermal runaway test information is from CSA cell level test report 80008629 provided by the client.

Thermal Runaway Methodology ..... :	External heating method with ceramic heater 1 PCS, rated 220/230V, 500W
Average Cell Surface Temperature at Gas Venting ..... :	143.3°C
Average Cell Surface Temperature at Thermal Runaway..... :	209.8°C

2.2 Module

2.2.1 Product information and parameters

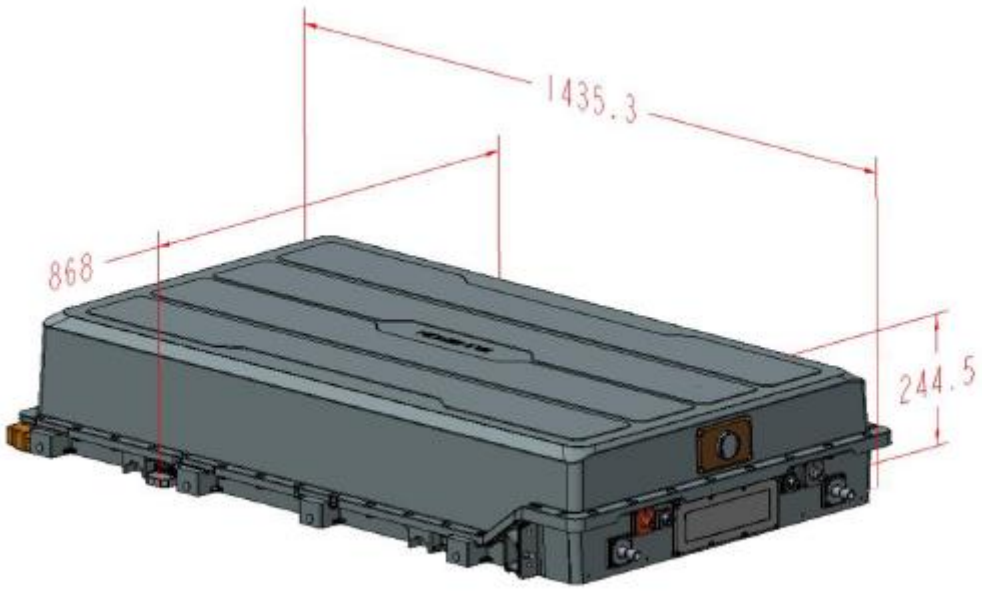
The product information and parameters are provided by the client as below.

Manufacturer name.....:	SUNGROW ENERGY STORAGE TECHNOLOGY CO., LTD.		
Model number .....:	P573AL-112 P573BL-112	P286BL-112	P573-111 P573B-111
Physical configuration.....:	Metal enclosure with plastic cover		
	Weight: ≤400kg	≤230kg	≤400kg
	Cells in series/parallel: 64 in series	32 in series	64 in series
Cooling method.....:	Liquid Cooling		
Separation between cells ....:	0.45 mm separation between cells by air		
Electrical rating .....:	Rated capacity: 280 Ah	280 Ah	280 Ah
	Nominal voltage: 204.8V	102.4V	204.8V
Standard charge method .....:	Charge current: 280 A	280 A	140A
	End of charge voltage: 233.6 V	116.8 V	233.6 V
	Cut of current: 14 A	14 A	14 A
Standard discharge method :	Discharge current: 280 A	280 A	140A
	End of discharge voltage: 172.8 V	86.4 V	172.8 V

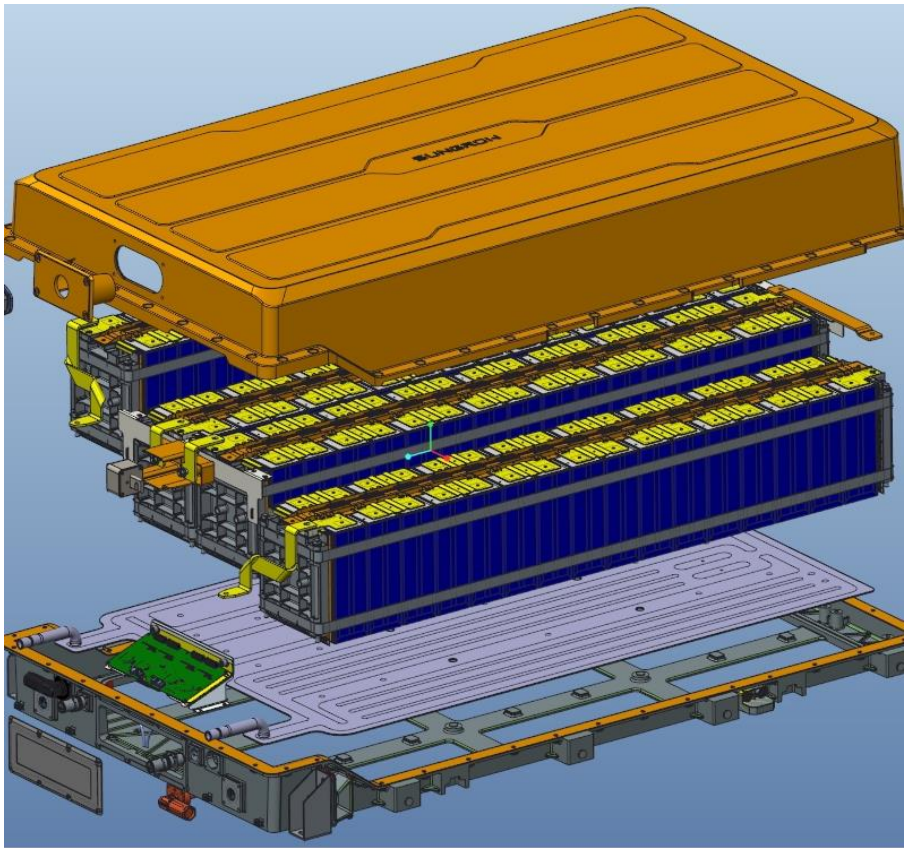
Compliance with UL 1973 ...:	Under certification, not finished

Manufacturer name.....:	SUNGROW ENERGY STORAGE TECHNOLOGY CO., LTD.	
Model number .....:	P537AL-112 P537BL-112	P537AL-111 P537BL-111
Physical configuration.....:	Metal enclosure with plastic cover	
	Weight: ≤384kg	≤384kg
	Cells in series/parallel: 60 in series	60 in series
Cooling method.....:	Liquid Cooling	
Separation between cells ....:	0.45 mm separation between cells by air	
Electrical rating .....:	Rated capacity: 280 Ah	280 Ah
	Nominal voltage: 192V	192V
Standard charge method.....:	Charge current: 280 A	140 A
	End of charge voltage: 219 V	219 V
	Cut of current: 14 A	14 A
Standard discharge method :	Discharge current: 280 A	140 A
	End of discharge voltage: 150 V	150V
Compliance with UL 1973 ...:	Under certification, not finished	

2.2.2 Diagram with overall dimension

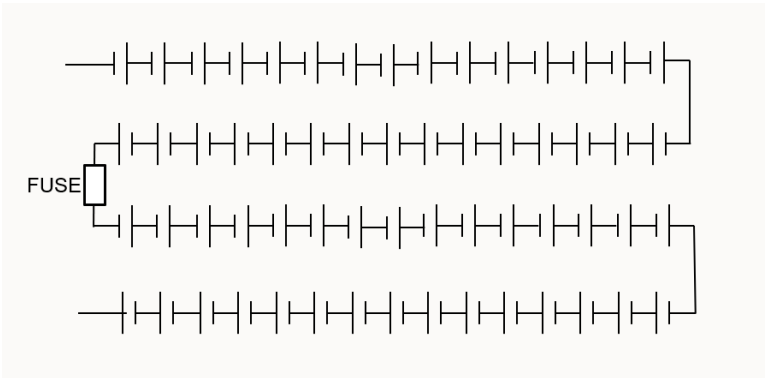


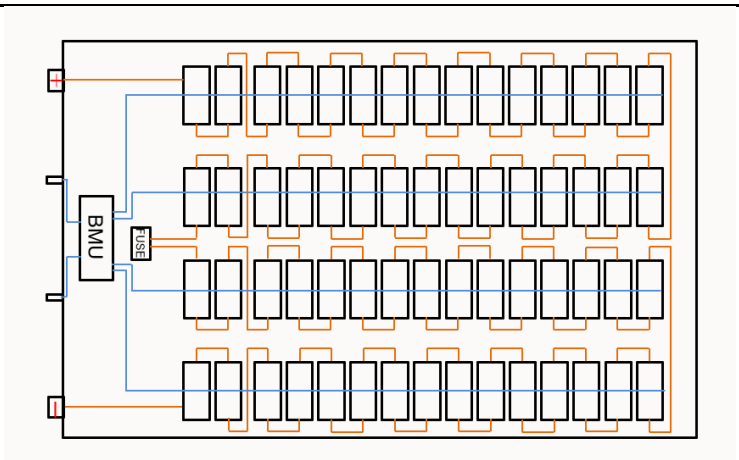
2.2.3 Layout of the module contents



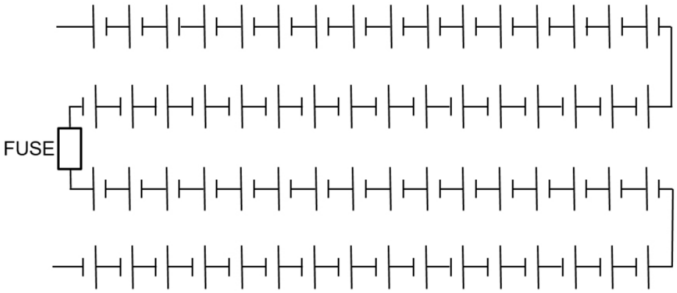
2.2.4 Configuration diagram of the module

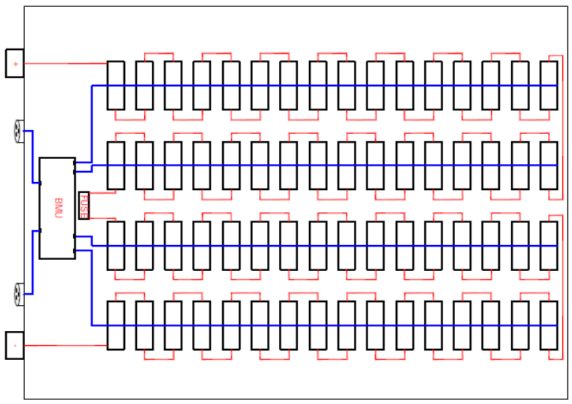
1P60S



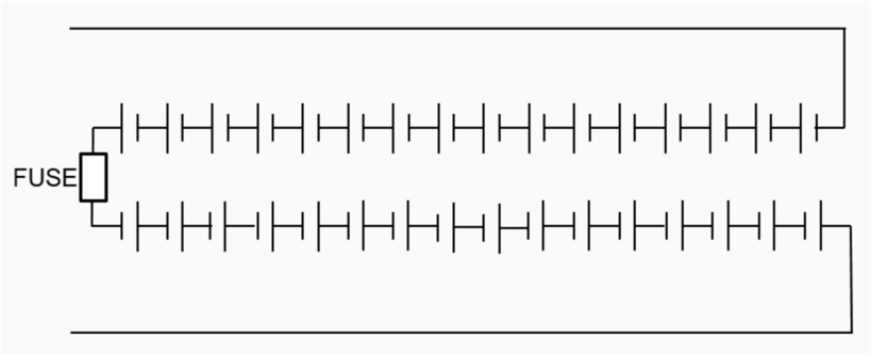


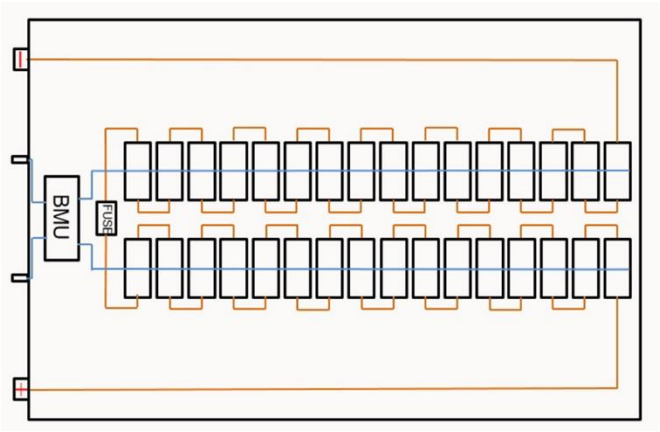
1P64S





1P32S





2.3 Battery system (rack)

2.3.1 Manufacture information and model list

	Battery system	Battery system	Battery system
Product	LFP Lithium Ion Energy Storage System	LFP Lithium Ion Energy Storage System	LFP Lithium Ion Energy Storage System
Type/model	R344-111	R287-111	R688-111
Cell Capacity [Ah]	280	280	280
Cell Quantity	384	320	768
Battery structure	(64S)6S	(64S)5S	((64S)6S)2P
Nominal voltage [V]	1228.8	1024	1228.8
Rated capacity [Wh]	344064	286720	688128
Upper limit charging voltage [V]	1401.6	1168	1401.6
Recommend charging current [A]	140	140	140
Maximum charging current [A]	140	140	140
Recommend discharging current [A]	140	140	140
Maximum discharging current [A]	140	140	140
Discharge cut-off voltage [V]	1036.8	864	1036.8
Temperature range for charging [°C]	0 to 50*	0 to 50*	0 to 50*
Temperature range for discharging [°C]	-30 to 50*	-30 to 50*	-30 to 50*
Temperature threshold for protection	50	-	50
Overcharge protected voltage supply by battery system	≥3.65V /Cell	-	≥3.65V /Cell
Recommend charging method by manufacturer	Charge at constant current 140A until the voltage reaches 1401.6V, then switch to constant voltage 1401.6V till charge current drops to 14A	Charge at constant current 140A until the voltage reaches 1168V, then switch to constant voltage 1168V till charge current drops to 14A	Charge at constant current 140A until the voltage reaches 1401.6V, then switch to constant voltage 1401.6V till charge current drops to 14A
Dimension [mm]	Rack: 3117±10mm(W)×1474±10 mm(D) ×520±10mm(H) DC/DC: 720±5mm(W)×788±5mm(D) ×294±5mm(H)	Rack: 3117±10mm(W)×1474±10 mm(D) ×520±10mm(H) DC/DC: 720±5mm(W)×788±5mm(D) ×294±5mm(H)	Rack: 3117±10mm(W)×1474±10 mm(D) ×1040±10mm(H) DC/DC: 720±5mm(W)×788±5mm(D) ×294±5mm(H)
Weight [kg]	Rack: ≤2400kg DC/DC: 75kg	Rack: ≤2000kg DC/DC: 75kg	Rack: ≤4800kg DC/DC: 75kg
Ingress Protection (IP)	IP65	IP65	IP65
Protective Class	I	I	I
Cooling type	Liquid cooling	Liquid cooling	Liquid cooling
Altitude	4000m	4000m	4000m

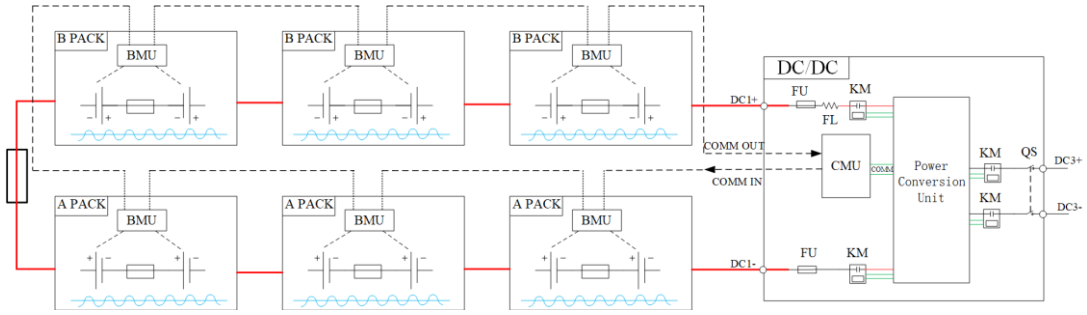
*: Constant Power 172kW and max charging and discharging current is 140A when ambient temperature is no more than 45°C, it will start derating when ambient temperature more than 45°C. The battery cell shall be heated first through the liquid cycle when discharging below -20°C.

	Battery system
Product	LFP Lithium Ion Energy Storage System
Type/model	R573-111
Cell Capacity [Ah]	280
Cell Quantity	640
Battery structure	((64S)5S)2P
Nominal voltage [V]	1024
Rated capacity [Wh]	573440
Upper limit charging voltage [V]	1168
Recommend charging current [A]	140
Maximum charging current [A]	140
Recommend discharging current [A]	140
Maximum discharging current [A]	140
Discharge cut-off voltage [V]	864
Temperature range for charging [°C]	0 to 50*
Temperature range for discharging [°C]	-30 to 50*
Temperature threshold for protection	50
Overcharge protected voltage supply by battery system	≥3.65V/Cell
Recommend charging method by manufacturer	Charge at constant current 140A until the voltage reaches 1168V, then switch to constant voltage 1168V till charge current drops to 14A
Dimension [mm]	Rack: 3117±10mm(W)×1474±10mm(D) ×1040±10mm(H) DC/DC: 720±5mm(W)×788±5mm(D) ×294±5mm(H)
Weight [kg]	Rack: ≤4000kg DC/DC: 75kg
Ingress Protection (IP)	IP65
Protective Class	I
Cooling type	Liquid cooling
Altitude	4000m

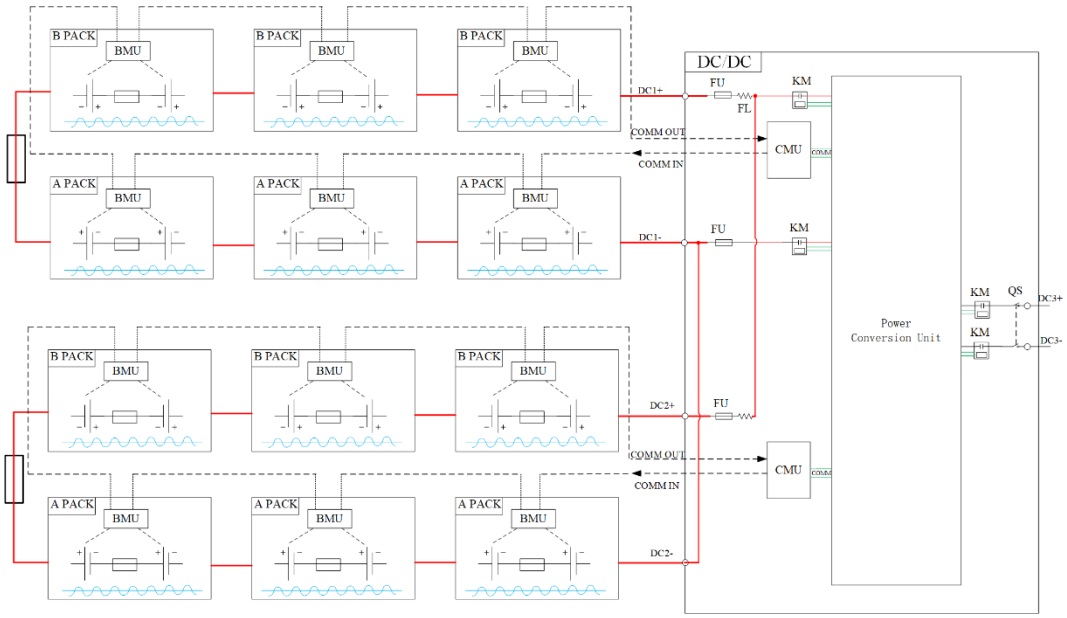
2.3.2 Product information

This product is used for Energy Storage System.
The EUTs covered by this report are 4 models of LFP lithium ion battery energy storage systems which include one DC-DC converter box and several battery packs in series(parallel) connection. The number of battery packs are 5, 6, 10,12 for model R287-111, R344-111, R573-111 and R688-111.

Block diagram for R344-111 is as below (R287-111 is the same except for one less pack) :



Block diagram for R688-111 is as below (R573-111 is the same except for two fewer packs) :

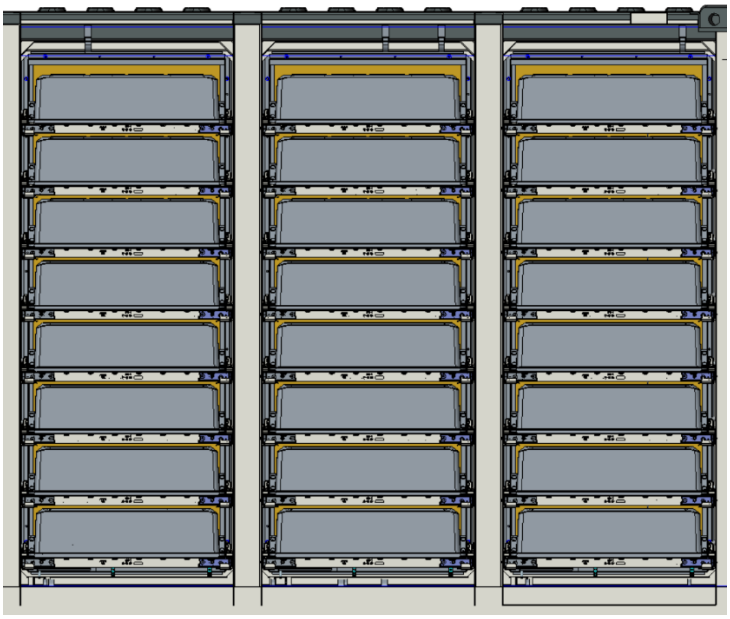


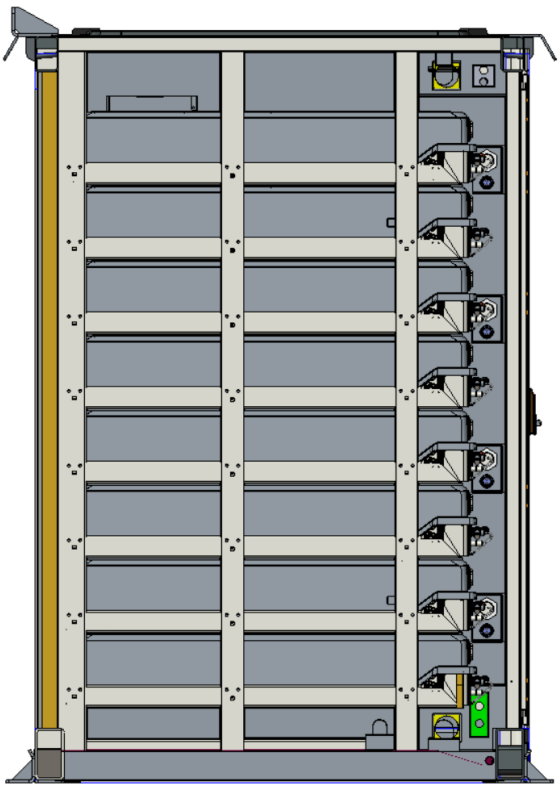
Each battery pack contains 64 cells in structure 64S. And it contains one BMU board for measuring and collecting the cell parameters and uploading the information of cell voltage and temperature to CMU in DC-DC converter box.
DC-DC box: Including CMU function and DC-DC converter which is certified with UL 1741.

The EUTs are indoor type. The insulation between the DC circuit and the metal enclosure is basic insulation. And the insulation between the DC circuit and communication ports is reinforced insulation or double insulation.
BMS functional safety was evaluated according to IEC 60730-1 Annex H by TÜV Rheinland.

Compliance with UL9540 ..... :	without
Compliance with UL1973 ..... :	Yes, (repot number: CN21XPKR 001)
Integrated fire protection system in the unit ..... :	No integrated fire protection system

Diagram with dimension of R688-111





2.4 Photo

Module

Battery Rack

3 Unit level test (section 8 of UL 9540A)

3.1 General

Unit level testing corresponds with the testing anticipated by fire codes and other codes impacting energy storage system installations to evaluate the large scale fire performance of BESS units installed in, on or adjacent to buildings or in other areas and their resultant performance to qualify for exceptions to limits in the codes imposed on these installations. The limitations where exceptions may be sought are limitations on the size of the individual BESS units, the total number of BESS units installed within a room, and the separation distances between BESS units and between BESS units and walls of the building.

In this test the initiating BESS unit is placed a set distance from target BESS units simulating BESS units identical to the initiating BESS unit, and from simulated walls representative on the installation. A thermal runaway is induced in cells, using the same approach as used in the module level testing within one of the modules in the initiating BESS, and a variety of measurements are taken. The results are intended to be used to verify that a fire within a single BESS unit will not spread to other units, nor breach the walls or the BESS enclosure (if provided), and there shall be no flying debris or explosive discharge of gases.

The test arrangement include the largest (energy) BESS unit for the installation to be represented by the test, and minimum spacing to adjacent walls and BESS units. The BESS may be tested with an internal fire suppression system provided by the manufacturer if that fire suppression system is required to be installed in the BESS. Optional internal fire suppression systems are not included in the unit level testing.

The test monitors the fire behavior of the BESS unit and measures heat release rates (convective and chemical); gas generation and composition; smoke release rate; maximum heat flux on the target BESS units, wall surfaces and within the accessible means of egress; maximum surface temperatures of the walls and modules within the target BESS units; and documents any explosions, deflagrations and flying debris from the BESS under test.

3.2 Unit sample preparation

The battery system is constructed with open rack without enclosure. One series of the rack with 6 complete modules was considered as a unit for purposes of the test.

All 6 module samples were conditioned together as a unit, through 3 charge/ discharge cycles per the manufacturer's instructions to verify that the module was functional.

The Charge/discharge was performed at 140A. Each cycle was defined as a charge to 100% SOC and allowed to rest 60 minutes and then discharged to an end of discharge voltage (EODV) determined by the module specification. Refer to section 2.2 for the end of the condition of charge and discharge.

Cycling was conducted on Sep 16, 2021 under ambient temperature 25°C ± 3°C and R.H. 70% ± 5%.

3.3 Setup of the test

3.3.1 Battery system installation information

The installation information was provided by the client as below.

Intended use location ..... :	☐ Residential	☒ Non-residential
	☐ Non-residential rooftop	
	☐ Non-residential open garage use	
Type of installation ..... :	☒ Indoor	☐ Outdoor
	☒ Floor/ground mounted	☐ Wall mounted
Row(s) of installation	☐ Single	☒ Multiple

3.3.2 Test site setup

Two instrumented walls with 3.8 m height and 3.55 m width form a right angle. Walls were constructed of 5/8 in gypsum painted flat black.

Three racks were used for the purpose of the test. As specified by the manufacture, the two target racks will be installed up and down of the initial unit. All racks were positioned facing instrumented wall A. See Figure 1 and 2 and photos on page 47.

The initiating unit (unit A) was positioned at the middle, adjacent to the two instrumented wall sections.

The minimum separation distance from the rack to wall and between racks were defined by the client. Subject to the actual conditions of the testing environment, there was 1cm tolerance in the actual setup.

Figure 1 was the test site setup diagram with separation distance.

The test side setup was located under the smoke collection hood of the calorimeter measurement system.

Figure 1. Test site setup diagram with separation distance. (Top view)

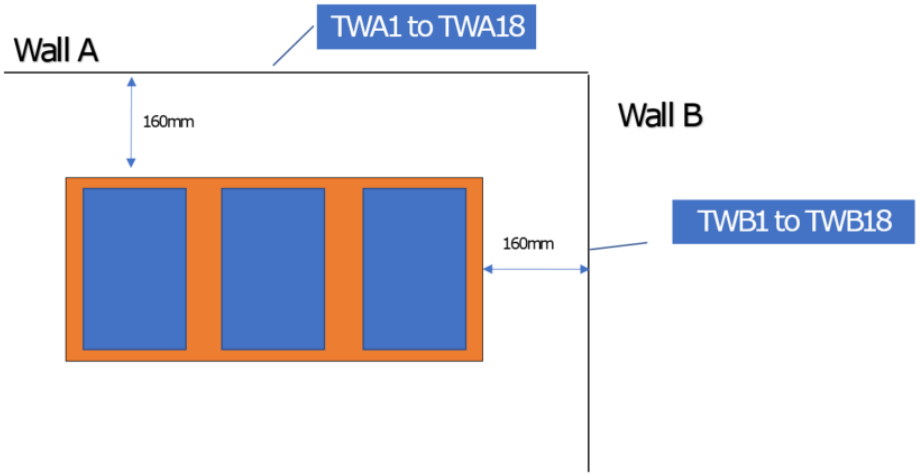
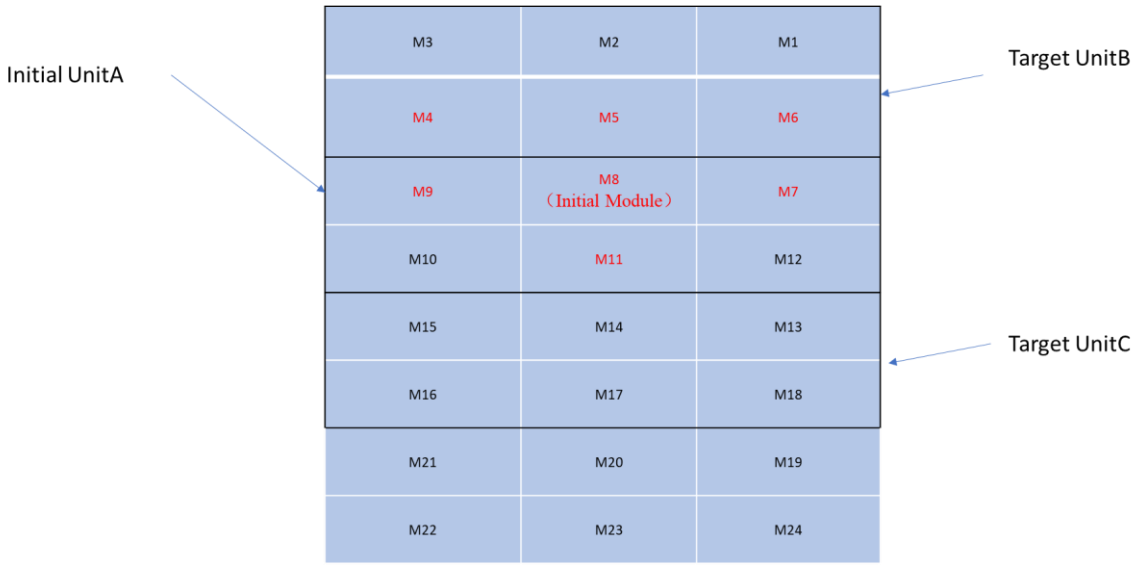


Figure 2. Test site setup diagram with separation distance. (Front view)



For the purpose of this test, the modules were numbered according to the electrical continuity.

In Initial Unit A, modules numbers from M7 to M12.

In Target Unit B, modules numbers from M1 to M6 which was the target unit situated above the Initial Unit A.

In Target Unit C, modules numbers from M13 to M18 which was the target unit situated below the Initial Unit A.

See Figure 3.

4 complete modules were used for unit A (M7 to M9 and M11).

3 complete modules were used for unit B (M4 to M6) to check the possible propagation form unit to unit.

Empty modules without cells were used for the other modules.

Figure 3. Module numbering in units showing fully populated modules in red.

M3	M2	M1
M4	M5	M6
M9	M8 （Initial Module）	M7
M10	M11	M12
M15	M14	M13
M16	M17	M18
M21	M20	M19
M22	M23	M24

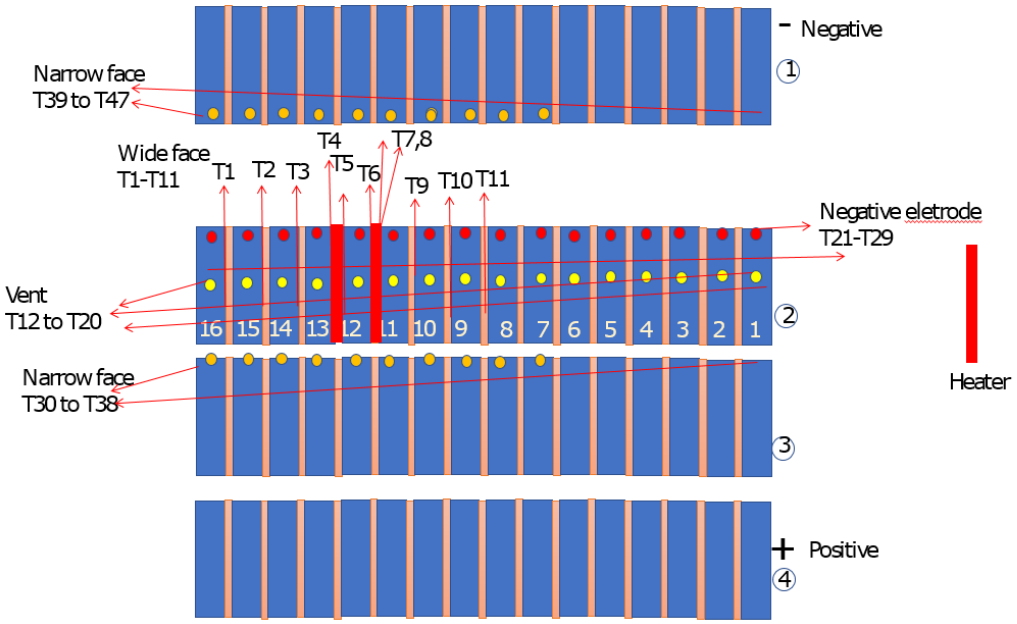
3.3.3 Thermal runaway setup

External heating method, agreed with the client, was used to initiate the thermal runaway within the module.

Module M8 was prepared with two heaters inside. Same as the method in module level test.

Cells inside the module were numbered from 1 to 16 as Figure 3.

Figure 3. Cell numbering inside the initiating module



Consider the unit level installation and airflow of the liquid cooling in the module. #11, #12 and #13 cell located in the back of the module were chosen as target cell to be forced into thermal runaway.

The cell #12 was heated by two external heater on each wide side, the cell #11 and cell#13 was heated by one external heater on wide near cell #12. The heater is rated 220VAC/500 W (size 207*174*4mm).

11 glass fiber thermocouples Type K, 24 AWG were attached to the center of the wide surface of #1 to #16 cells. 20 glass fiber thermocouples Type K, 24 AWG were attached on the center of narrow surface of opposite cells near #7 to #16 cells.

The initiating module M8, internal voltage sample wire and signal wire covered by glass fiber tube. The BMS control board was disabled during the test.

A PID controller was used to control the voltage supply to the heater and maintain a 5.5°C/min heating rate. When heater temperature reached to 180°C (T-set), hold about 60min (10:10 to 11:10), then continue to heat and maintain a 4°C/min to 7°C/min heating rate.

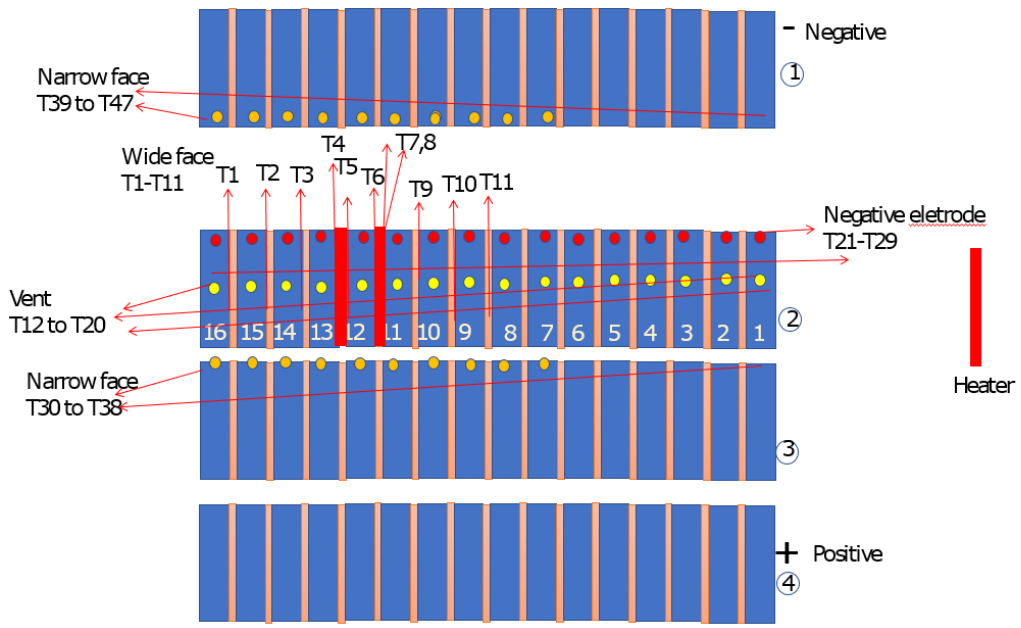
Once thermal runaway was observed, the heaters were immediately de-energized.

Four thermocouples(located below the heater at the wide surface center of #11,#12,#13 cell and two thermocouples located below the heater at the wide surface center of #4 cell were used to feedback the temperature to the controller.

6 glass fibers insulated thermocouples on the center of the wide surface of #14 to #16, #8-#10 cell s to check the possible propagation from cell to cell.

Voltage of the module are monitored during the test.

Figure 5: Thermocouples on module M8



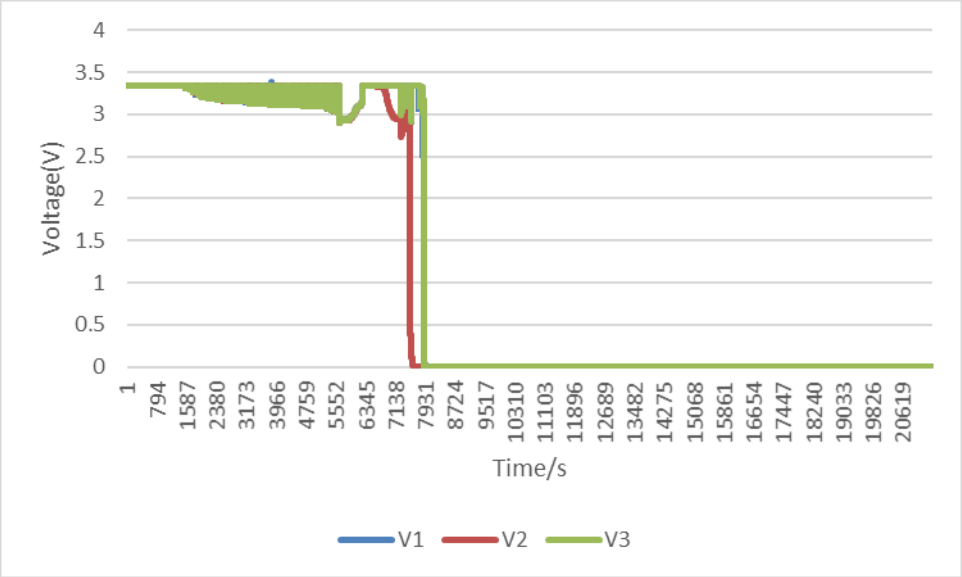
3.4 Observations and records

Before the test, the initiating module was 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.

The ambient condition at the initiation of the test was 25°C, 66% RH.

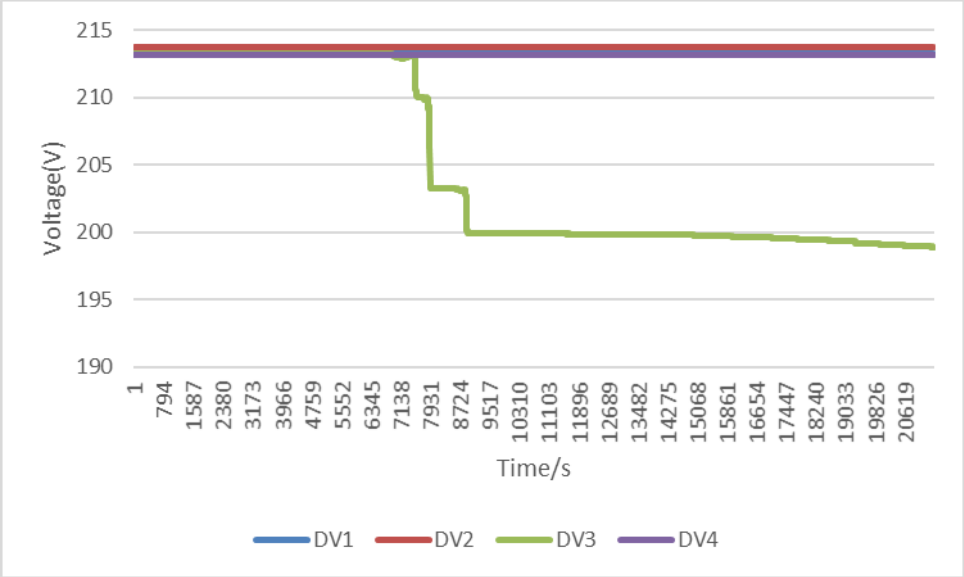
The voltage of the modules was recorded as below:

Figure 6: Voltage record of cells during the test



V1: Cell voltage of #13
V2: Cell voltage of #12
V2: Cell voltage of #11

Figure 7: Voltage record of Modules during the test



DV1: Module voltage of #4
DV2: Module voltage of #5
DV3: Module voltage of #6
DV4: Module voltage of #8

Tests were performed on Sep 16, 2021, started at 09:40 AM.

Observations during the test:

Audible pop was heard on 11:14 AM (the pressure relief valve burst), followed by smoke release after several seconds.

A large amount of white smoke was observed after thermal runaway.

Cell to cell propagation was observed in the initial model.

Module to module propagation was not observed.

No flying debris or explosive discharge of gases observed during test.

No sparks, electrical arcs, or other electrical events observed during test.

No external flaming was observed during the test.

Observations after the test:

Leakage outside the initiating module enclosure was observed. See photos in page 46~54.

No damage and contamination on the instrument walls.

No damage and contamination on the modules of target units.

The plastic top enclosure near the initial cell of module M8 was melted and significantly damaged. Module voltage of M8 was 198.6 Vdc.

Four cells inside the initial module M5 was damaged. Cell to cell propagation was observed on cell #14 after receiving thermal energy from cell #13. Voltage measured on each remaining undamaged in other sub-modules were 3.33Vdc.

Weight loss of the initiating module was 1.7 kg (before test 401.5kg, after test 399.8kg)

See photos in page 53.

3.5 Temperature measurements

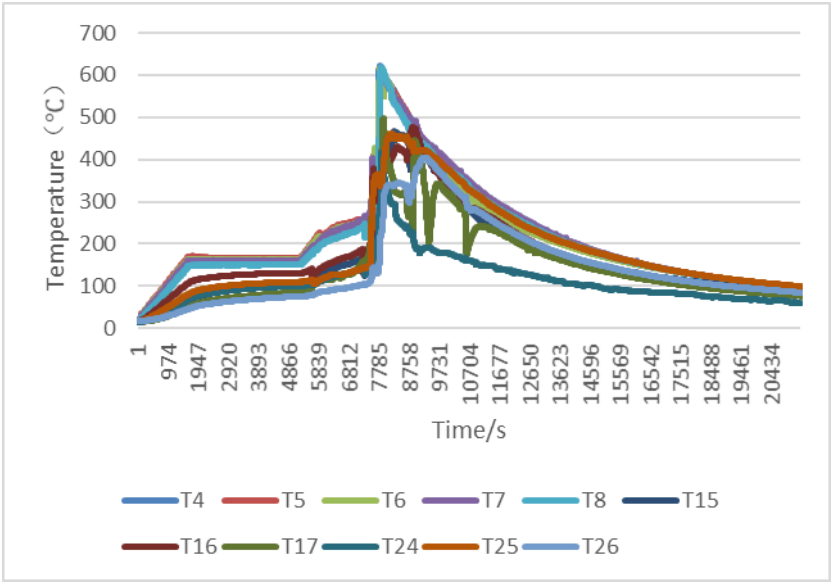
3.5.1 Temperature measurement of initiating cells

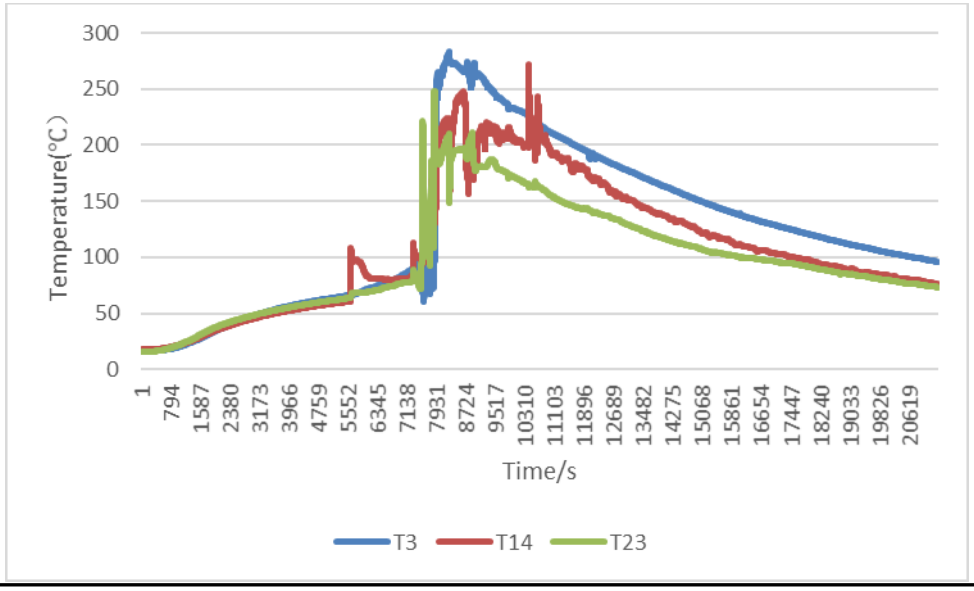
Surface temperature of cells #8 - #16 was recorded during the test. Cell to cell propagation occured during the test. See Figure 6 for the temperature vs time curve.

Cell thermal runaway occurred on cell #12, #13, #11 in turn at around 11:46, 11:50, 11:52 Maximum temperature 617.4°C, 623.7°C,619.5°C were measured on the cell #12, #13, #11 surface.

Cell to cell thermal runaway propagation occurred on cell #14. Maximum temperature 283.8°C was measured on the cell #14 surface.

Figure 8. Surface temperatures of thermal runaway cells on module M8





Cell in other sub-module did not go to thermal runaway, maximum temperature 108.2°C, 131.7°C, 553.8°C, 353.5°C, 646.6°C, 566.6°C, 133.7°C, 142.7°C, 163.7°C were measured on narrow surface center of cell near cells #8 - #16 in sub-modules 1 and 3.

Figure 9. Surface temperatures of no thermal runaway cells on sub-module 3 of module M8

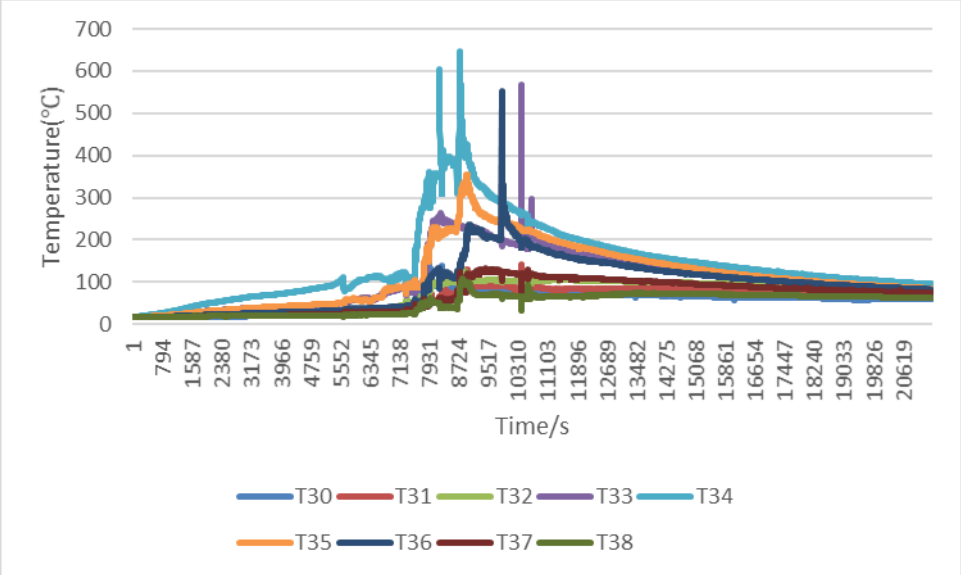
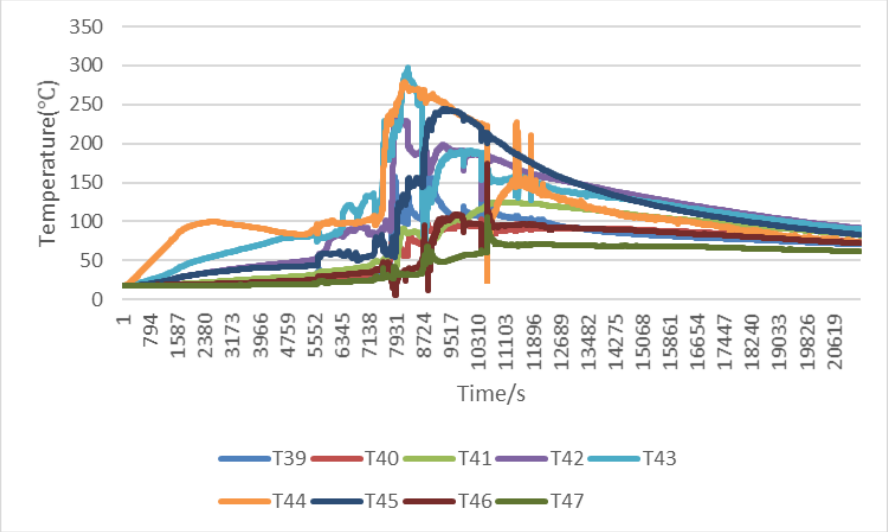


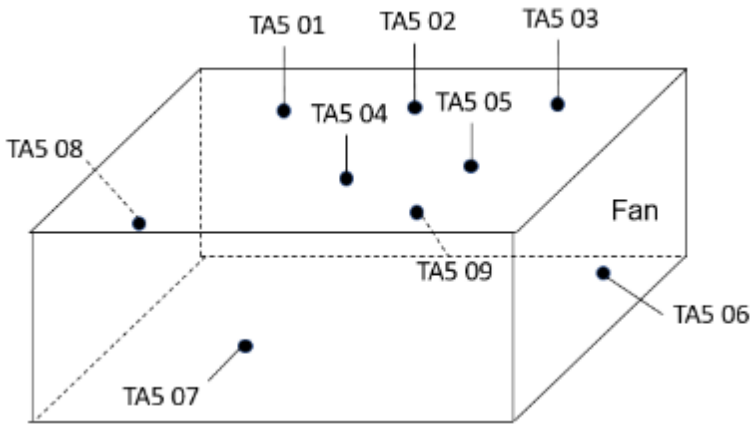
Figure 10. Surface temperatures of no thermal runaway cells on sub-module 1 of module M8



3.5.2 Temperature measurement of units

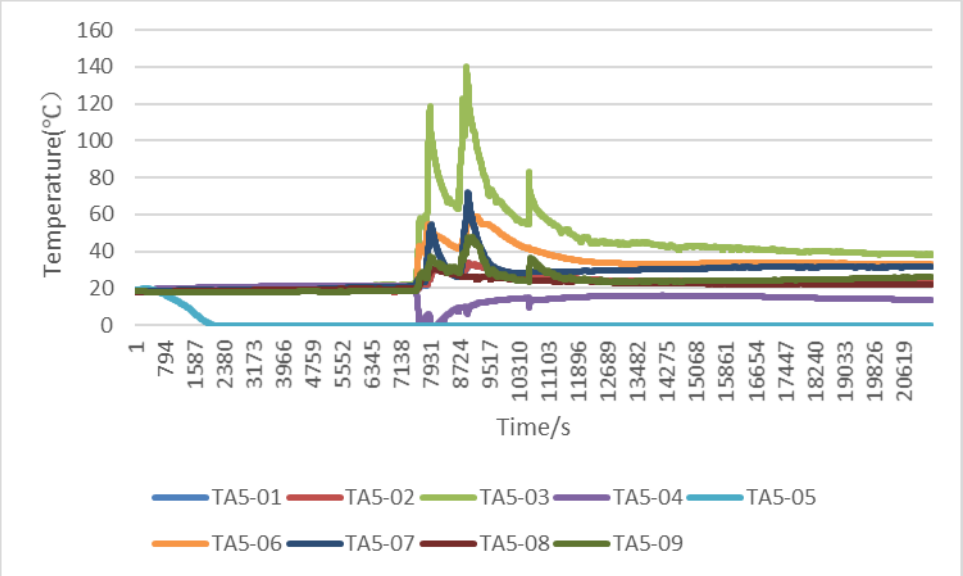
9 glass fiber insulated thermocouples (TA5 01~TA5 09), Type K, 24 AWG were attached to the external surface of module M8, as below Figure 11.

Figure 11. thermocouple of module M5 surface



TA5 01~TA5 03 were located on the top surface above cell in sub-module2. TA5 04, TA5 05 were located on the top surface above cell in sub-module3. TA5 06 was located in front of module, TA5 07 was located on the left side surface, TA5 08 located on the rear side, TA5 02 was located on the right side surface. Maximum temperature 407.3°C was measured on top of the module near #4 cell.

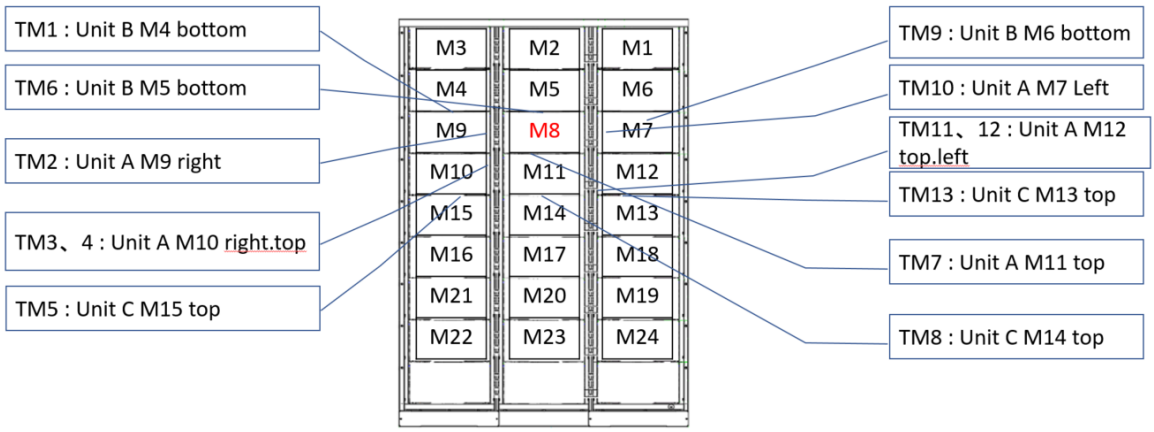
Figure 12. Surface temperatures of initiating module M8



13 glass fiber insulated thermocouples (TM1 to TM13), Type K, 24 AWG were attached to the center of the top surface of modules M4 to M15.

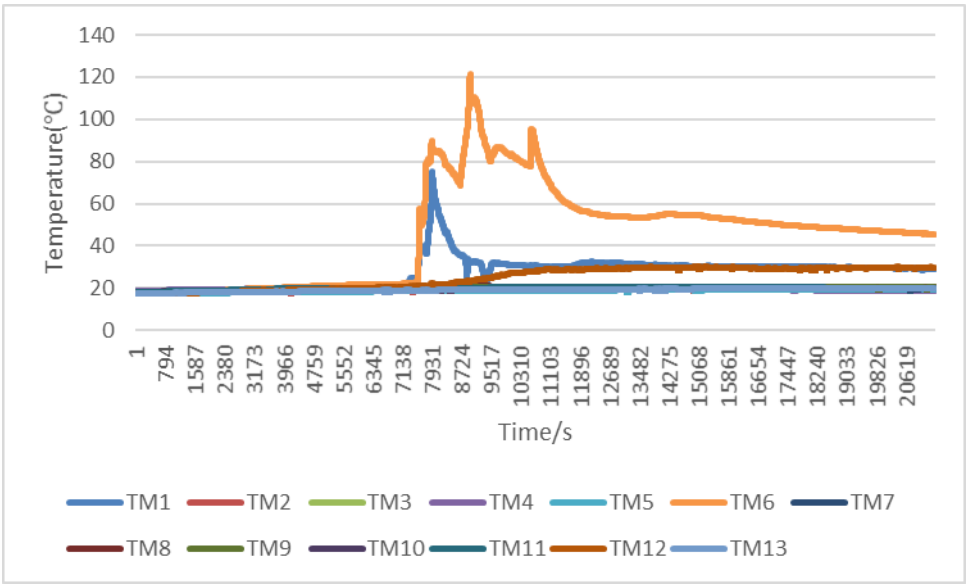
Maximum temperature 121.5°C was measured on bottom of the module M5.

Figure 13. Thermocouple location on modules in units A,B,C (Rack 1)



View direction: towards instrument wall A with reference to Figure 2

Figure 14. Surface temperatures of modules from M4 to M15

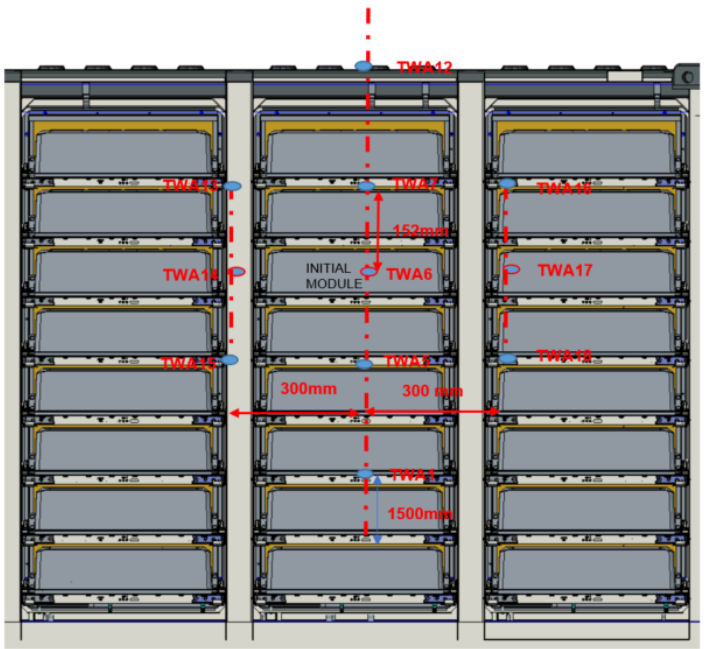


Maximum temperature 121.4°C was measured on side surface of the module M5 of Unit B.

Maximum temperature 21.2°C was measured on rear surface of the module M14 of Unit C.

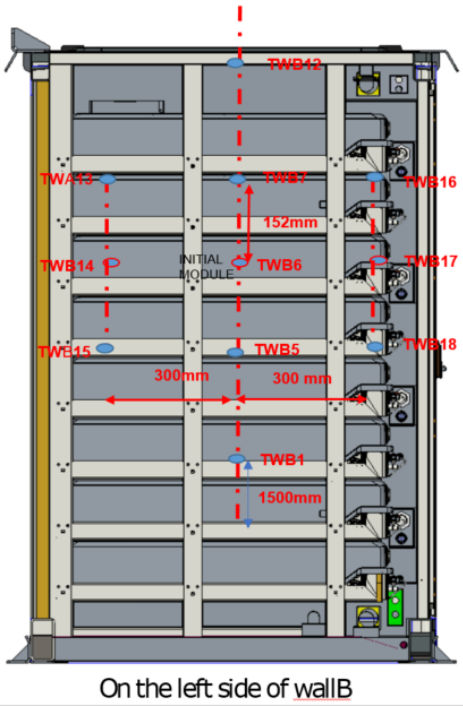
Figure 15. Thermocouple location on the back side of Wall A

View direction: from instrument wall A with reference to Figure 2



On the back side of wallA

Figure 16. Thermocouple location on the left side of wall B



On the left side of wallB

View direction: towards instrument wall B with reference to Figure 2

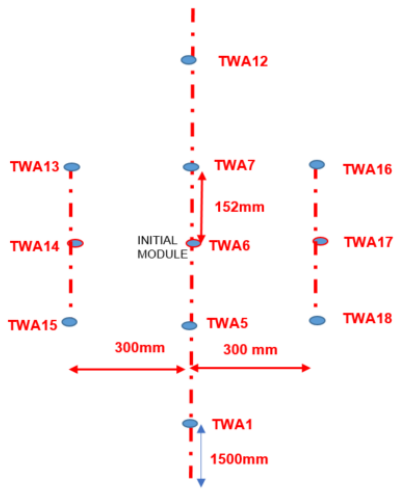
3.5.3 Temperature measurement of instrumented walls

Wall surface temperatures were measured in vertical arrays at 152 mm intervals for the full height of the instrumented wall sections using Type K, 30 AWG thermocouple. The thermocouple arrays were collinear with the centre line of Initial Unit A. The red line in Figure 12 shows the thermocouple arrays on the wall.

The first thermocouple starts from 1500 mm from ground. Total 36 thermocouples were used for each array. The thermocouples were numbered from low to high as TWA1 to TWA18 for wall A and TWB1 to TWB18 for wall B.

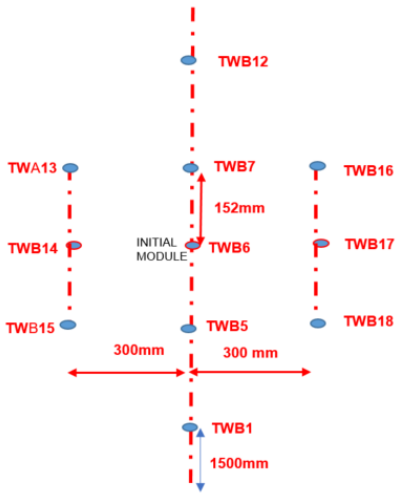
Figure 17. Vertical position of the thermocouples on the wall

Instrumented wall A



View direction: towards instrument wall A with reference to Figure 2

Instrumented wall B



View direction: towards instrument wall B with reference to Figure 2

Additional 6 thermocouples were positioned horizontally near the initial module M8 300 mm away from the vertical array each side, on instrumented wall A and wall B. See Figure 18.

Maximum temperature measured on instrument wall A was 21.4°C at TWA13, temperature curve see figure 18 for detail.

Maximum temperature measured on instrument wall B was 24.6°C at TWB10, temperature curve see figure 19 for detail.

Figure 18. Horizontal position of the thermocouples on the wall A and wall B

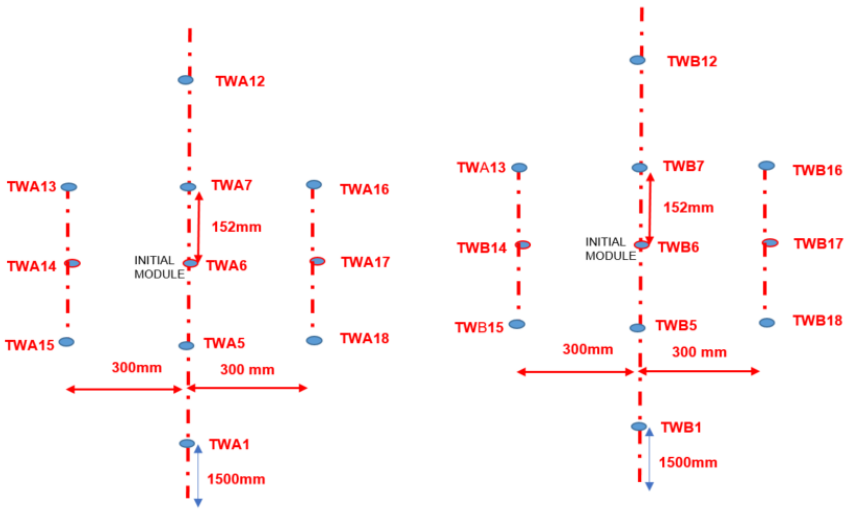


Figure 19. Temperatures on instrument wall A.

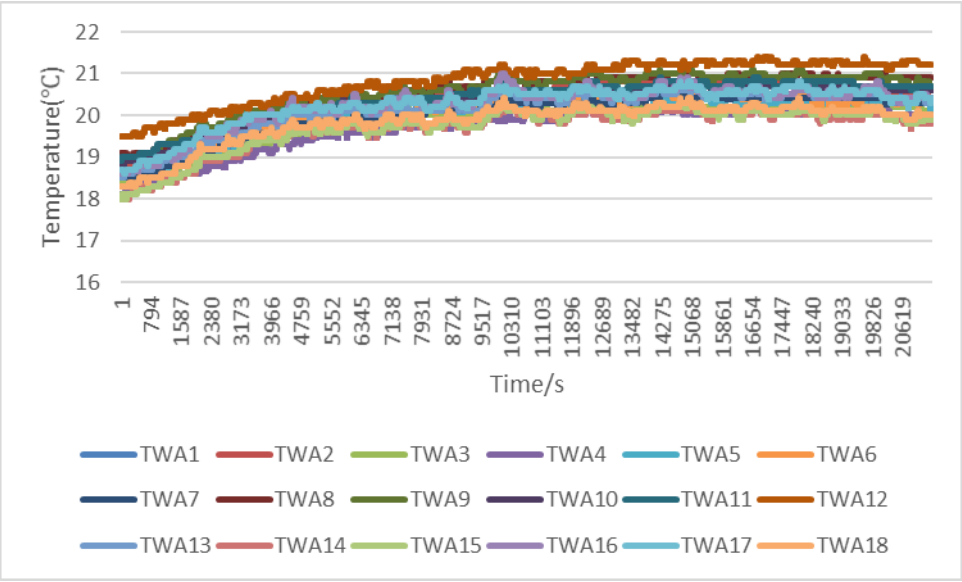
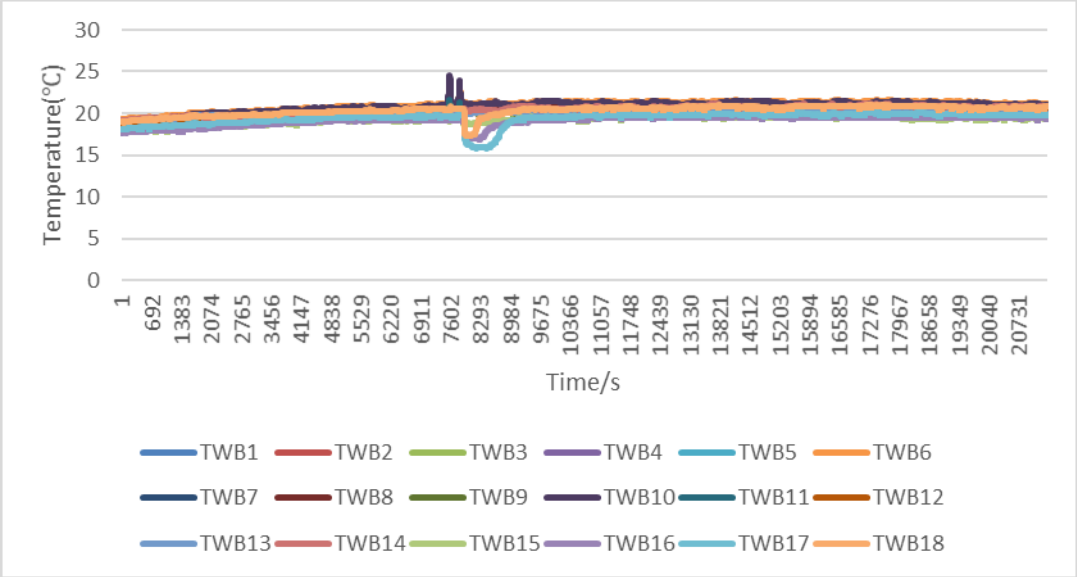


Figure 20. Temperatures on instrument wall B.



3.6 Heat flux measurement

Two sensors were placed on the surface of instrumented wall A, wall B and adjacent unit A that faces the initiating unit.

The sensors were collinear with the vertical thermocouple array. One was positioned at the height equivalent to module M8 top edge, which was estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating unit. Another was positioned at the height equivalent to module M11 top edge, which was estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating unit.

Figure 21 shows the positions of the sensors. Sensor H1 & H2 were positioned at unit A; All sensors were numbered from low to high.

Figure 21. Heat flux sensor locations on unit

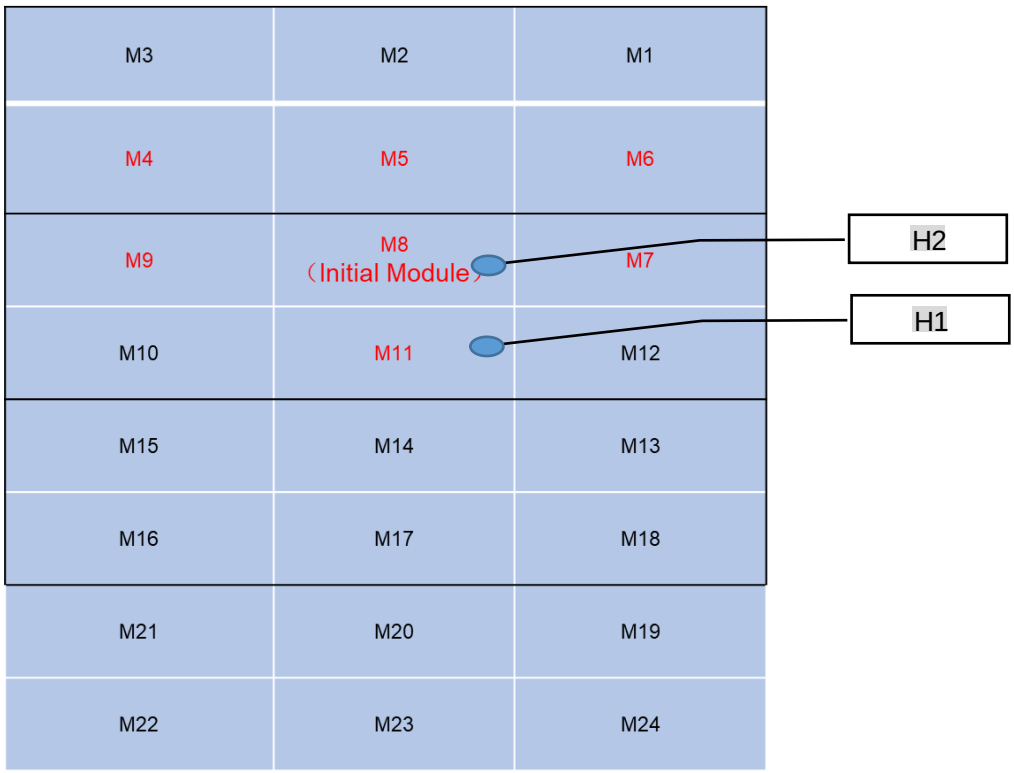
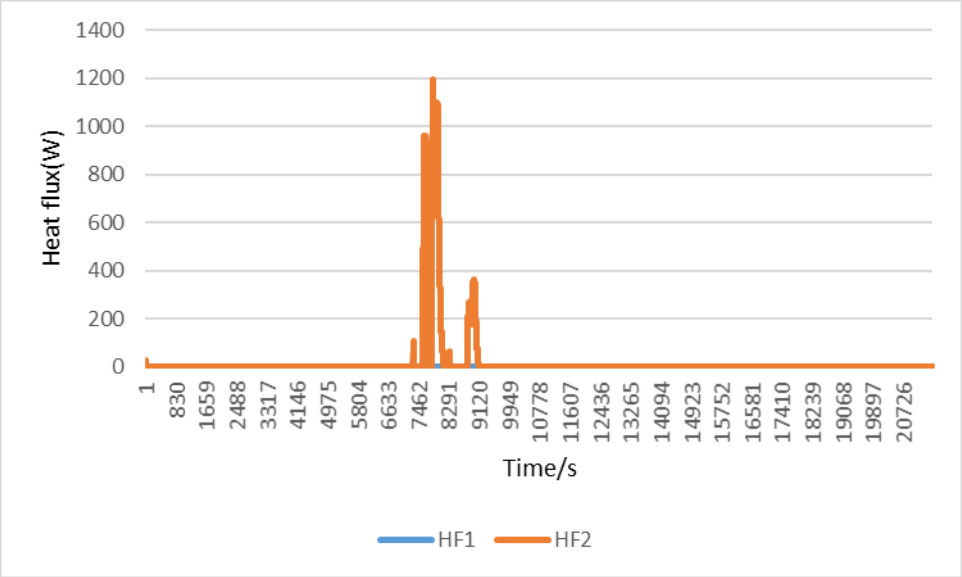


Figure 22. Measured heat flux of target wall and target units



3.7 Chemical heat release rate measurement

The chemical heat release rates were measured by an oxygen consumption calorimeter measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple.

The instrumentations are located in the exhaust duct of the heat release rate calorimeter.

The chemical heat release rate was calculated at each of the flows as follows:

$$HRR_1 = \left[E \times \varphi - (E_{co} - E) \times \frac{1-\varphi}{2} \times \frac{X_{co}}{X_{O_2}}\right] \times \frac{\dot{m}_e}{1+\varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^o_{H_2O}) \times X^o_{O_2}$$

In which:

HRR_t = total heat release rate, as a function of time (kW)

E = Net heat released for complete combustion per unit of oxygen consumed (adjusted for oxygen contained within cell chemistry, 13,100 kJ/kg)

E_{CO} = Net heat released for complete combustion per unit of oxygen consumed, for CO (adjusted for oxygen contained within cell chemistry, 17,600 kJ/kg)

φ = Oxygen depletion factor (non-dimensional), where:

$$\varphi = \frac{X^o_{O_2} \times [1 - X_{CO_2} - X_{CO}] - X_{O_2} \times [1 - X^o_{CO_2}]}{X^o_{O_2} \times [1 - X_{O_2} - X_{CO_2} - X_{CO}]}$$

X_{CO} = Measured mole fraction of CO in exhaust flow (non-dimensional)

X_{CO_2} Measured mole fraction of CO_2 in exhaust flow (non-dimensional)

$X°_{CO_2}$ = Measured mole fraction of CO_2 in incoming air (non-dimensional)

$X°_{H_2O}$ = Measured mole fraction of H_2O in incoming air (non-dimensional)

X_{O_2} = Measured mole fraction of O_2 in exhaust flow (non-dimensional)

$X°_{O_2}$ = Measured mole fraction of O_2 in incoming air (non-dimensional)

α = Combustion expansion factor (non-dimensional; normally a value of 1.105)

M_a = Molecular weight of incoming and exhaust air (29 kg/kmol)

M_{O_2} = Molecular weight of oxygen (32 kg/kmol)

$\dot{m}_e$ = Mass flow rate in exhaust duct (kg/s), in which:

$$\dot{m}_e = C \times \sqrt{\frac{\Delta p}{T_e}}$$

or

$$\dot{m}_e = 26.54 \times \frac{A \times k_c}{f(\mathrm{Re})} \times \sqrt{\frac{\Delta p}{T_e}}$$

C = Orifice plate coefficient (in $kg^{1/2}m^{1/2}K^{1/2}$)

Δp = Pressure drop across orifice plate or bidirectional probe (Pa)

T_e = Combustion gas temperature at orifice plate or bidirectional probe (K)

A = Cross sectional area of the duct (m^2)

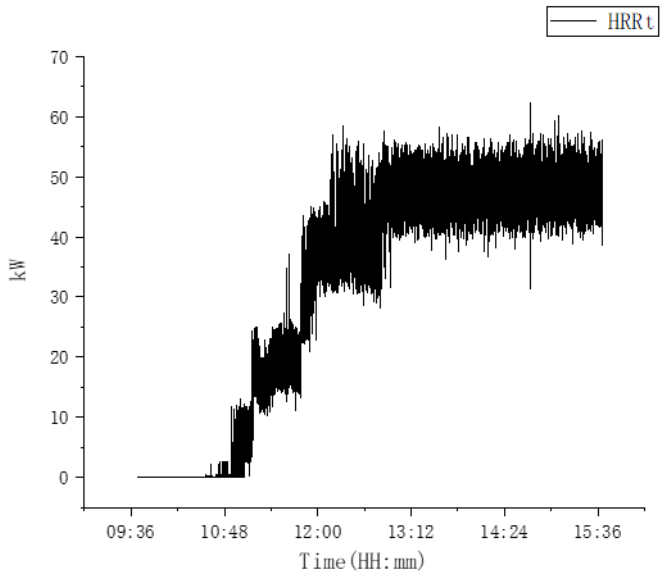
k_c = Velocity profile shape factor (non-dimensional)

$f(Re)$ = Reynolds number correction (non-dimensional)

The heat release rate measurement system was calibrated at 50kW and 70kW heat release rate using a standard propane burner before the test. The calibrations were performed using flows of 1078mg/s and 1510mg/s of propane.

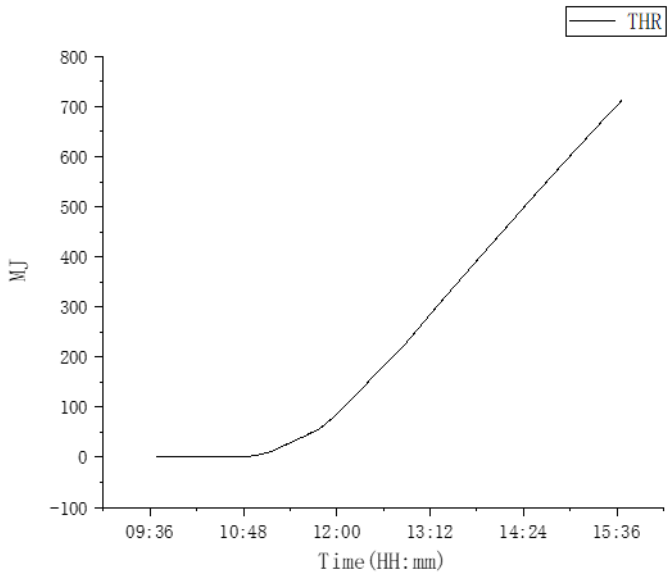
Measured peak chemical heat release rate HRR_t was 62.37kW

Figure 23. HRRt curve



Measured total heat release THR through the test was 712.474 MJ

Figure 24. THR curve



3.8 Convective heat release rate measurement

The convective heat release rate was measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct.

The convective heat release rate was calculated at each of the flows as follows:

$$HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$$

Where:

HRR_c = *The convective heat release rate (kW)*

V_e = *The exhaust velocity (m/s)*

A = *The exhaust duct cross sectional area (m^2)*

T_e = *The temperature at the location where exhaust velocity is measured (K)*

$353.22/T_e$ = *The density of air at the velocity measurement location (kg/m^3)*

T_o = *The ambient temperature (K) in the test room*

T = *The thermopile temperature (K)*

$$\int_{T_o}^{T} C_p dT = A_0(T - T_o) + A_1 / 2(T^2 - T_o^2) + A_2 / 3(T^3 - T_o^3) + A_3 / 4(T^4 - T_o^4)$$

Cp = Specific heat of air (kJ/kg-K), given as $\boldsymbol{C_p = A_0 + A_1 T + A_2 T^2 + A_3 T^3}$, where:

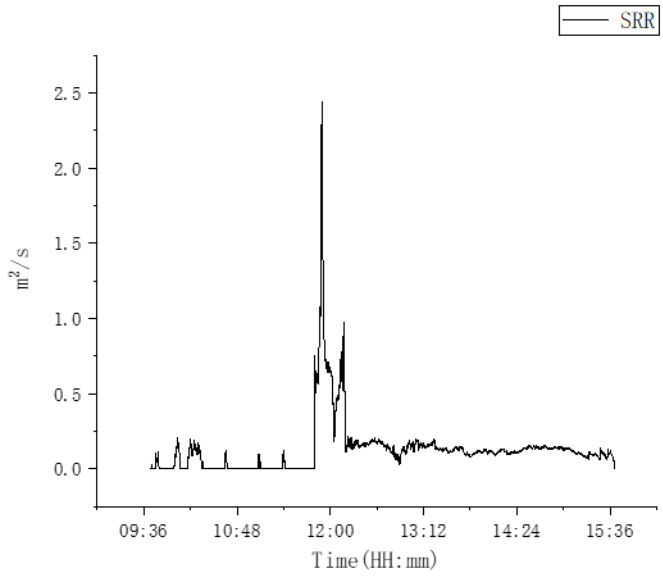
A_0 = *0.9950*

A_1 = *-5.29933E-05*

A_2 = *3.21022E-07*

A_3 = *-1.22004E-10*

Figure 25. Peak smoke release rate SRR: 22.5863 m2/s



3.9 Gas generation measurement

The composition, velocity and temperature of the vent gases were measured within the calorimeter's exhaust duct.

Gas compositions were measured using a Fourier-Transform Infrared Spectrometer with a resolution of 1 cm^{-1} and a path length of 4.2 m within the calorimeter's exhaust duct.

The total hydrocarbon content of the vent gas was measured using flame ionization detection.

Hydrogen gas was measured with electrochemical method.

Composition, velocity and temperature measurement instrumentation were collocated with heat release rate calorimetry instrumentation.

3.10.1 Total gas release

The flow rates of various gases were integrated over the test duration and the total cumulative volume of gas calculated for the total test duration (09:05 ~ 16:20) was presented in the below table.

The total cumulative volume of gases before cell venting (09:05 ~ 10:06) was also presented in the table for reference. Which may be considered as ambient gases background before the test.

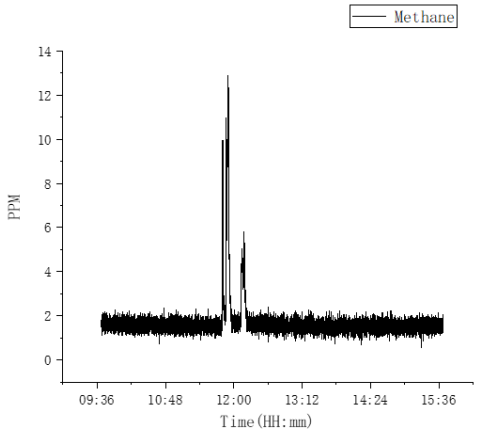
Gas type	Gas components		Total volume of gas (L)	
			Before cell venting	Throughout the test
Hydrocarbon species	Methane	CH_4	0.5	26.1
	Ethylene	C_2H_4	0.7	15.2
	Ethane	C_2H_6	0.2	6.5
	Propane	C_3H_8	0.1	36.3
	Propylene	C_3H_6	0	69.1
Hydrogen halide species	Hydrogen Fluoride	HF	0	12.2
Nitrogen containing species	Nitrous Oxide	NO	0.2	6.8
Others	Carbon Monoxide	CO	0	60.1
	Carbon Dioxide	CO_2	20670.4	54337.6
	Hydrogen	H_2	0	164.8
	Dimethyl carbonate(DMC)	$C_3H_6O_3$	0.3	177.2
	Ethylmethyl carbonate	$C_4H_8O_3$	0.1	30.7
	Oil as octane		0	5.9
Total Hydrocarbons				262.3

Note:
1) The collection time is from 09:40 to 16:20;
2) The carbon dioxide in the air during this period1) was also counted;
3) Total hydrocarbon gas volume was measured by flame ionization detection (FID);
4) Total volume of carbon monoxide (CO) and carbon dioxide (CO2) was measured using nondispersive infrared spectroscopy (NDIR);
5) The volume of hydrogen (H2) was measured using electrochemical with MODEL5000 sensor.

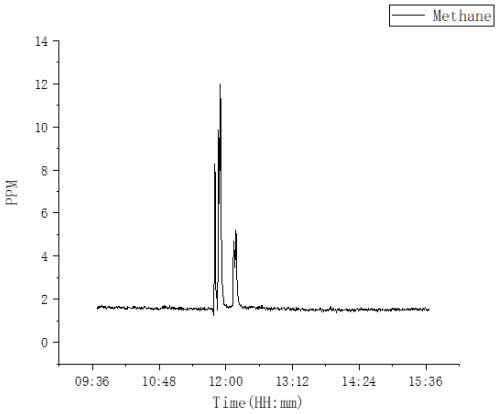
3.10.2 Gas components

Concentrations of the gases were scaled based on the measured flow rate of the exhaust system and were presented in the standard volume flow rate of gas ventilated in below figures.

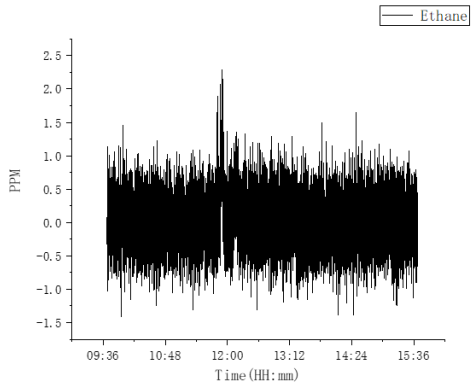
Figure 26. Hydrocarbon species



Raw original data



Savitzky-Golay filtered data



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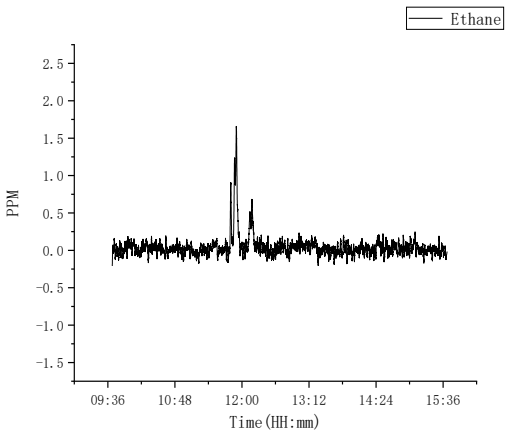

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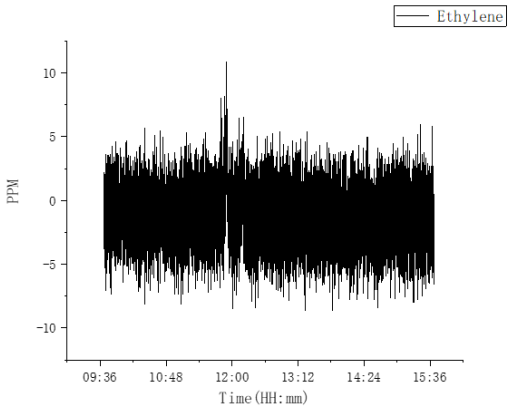

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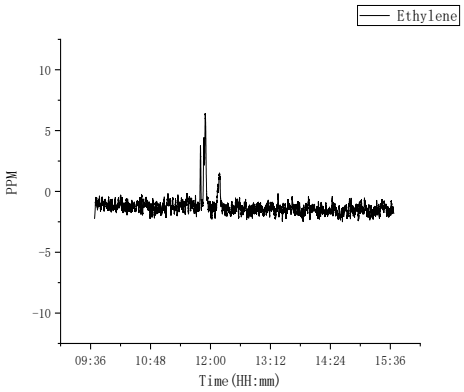

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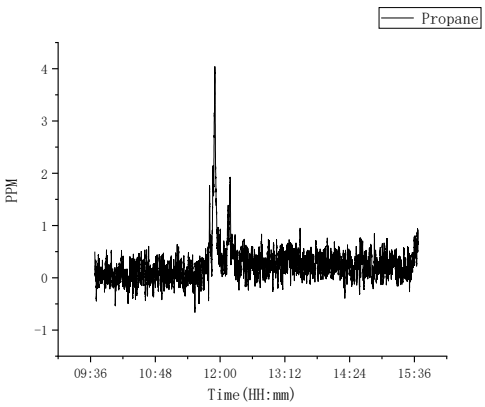

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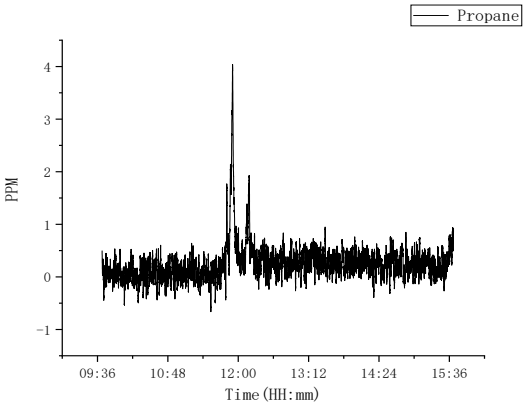
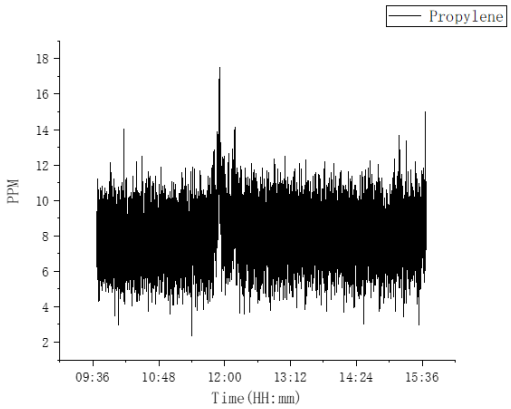


Savitzky-Golay filtered data



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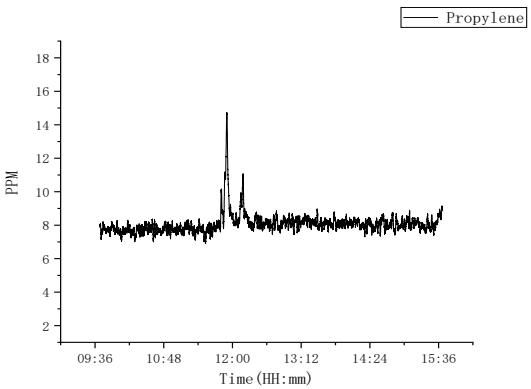
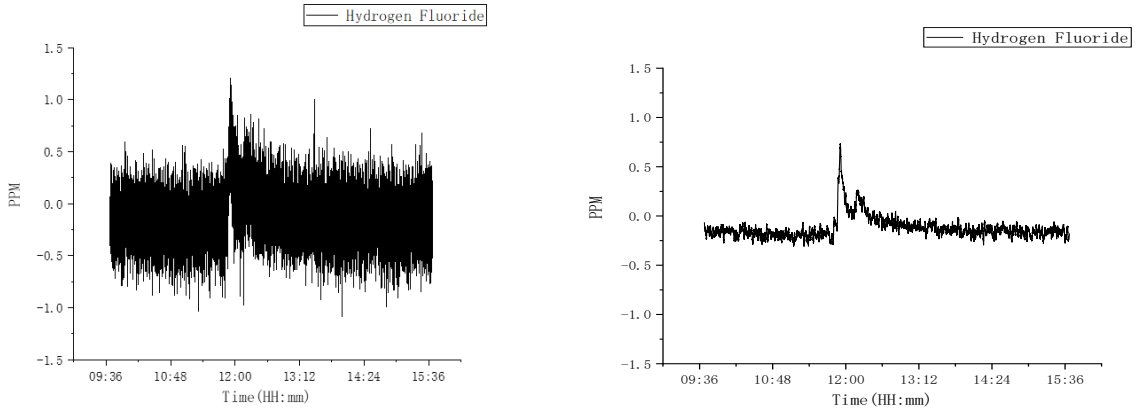


Savitzky-Golay filtered data

Figure 27. Hydrogen halide species



Raw original data

Savitzky-Golay filtered data

Figure 28. Nitrogen containing species

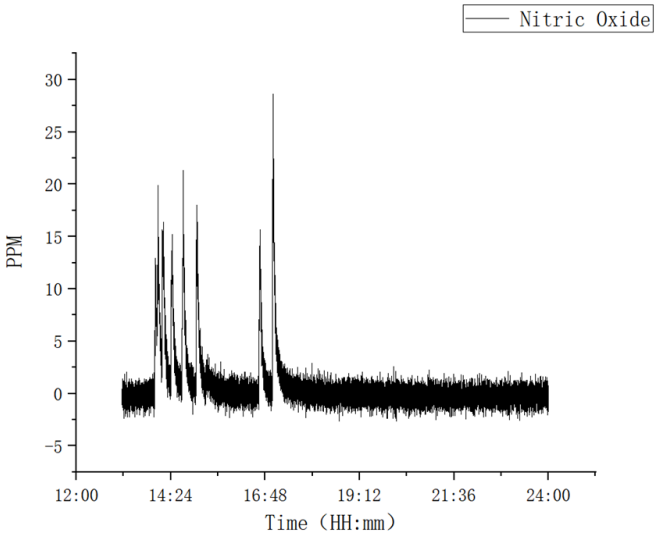


Figure 29. H_2 containing species

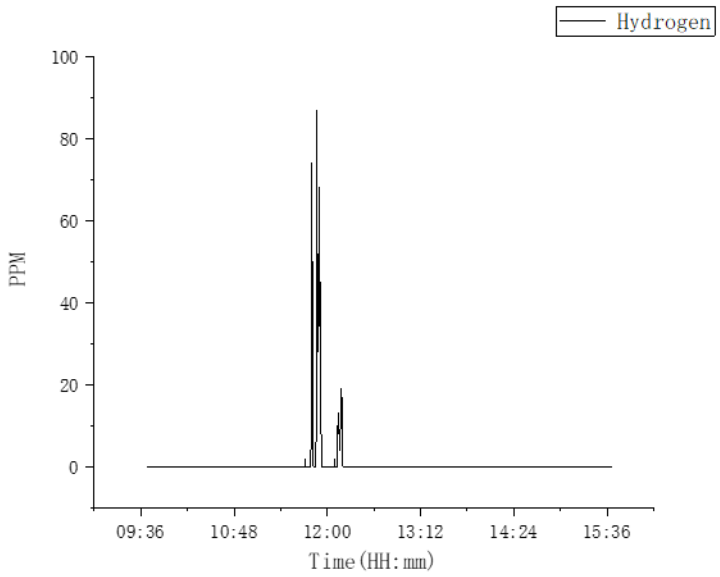
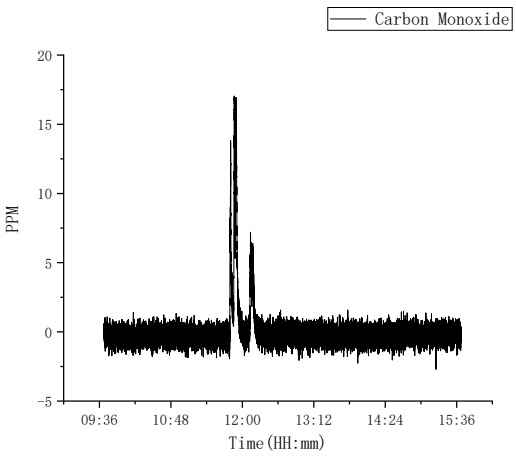


Figure 30. CO, CO_2 containing species



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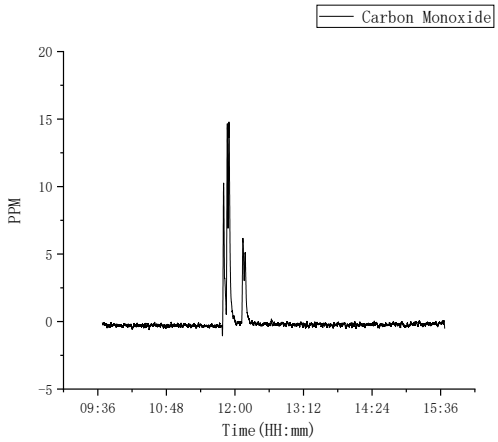
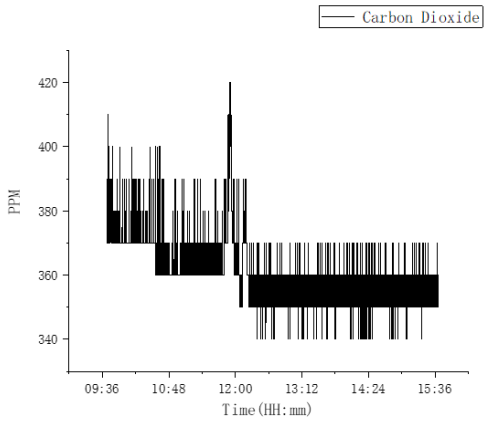


Savitzky-Golay filtered data



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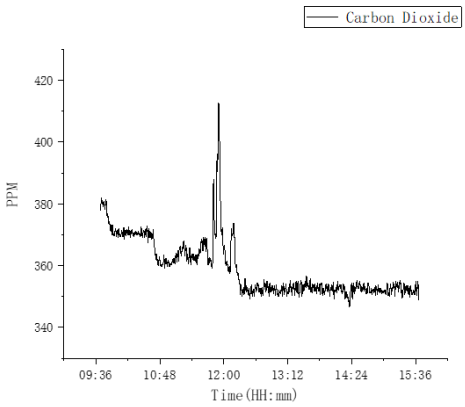


Savitzky-Golay filtered data

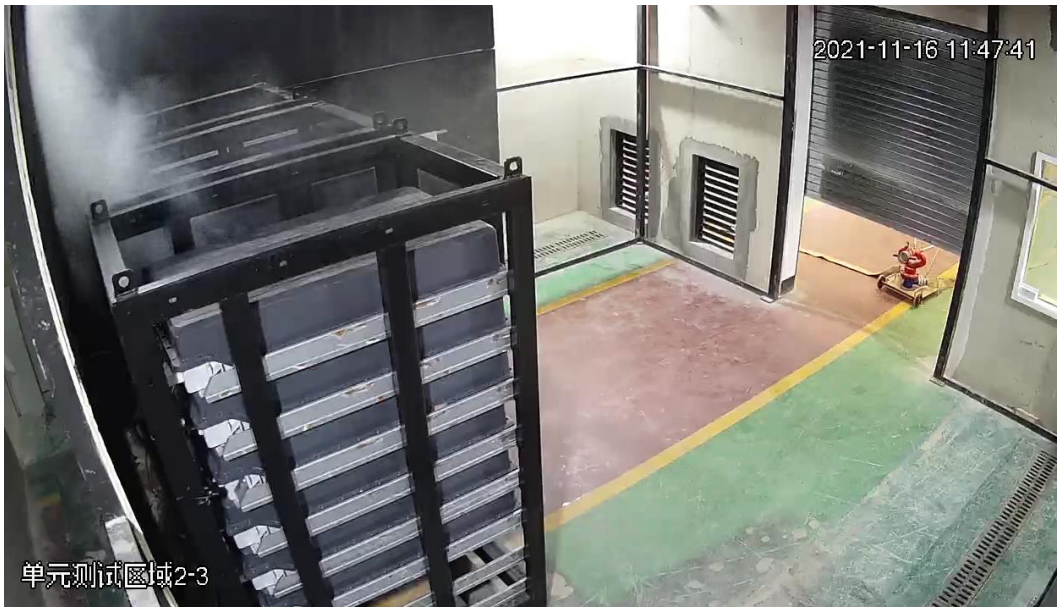
Note: Since raw original data is hard to interpret. Savitzky-Golay filtered data is also provided as this smooths the data and increases the precision of the data without distorting the signal tendency.

3.10 Photos

Initial module

Test setup

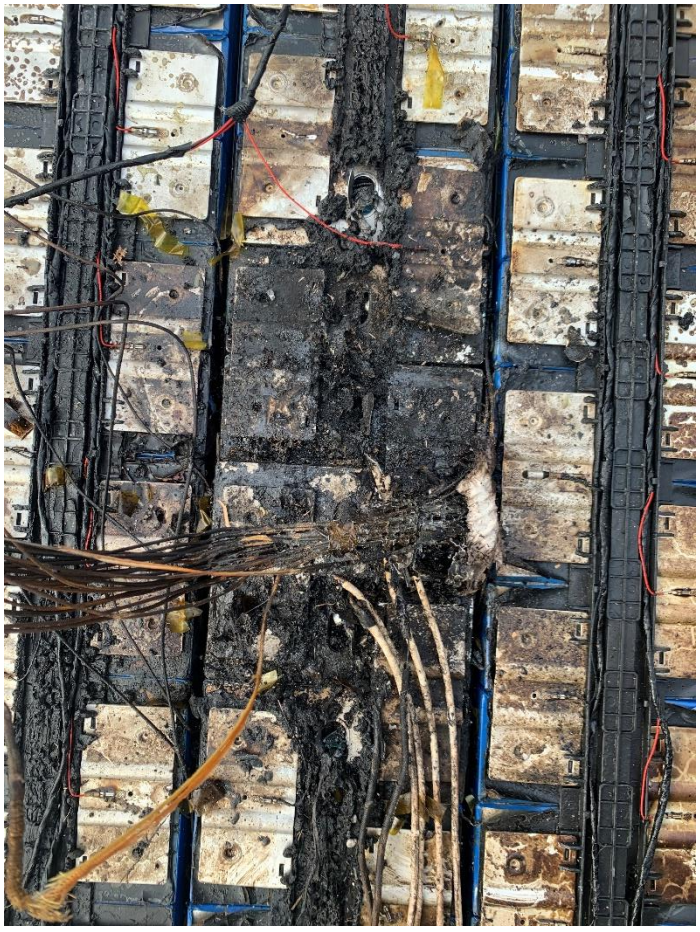
Smoke release during the test



Photos after the test

Initial module after test

Initial cell after test



4 List of Test and Measurement Instruments

No.	Equipment		Model	Rating	Inventory no.	Last Cal. date
1	Ambient monitor		WSB-2-H1	0-40°C，10-90%RH	T-125	2021.07.24
2	Ambient monitor		WSB-2-H1	0-40°C，10-90%RH	S-050	2021.05.31
3	Data acquisition equipment		DTM	0-1000°C	S-029	2021.04.19
4	Data acquisition equipment		ADAM-4117 ADAM-4118 MT4W DTB4824	0-10V 0-1000°C 0-100V 0-1000°C	S-028-3 S-028-4 S-030-(5~8) S-046-2	2021.04.19 2021.05.06 2021.07.19 2021.07.20
5	Digital multi-meter		FLUKE101	0-600V	S-038	2021.04.22
6	Tape		1000mm 5000mm	0-1000mm 0-5000mm	S-040 S-042	2021.04.22 2021.04.22
7	Electronic scale		TCS-500	0-500kg	S-039	2021.04.19
8	Oxygen consumption calorimeter measurement system	Paramagnetic oxygen analyzer	SERVOMEX MultiExact 4100	O_2: 0-21% CO_2: 0-10% CO: 0-1%	S-024	2021.03.20
		CO and CO2 sensor				
		Velocity probe	WIKA	0~0.4MPa	S-024-5	2021.03.08
		Photo detector	DP101MD	-100~100Pa	S-024-4	2021.03.08
		Light filter	——	25%、50、75%	S-024-6 S-024-7 S-024-8	2021.03.12
9	Palladium-nickel thin-film solid state sensor		H2scan 740B MODEL5000 OMD-650	500ppm-100% 0-4% <20%	S-023-1 S-023-2 S-023-3	2021.03.20
10	Fourier-Transform Infrared Spectrometer		MG6000	0.01ppm-100%	S-019	2021.03.20
11	Flame Ionization Detector		ABB AO2000	0-3000ppm	S-025	2021.03.20
12	Thermopile		OMEGA TT-K-24	0-260℃	S-026	2021.04.01

13	Heat flux measurement equipment	Schmidt-Boelter, 64-5-20	0-50kW	S-031 S-032 S-033 S-034 S-035 S-036 S-037 S-065	2021.06.21

End of Test Report

Appendix M

CATL Battery Spacing Review Documentation

Letter of Attestation

Document: 80028282 **Master Contract:** N/A

Project: 80051872 **Date Issued:** Sep 30, 2020

Issued to: Contemporary Amperex Technology Co., Limited
No. 2 Xingang Road, Zhangwan Town, Jiaocheng District
Ningde City, Fujian Province 352100, P. R. China
Attention: Ms. Sandy Lv

CSA Group hereby confirms that it has completed an evaluation of: Li-ion Battery Rack, models R852280-P-T-I-1, R852280-E-T-I-1, Rx52280-P-T-U-1, Rx52280-E-T-U-1, FRx52280-P-T-U-0, FRx52280-E-T-U-0, Ox52280-P, Ox52280-E (x means module number 4-8)

CSA Group hereby attests that the products identified above and described in test report 80028282 dated Jan 17, 2020 complies with the following standards/tests, to the extent applicable:

UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 3rd edition, Revision Date Jun 15, 2018, Section 8 Unit Level Testing.

Issued by: *Joseph Zhou*

CSA Group

THIS LETTER OF ATTESTATION DOES NOT AUTHORIZE THE USE OF THE CSA MARK ON THE SUBJECT PRODUCTS.
QUOTATIONS FROM THE TEST REPORT OR THE USE OF THE NAME OF THE CANADIAN STANDARDS ASSOCIATION AND CSA GROUP OR ITS REGISTERED TRADEMARK, IN ANY WAY, IS NOT PERMITTED WITHOUT PRIOR WRITTEN CONSENT OF CSA GROUP.

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Descriptive Report and Test Results

MASTER CONTRACT: N/A
REPORT: 80028282
PROJECT: 80051872

Edition 1: Feb 25, 2020; Project 80028282 - Cleveland
Issued by Joseph Zhou, Reviewed by Anuj Amin

Edition 2: Sep 30, 2020; Project 80051872 - Cleveland
Prepared by Joseph Zhou, Authorized by Anuj Amin

Contents: Letter of Attestation - Page 1 to 1
Description and Tests - Pages 1 to 28

PRODUCTS

Li-ion Battery Rack, models R852280-P-T-I-1, R852280-E-T-I-1, Rx52280-P-T-U-1, Rx52280-E-T-U, FRx52280-P-T-U-0, FRx52280-E-T-U-0, Ox52280-P, Ox52280-E (x means module number 4-8)

APPLICABLE REQUIREMENTS

UL 9540A - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, 3rd edition

MARKINGS

N/A

ALTERATIONS

N/A

FACTORY TESTS

N/A

Test related only to the items tested.This report shall not be reproduced, except in full, without the approval of CSA Group.

8501 East Pleasant Valley Road, Cleveland, OH, U.S.A. 44131-5575
Telephone: 216-524-4990 1.800.463.6727 Fax: 216-642-3463 www.csagroup.org

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DESCRIPTION

Testing Laboratory Name:	CCIC-CSA International Certification Co., Ltd. Kunshan Branch
Address:	Building 8, Tsinghua Science Park, No. 1666 Zu chongzhi Rd (S), Kunshan, Jiangsu (215347)
Testing Program:	**Custom Test:** Latter of Attestation [X] Testing Only [ ] Note: Mark "X" in applicable test program block

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

Testing Laboratory Name:	Contemporary Amperex Technology Co., Limited
Address:	No.2 Xingang Road, Zhangwan Town, Jiaocheng District Ningde, Fujian, 150 35200, China
Facility Number: **Qualification**	N/A

	As above / or describe otherwise
Customer:	Contemporary Amperex Technology Co., Limited
Address:	No.2 Xingang Road, Zhangwan Town, Jiaocheng District Ningde, Fujian, 150 35200, China

Tested By: Jianfang Zhu, Test Engineer
Name, Title

Jianfang Zhu, Test Engineer 2019-11-30 to 2019-12-4
Signature *Date (YYYY-MM-DD)*

☐ **Reviewed by:** Joseph Zhou/Giggle Pei, Certifier
☒ **Witnessed by:**
Name, Title

Joseph Zhou 2019-12-04
Signature *Date (YYYY-MM-DD)*

Version: 2019-05-09

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Product Details	
Test Request:	☐ Cell Level Testing ☐ Module Level Testing ☒ Unit Level Testing ☐ Installation Level Testing
Manufacturer	☐ Cell: ☐ Module: ☒ Unit: Contemporary Amperex Technology Co., Limited
Brand name / Trademark	☐ Cell: ☐ Module: ☒ Unit: NA
Model Number	☐ Cell: ☐ Module: ☒ Unit: refer to the models indicated on the cover page
Date of receipt of test sample(s)	2019-11-30 (YYYY-MM-DD)
Cell/Battery Type	Li-ion, LFP
Approximate Dimension (mm)	☐ Cell: ☐ Module: ☒ Unit: 924*1185*2329 (W*D*H) [mm]
Mass (g)	☐ Cell: ☐ Module: ☒ Unit: 3100kg
DUT Sample/Serial Number	☐ Cell: ☐ Module: ☒ Unit: TD19-0237
DUT Nominal Voltage Rating (V)	☐ Cell: ☐ Module: ☒ Unit: 1331.2
DUT Nominal Charge Capacity Rating (Ah)	☐ Cell: ☐ Module: ☒ Unit: 280
Fire Mitigation Strategies: (For installation level testing)	☒ Water: ☐ Other (Specify): ☐ N/A
Additional Information	N/A

Model Difference: refer to table below for the model differences:

Model No.	Suffix 1	Rated Current, A	Suffix 2	
R852280-P-T-U-1	P	280	U	UL approved
R852280-P-T-I-1	P	280	I	IEC approved
R852280-E-T-U-1	E	140	U	UL approved
R852280-E-T-I-1	E	140	I	IEC approved

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Per client confirmed, models subjected for US certification are the same as models approved IEC standard certification, herein, test performed on models R852280-P-T-U-1 was considered representative of models R852280-P-T-I-1, R852280-E-T-U-1, R852280-E-T-I-1.

Description of changes from models R852280-P-T-I-1, R852280-E-T-I-1, R852280-P-T-U-1, R852280-E-T-U-1 to Rx52280-P-T-U-1, Rx52280-E-T-U-1 (x means module number 4-8).

Compared to models R852280-P-T-I-1, R852280-E-T-I-1, R852280-P-T-U-1, R852280-E-T-U-1, the following changes were included to add models Rx52280-P-T-U-1 and Rx52280-E-T-U-1 (x means module number 4-8)

1. Change the rating label for weight, voltage ranges and capacities;
2. Change the name of component cell from 001CB310 to CB310 and CB2W0.
3. Add new critical components, like Service Plug-Alternate (MSD) and HV connector (B+, B-, HV+, HV-).
4. Update the liquid cooling tube adapter on the top.

Description of changes from Rx52280-P-T-U-1, Rx52280-E-T-U-1 to FRx52280-P-T-U-0, FRx52280-E-T-U-0 (x means module number 4-8):

Compared to models Rx52280-P-T-U-1, Rx52280-E-T-U-1, the following changes were included to add models FRx52280-P-T-U-0, FRx52280-E-T-U-0 (x means module number 4-8):

1. Cancel the rack door, rack feet and baseboard.
2. Change the grounding position to left bottom of rack frame; cancel grounding position on the top.
3. Cancel the water protection cover on the top of rack.
4. Change the shape of cabling outlet on the top of rack.
5. Change the nameplate position: two pieces on the left and right side of rack frame.
6. Size change: 914mm*1185mm*2327mm changed to 919mm*1250mm*2248mm

Model series Ox52280-P, Ox52280-E are same as model series Rx52280-P-T-U-1, Rx52280-E-T-U-1 except for the location of control box and addition of liquid chiller.

Based on the model difference indicated, no additional test deemed necessary for the above alternation.

THE TESTING SPECIFIED IN THIS PROCEDURE IS INHERENTLY DANGEROUS

DO NOT ATTEMPT TO PERFORM THIS TEST UNLESS YOU HAVE BEEN PROPERLY TRAINED REGARDING SAFELY WORKING WITH THE HAZARDS INVOLVED

Important Test Consideration:

- As some batteries expose in test described above, it is important that personal be protected from the flying fragments, explosive force, and sudden release of heat, chemical burns, and noise result from such explosions. The test area is to be well ventilated to protect personal from possible harmful fumes or gases.
- Temperature of the surface of the battery casing shall be monitored during the tests described above. All personal involve in the testing of batteries are to be instructed never to approach a battery until the surface temperature return to ambient temperature.

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- Test shall be conducted in separate room or equipped with an adequate safety barrier separating the test area from observer.

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UL 9540 A – Definition

- "BATTERY ENERGY STORAGE SYSTEM (BESS)" - Stationary equipment that receives electrical energy and then utilizes batteries to store that energy for later use in order to supply electrical energy when needed. The BESS consists of one or more modules, a power conditioning system (PCS) 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 8).
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.

- "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.

- "DUT" – Device under test.

- "ELECTRICAL RESISTANCE HEATERS" – Devices that convert electrical energy supplied from a laboratory source into thermal energy.

- "FLEXIBLE FILM HEATERS" – Electrical resistance heaters of a film, tape or otherwise thin sheet like construction that easily conform to the surface of cells.

- "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.

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

- "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.

- "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.

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UL 9540A Third Edition, Dated June 15, 2018 - Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

Section	Requirement	Test (T) / Waive (W) / Not App. (N/A)	Comments
1	**Scope:** The test methodology in this document evaluates the fire characteristics of a battery energy storage system that undergoes thermal runaway. Fire protection requirements not related to battery energy storage system equipment are covered by appropriate installation codes.		
	Section 6: Cell Level Test	W	1. Cell testing not requested by manufacturer Cell Thermal runaway methodology: External heating method with ceramic heater 1 PCS, rated 220/230V, 500W Cell Surface temperature at gas venting (ºC): 143.3 Cell Surface temperature at thermal runaway(ºC): 209.8 Gas Composition and LFL: C2H4, C2H6, C3H6, C3H8, H2, CH4, CO, CO2 Lower Flammability Limit(LFL) = 6.14%@12~18 ºC,101.3~101.5kPa Pmax:109.36PSI(0.754MPa) Pmax Rise Rate: 23153.83(159.64MPa/Sec) PSI/Sec Lower Flammability Limit(LFL）at venting temperature = 5.4%@143±1°C, 101±2kPa Gas Burning Velocity: 0.584m/s @ ambient temperature (22~30°C), atmospheric pressure See project 80040846 for Cell Level testing data provided by manufacturer
	Section 7: Module Level Test	W	Module testing not requested by manufacturer Cell Thermal Runaway Methodology: External heating method with ceramic heater 1 PCS, rated 220/230V, 500W Cell Surface Temperature at Gas Venting (ºC): 92.3 Cell Surface temperature at thermal runaway(ºC): 123.9 Module Heat Release Rate (kW/m^2): 0 Cell/Module Gas Generation and Composition: C2H2, C2H4, C2H6, C3H6, C3H8, H2, CH4, CO, CO2

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Section	Requirement	Test (T) / Waive (W) / Not App. (N/A)	Comments
			Module External Flaming and Flying Debris Hazard: N/A, no fire or explosion, no flying debris during test Module Location of Flame Venting: Not applied no fire occurred during the whole testing See project 80025390 for Module Level testing data provided by manufacturer
	Section 8: Unit Level Test	T	Manufacturer Name: Contemporary Amperex Technology Co., Limited Model: R852280-P-T-U-1 Electrical Rating: nominal voltage 1331.2V BESS Energy (Whr): 332736 BESS Capacity (Ahr): 280 Number of Module: 8 Module Configuration: 52S-1P Approximate Dimension (mm): 924*1185*2329 (W*D*H) Weight (kg): 3100 BMS Model no: N/A Fire Detection System: N/A Fire Suppression System: N/A Fire Detection/Suppression System (Optional/Part of system): N/A Manufacturer request to perform test with Fire Detection/suppression System (Yes/No): No, no fire detection/suppression test designed on the battery system. BESS Enclosure Material: Metallic BESS Comply with UL 1973 Requirement (Yes/No): Yes, refer to Certification No. CU 50272100 001 from TUV Rheinland, and report No. 64.280.20.60131.01 from TUV SUD
	Section 9: Installation Level Test (With fire mitigation strategies)	N/A	1. BESS Meet Unit level performance requirement and No Installation Level test required.

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UL 9540A Third Edition, Dated June 15, 2018 - Section 8 Unit Level Testing

Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
8	Unit Level Testing		P
8.1	BESS Sample tested within 8 after charging BESS as per manufacturer specification to obtain maximum operating state of charge.	Manufacture recommended charge/discharge method: Charging Procedure: CP-CV Charging Voltage (V): 1497.6 Charging Current (A): see below： 1. charge the unit with 0.25P(93184W) to cell voltage 3.65V 2. charge the unit with 0.1P(37273.6W) to cell voltage 3.65V 3. charge the unit with 0.05P(18636.8W) to cell voltage 3.65V Charging End Condition (A): 14A Discharging Procedure: CP Discharging Current (A): 140 0.25P(93184W) End of Discharge Voltage (V): 2.5V/Cell Rest Duration after charging (HH:MM): 8h	P
	Following test configuration used for testing.	See below	P
	- Installation of BESS unit with two or more rows	confirmed	P
	- Installation of BESS units with a single row	See above	N/A

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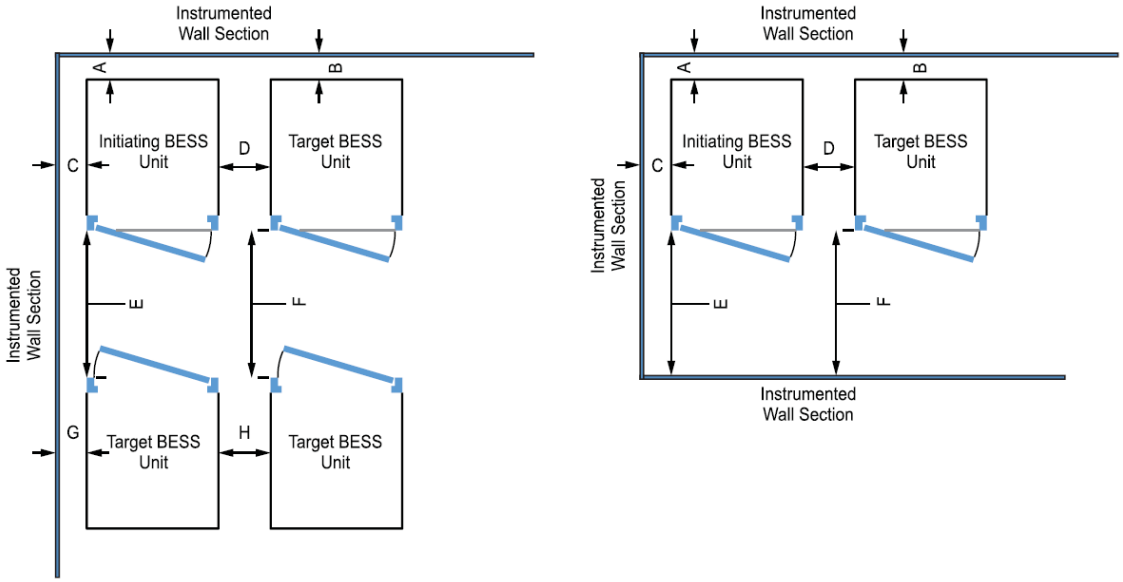
Section	Requirement	Comments	Verdict

Possible test case verdicts:

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

Figure 8.1
Examples of potential SBA test arrangements



ID.	Location	Required Value (mm)	Measured Value (mm)
A	Separation distance between the initiating BESS unit and instrumented wall section behind initiating BESS unit.	160	150
B	Separation distance between the target BESS unit and instrumented wall section to the side of target BESS unit.	160	150
C	Separation distance between the initiating BESS unit and instrumented wall section to the side of the initiating BESS unit.	260	250
D	Separation distance between initiating BESS unit and target BESS unit.	10	10
E	Separation distance between initiating BESS unit and target BESS unit or instrumented wall section.	10	10
F	Separation distance between target BESS unit and target BESS unit or instrumented wall section.	10	10
G	Separation distance between target BESS unit and instrumented wall section.	260	250
H	Separation distance between target BESS units.	10	10

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Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: N/A (Not Applicable) Test object does meet the requirement: P (Pass) Test object does not meet the requirement: F (Fail)			
	Note: The physical spacing between BESS units (both initiating and target) and adjacent walls shall be representative of the intended installation. For example, the left side of Figure 8.1 shows a layout of BESS units of two or more rows. The right side of Figure 8.1 shows a layout of BESS units of a single row, with an instrumented wall taking place of the target BESS units as the nearest potential item exposed to thermal energy from the initiating BESS unit in thermal runaway		
	The initiating BESS unit contained components representative of a BESS unit in a complete installation.	☒ Conformed	P
	Combustible components that interconnect the initiating and target BESS units included during testing.	☒ Conformed	P
	Target BESS units have the outer cabinet (if part of the design), racking, module enclosures, and components that retain cells components.	☒ Conformed Shelf included in the target BESS, also the module enclosure included to retain the cells.	P
	BESS unit included an integral fire suppression system	No integral fire suppression system designed in the BESS unit	N/A
	BESS unit provided with optional fire suppression system	No optional fire suppression system provided for the BESS unit.	N/A
	Ambient temperature during BESS charging and at beginning of test……..……..……: Note: Ambient indoor laboratory conditions shall be 25 ±5°C (77 ±9°F) and 50 ±25% RH at the initiation of the test.	Temperature(ºC): 22. 1 to 24. 4 Humidity (% RH): 50% to 75%	P
8.2	Any access door(s) or panels on the initiating BESS unit and adjacent target BESS units were closed, latched and locked at the beginning and duration of the test.	☐ Conformed No access door or panel designed on both the initiating and target BESS units	N/A
	The initiating BESS unit was positioned adjacent to two instrumented wall sections	☒ Conformed	P

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Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	Instrumented wall sections extend not less than 1.6 ft. (0.49 m) horizontally beyond the exterior of the target BESS units.	☒ Conformed	P
	Instrumented wall sections were minimum of 12-ft (3.66-m) tall at least 2-ft (0.61-m) taller than the BESS unit height.	☒ Conformed Height of the instrumented wall: 3.66m, Height of the BESS: 2329 mm.	P
	The surface of the instrumented wall sections were covered with 5/8-in (16-mm) gypsum wall board and painted flat black.	☒ Conformed	P
	The initiating BESS unit was centred underneath an appropriately sized smoke collection hood of an oxygen consumption calorimeter.	☐ Conformed The Initiating BESS unit was centered underneath a smoke collection hood without oxygen consumption calorimeter.	N/A
	The heat release rate measurement system was calibrated using an atomized heptane diffusion burner.	☐ Conformed Un-calibrated for the heat release rate measurement system.	N/A
	The convective heat release rate was measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct.	☐ Conformed See above	N/A
	Separation distance shown above in Section 8.1 were specified by manufacturer	☒ Conformed	P
	Wall surface temperature measurements were collected for BESS intended for installation in locations with combustible construction as defined by NFPA 220.	☒ Conformed	P
	Wall surface temperatures were measured in vertical array(s) at 6-in (152-mm) intervals for the full height of the instrumented wall sections	☒ Conformed	P

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Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	24-gauge Type-K exposed junction thermocouples were be used to measure wall surface temperatures.	☒ Conformed	P
	Thermocouples were secured to gypsum surfaces by the use of staples placed over the insulated portion of the wires. The thermocouple tip is to be depressed into the gypsum so as to be flush with the gypsum surface at the point of measurement and held in thermal contact with the surface at that point by the use of pressure-sensitive paper tape.	☒ Conformed	P
	Wall surface temperature measuring thermocouple arrays were horizontally positioned in the wall locations anticipated to receive the greatest thermal exposure from the initiating BESS unit.	☒ Conformed	P
	Heat flux were measured with the sensing element of a water-cooled Schmidt-Boelter gauge at the surface of each instrumented wall	See below	N/A
	- Collinear with the vertical thermocouple array	☐ Conformed Water-cooled Schmidt-Boelter gauge was installed on the surface of the instrumented wall collinear with the vertical thermocouple array.	N/A
	- Positioned at the elevation estimated to receive the greatest heat flux due to the thermal runaway of the initiating module; and	☐ Conformed No fire ignited during the testing. The gauge was installed at the height estimated to receive the greatest heat flux due to thermal runaway of the initiating module.	N/A
	- Positioned at the elevation estimated to receive the greatest heat flux during potential propagation of	☐ Conformed No fire ignited during the testing. One gauge was installed at the height of the initial BESS unit	N/A

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Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	thermal runaway within the initiating BESS unit.	enclosure which was estimated to receive the greatest heat flux within the initiating BESS unit.	
	Heat flux were measured with a water-cooled Schmidt-Boelter gauge at the surface of each adjacent target BESS unit that faces the initiating BESS unit	☐ Conformed No fire ignited during the testing. Gauge was installed at the surface of the No.2 target BESS unit which is close to the initial BESS unit.	N/A
	Heat flux gauges were positioned at the elevation estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating module	☐ Conformed Gauge was set up at the elevation estimated to receive the greatest surface heat flux. No fire ignited no heat fluxed during the testing.	N/A
	Twenty-four (24) gauge Type-K exposed junction thermocouples were installed to measure the temperature of the surface proximate to the cells and between the cells and exposed face of the module. Each module enclosure were instrumented with at least one thermocouple	☒ Conformed	P
	An internal fire condition was created within a single module in the initiating BESS unit	See below	P
	- The position of the module was selected to present the greatest thermal exposure to adjacent modules (e.g. above, below, laterally), based on the results from the module level test	☒ Conformed	P
	- The setup (i.e. type, quantity and positioning) of equipment for initiating thermal runaway in the module was same as that used to initiate and propagate thermal runaway within the module level test (Section 7); and	☒ Conformed	P

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Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	- A minimum of two 24-gauge Type-K thermocouples were placed within each module to provide data to monitor the thermal conditions within non-initiating modules.	☒ Conformed 2 thermocouples were placed in each module of the initiating BESS unit	P
	- Additional thermocouples were be placed to account for convoluted enclosure interior geometries in non-initiating modules.	☒ Conformed 1 thermocouples were placed in each module of the target BESS unit	P
	The composition, velocity and temperature of BESS unit vent gases were be measured within the calorimeter's exhaust duct.	☒ Conformed	P
	Gas composition was measured using a Fourier-Transform Infrared Spectrometer with a minimum resolution of 1 cm^{-1} and a path length of at least 6.6 ft. (2.0 m), or equivalent gas analyser.	☒ Conformed GC-MS was used for gas composition measurement	P
	Composition, velocity and temperature instrumentation shall be collocated with heat release rate calorimetry instrumentation.	☐ Conformed No fire ignited, no propagation occurred with the DUT	N/A
	The hydrocarbon content of the vent gas was measured using flame ionization detection	☐ Conformed GC-MS used, the gas composition was measured off line.	N/A
	Test Terminated at following test condition	See below	P
	- Temperatures measured inside each module within the initiating BESS unit return to ambient temperature;	☒ Conformed	P

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Section	Requirement	Comments	Verdict
Possible test case verdicts: Test case does not apply to the test object: Test object does meet the requirement: Test object does not meet the requirement:		N/A (Not Applicable) P (Pass) F (Fail)	
	- The fire propagates to adjacent units or to adjacent walls; or	☐ Conformed No fire ignited, no propagation occurred between adjacent cells in the initiating module.	N/A
	- Condition hazardous to test staff or the test facility requires mitigation.	☐ Conformed No condition hazards to the test staff or the facilities	N/A

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Section 8.3	**TD19-0237**
Sample No	TD-0196
Open Circuit Voltage of Initiating BESS Before Test(Vdc):	1404.4
Thermal runaway initiation Method:	External Heating
Location of Initiating module within BESS:	Module No.5. In 1# BESS from the BMS controller box ） Refer to page 22 for target module location and cell location in the initial BESS.

Heat Release Rate

The convective heat release rate shall be calculated using the following equation:

$$HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$$

In which:
HRRc = The convective heat release rate (kW)
Ve = The exhaust velocity (m/s)
A = The exhaust duct cross sectional area (m2)
Te = The temperature at the location where exhaust velocity is measured (K)
353.22/Te = The density of air at the velocity measurement location (kg/m3)
To = The ambient temperature (K) in the test room

T = The thermopile temperature (K)

$$\int_{T_o}^{T} C_p dT = A_0(T - T_o) + A_1/2(T^2 - T_o^2) + A_2/3(T^3 - T_o^3) + A_3/4(T^4 - T_o^4)$$

Cp = Specific heat of air (kJ/kg-K), given as Cp = A0 + A1T + A2T2 + A3T3, in which:
A0 = 0.9950
A1 = -5.29933E-05
A2 = 3.21022E-07
A3 = -1.22004E-10

Heat Release Rate Calculation: The heat release rate equals to almost 0 KW in the stage when the unit was forced into thermal runaway as no fire ignited and no propagation occurred between adjacent cells after thermal runaway forced during the whole testing.

Observation of Flying Debris or Explosive Discharge of Gases

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No flying debris or explosion triggered during unit level thermal runaway testing. See video records for further information.

Flammable Gas Generation and Composition Data

See Note

Activation of Integral Fire Protection System.

N/A, no fire protection system designed on the battery rack.

Temperature Measurement

Thermocouple Location	Temperature Limit (ºC)	Measured Maximum Temperature (ºC)
Ambient Temperature Before Test	-	23.8
Wall Surface Temperature	119.8	19.5（T25）
Maximum Target BESS Temperature	143.3	21.6（2# BESS, T5）
Maximum Surface temperature of Module within Target BESS	143.3	21.6（2# BESS, T5）

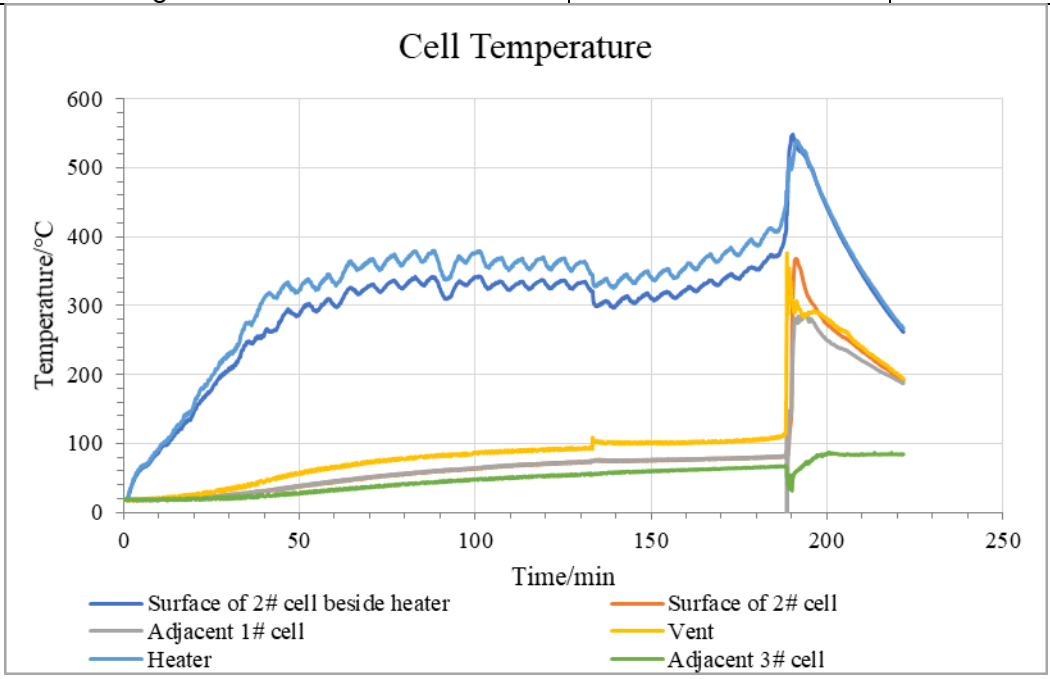

Fig.1 Cell Temperature during Unit Level Testing

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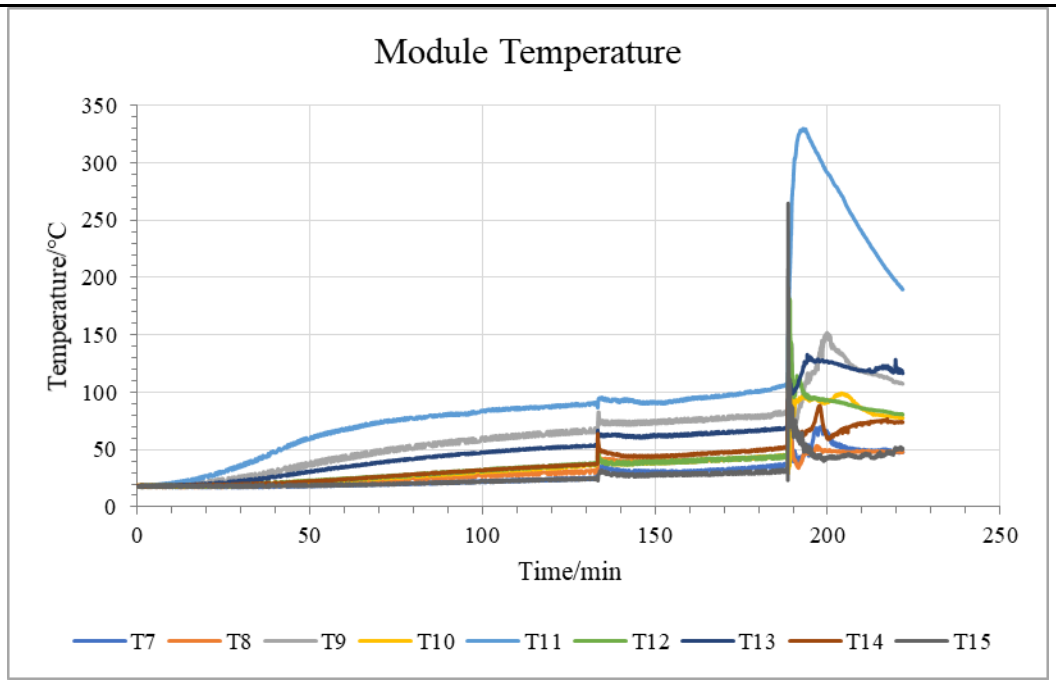

Fig.2 Cell Temperature in target module during Unit Level Testing

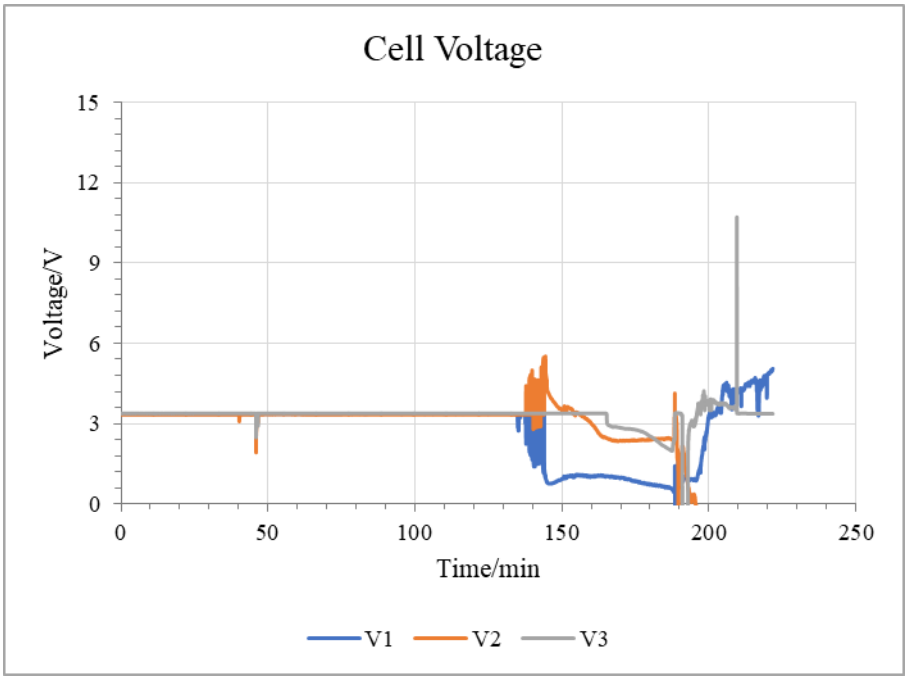

Fig.3 Cell Voltage in target module during Unit Level Testing

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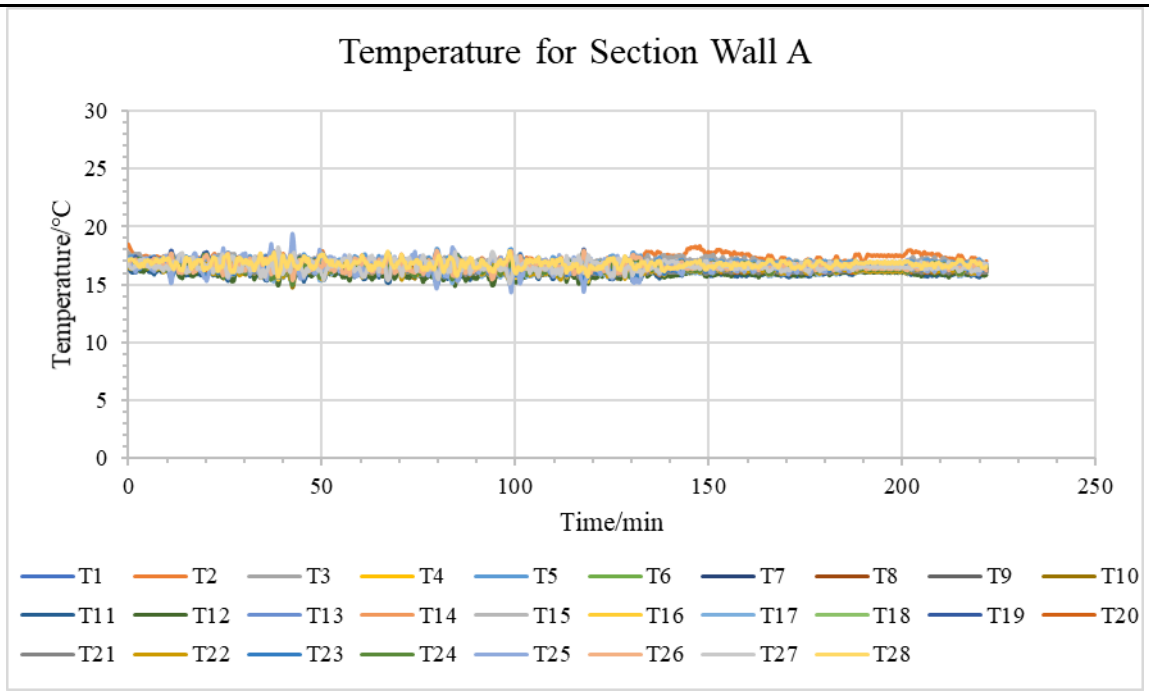

Fig. 4 Temperature of Section Wall A

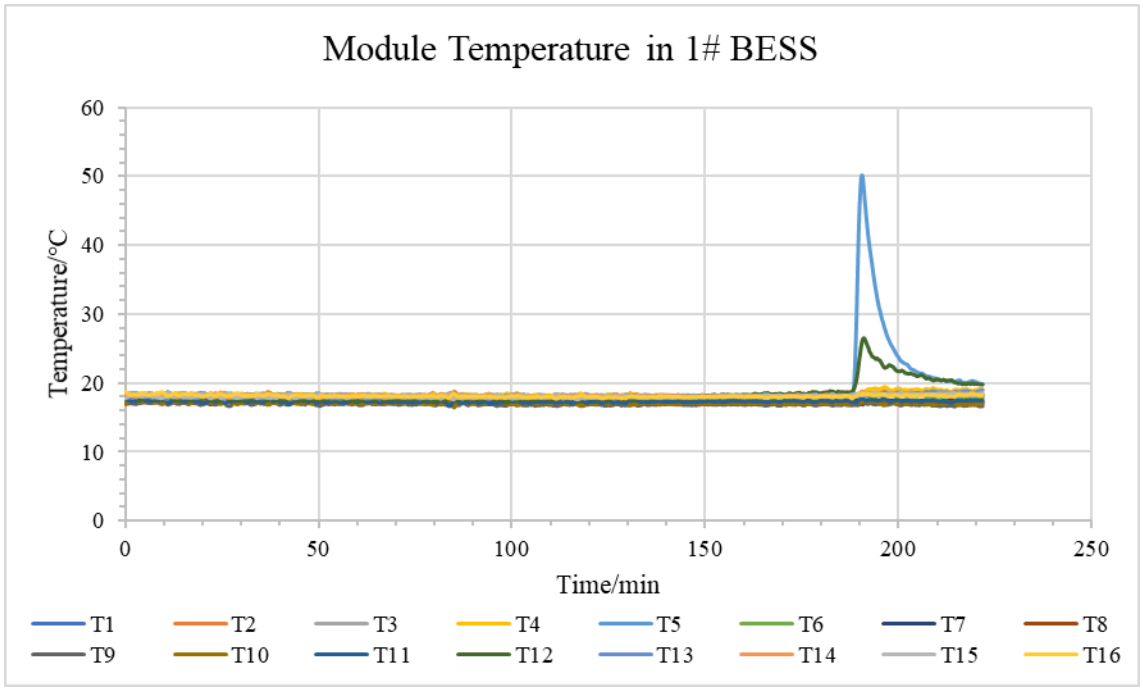

Fig. 5 Module Temperature in 1# BESS

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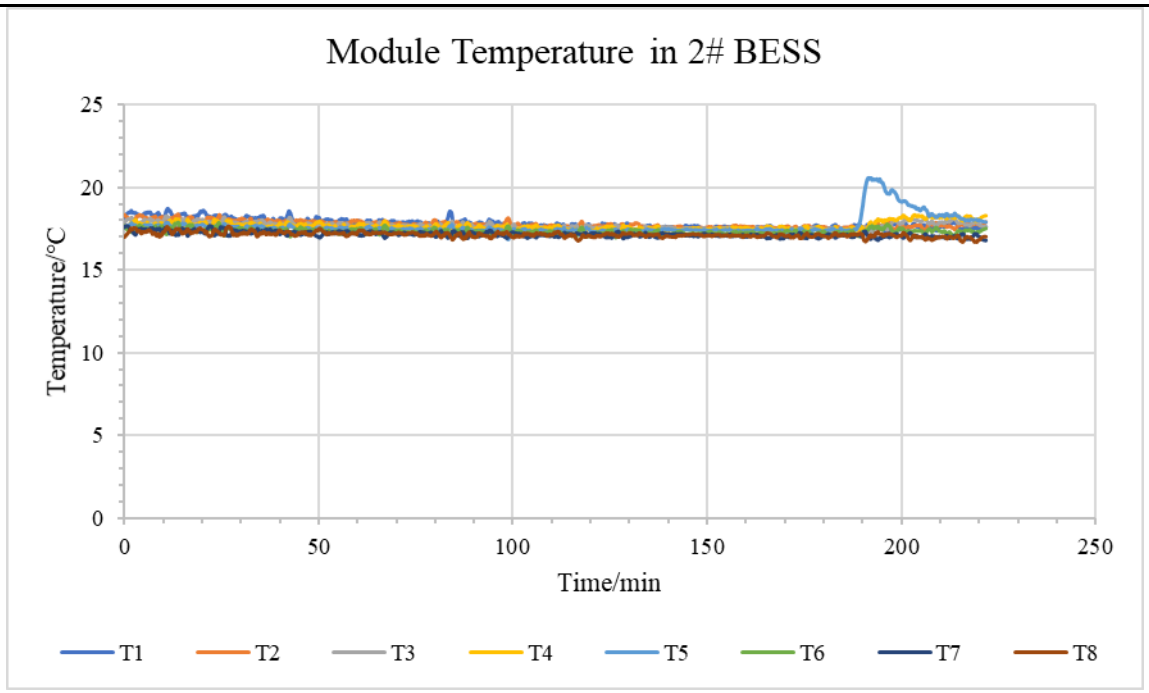

Fig. 6 Module Temperature in 2# Target BESS

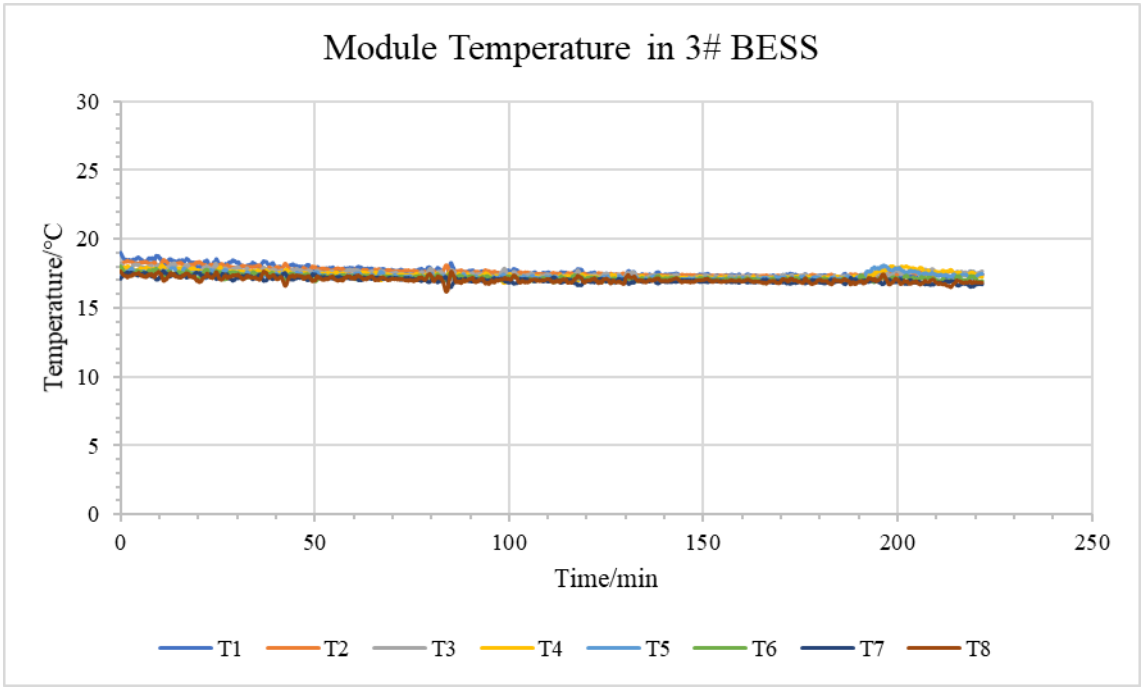

Fig. 7 Module Temperature（3# BESS）

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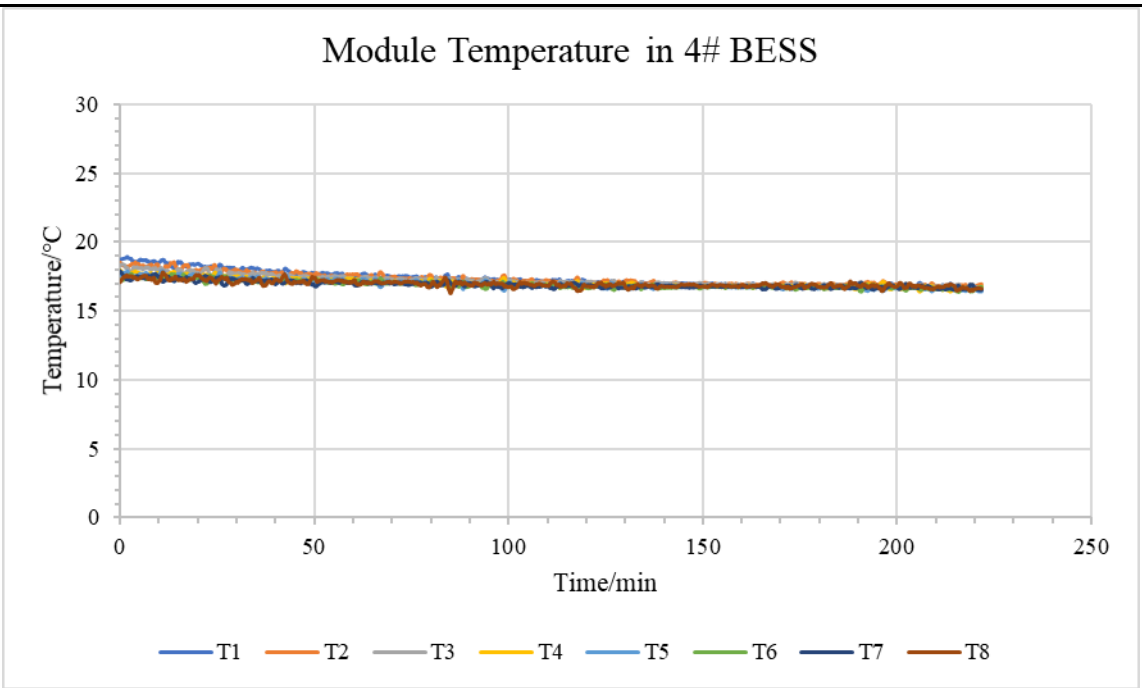

Fig. 8 Module Temperature（4# BESS）

Heat Flux Measurement

Heat flux Location	Measured Maximum Heat Flux (kW/m^2)
Target Wall 1	N/A, see note
Target Wall 2	N/A, see note
Target BESS Unit 1	N/A, see note
Target BESS Unit 2	N/A, see note

Supplementary information:

Note: Heat was not measured on above heat flux location, as no fire ignited during the whole testing.

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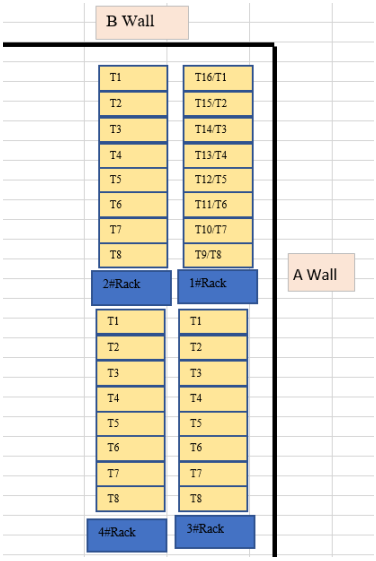

Fig 9 Module Temp in BESS

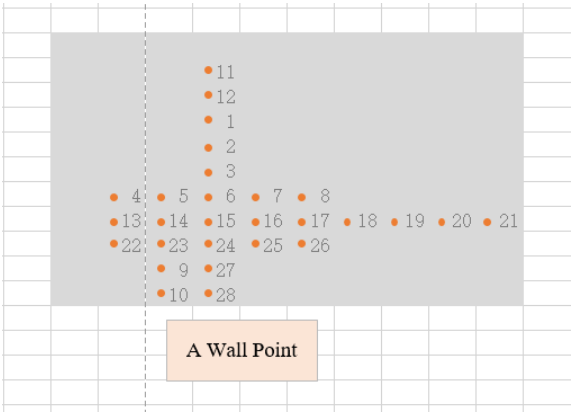

Fig. 10 Section Wall Temp

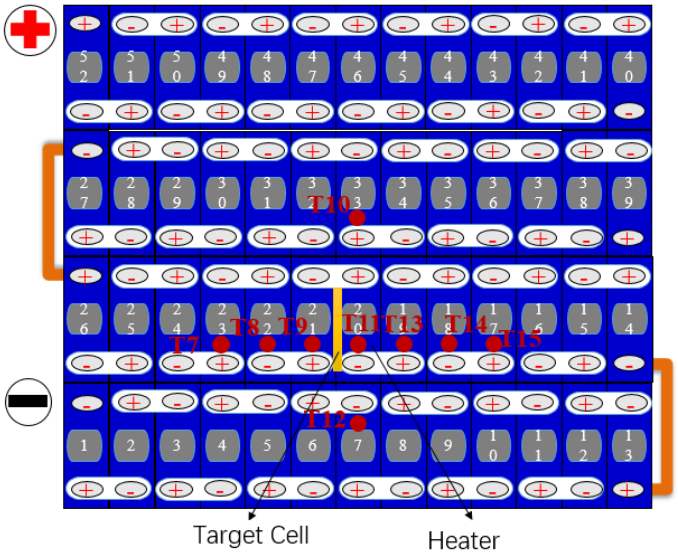

Fig. 11 Heater Location in Module

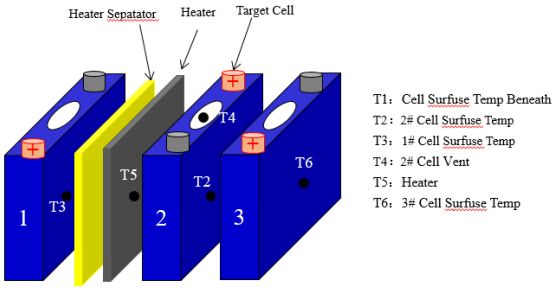

Fig. 12 Thermal Couple Location on Cell

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Fig 13 BESS under Test

Fig.14 Initial BESS after Test

Gas composition analysis

Sample No.	Gas Components									
	CO2	C2H2	C2H4	C2H6	C3H6	H2	O2	N2	CH4	CO
S1-20191204-0316-01	0.06	/	/	/	/	/	21.45	78.49	/	/
S1-20191204-0316-02	0.06	/	/	/	/	/	21.25	78.69	/	/
S1-20191204-0316-03	0.06	/	/	/	/	/	21.23	78.71	/	/
S1-20191204-0316-04	0.18	0.01	0.02	0.01	0.02	0.44	21.09	78.18	0.01	0.05
S1-20191204-0316-05	0.19	0.01	0.02	0.01	0.02	0.52	21.08	78.10	0.01	0.05
S1-20191204-0316-06	0.06	/	/	/	/	/	21.55	78.38	/	/
S1-20191204-0316-07	0.11	/	0.01	/	0.01	0.12	21.26	78.47	/	0.02
S1-20191204-0316-08	0.11	/	0.01	/	0.01	0.11	21.23	78.50	/	0.02

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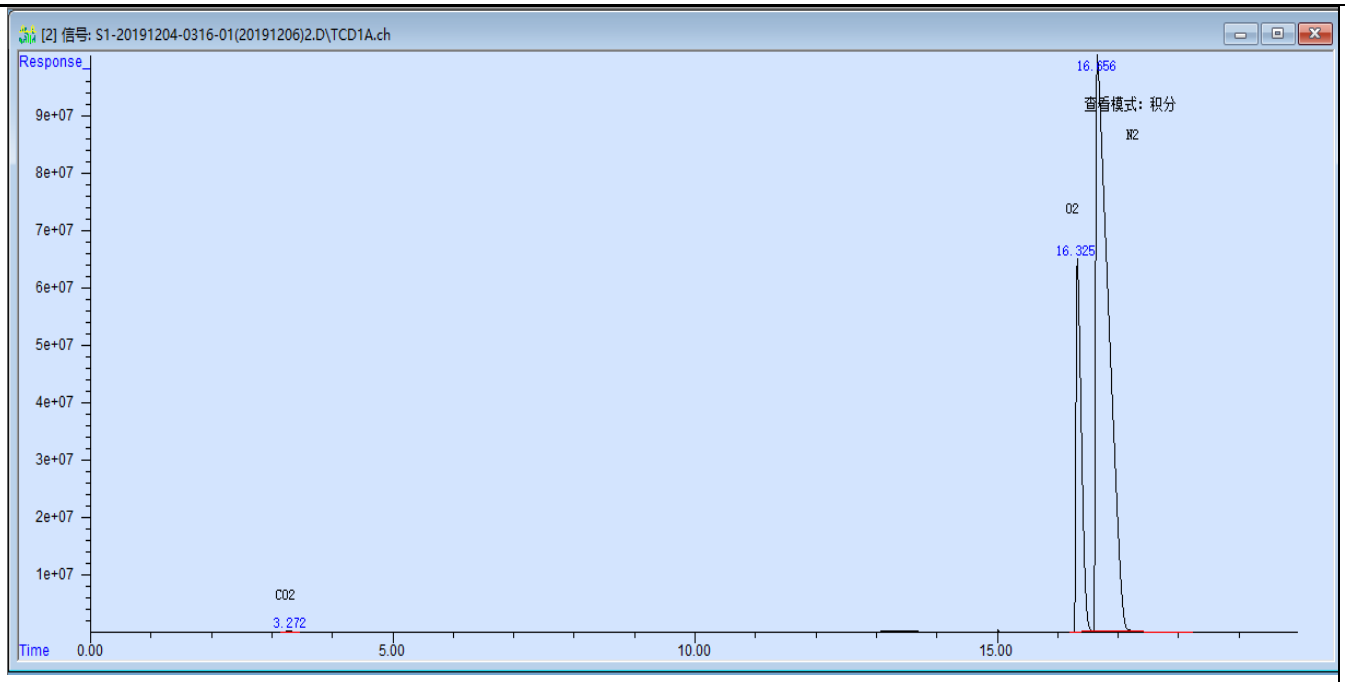

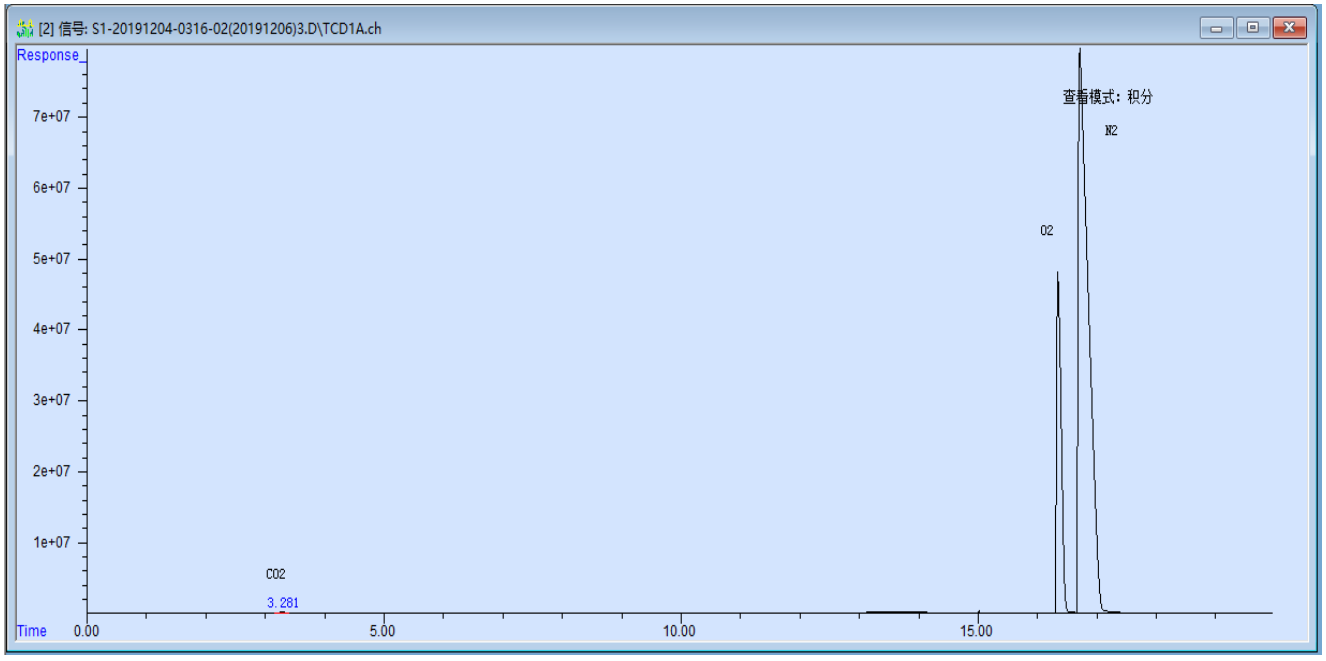

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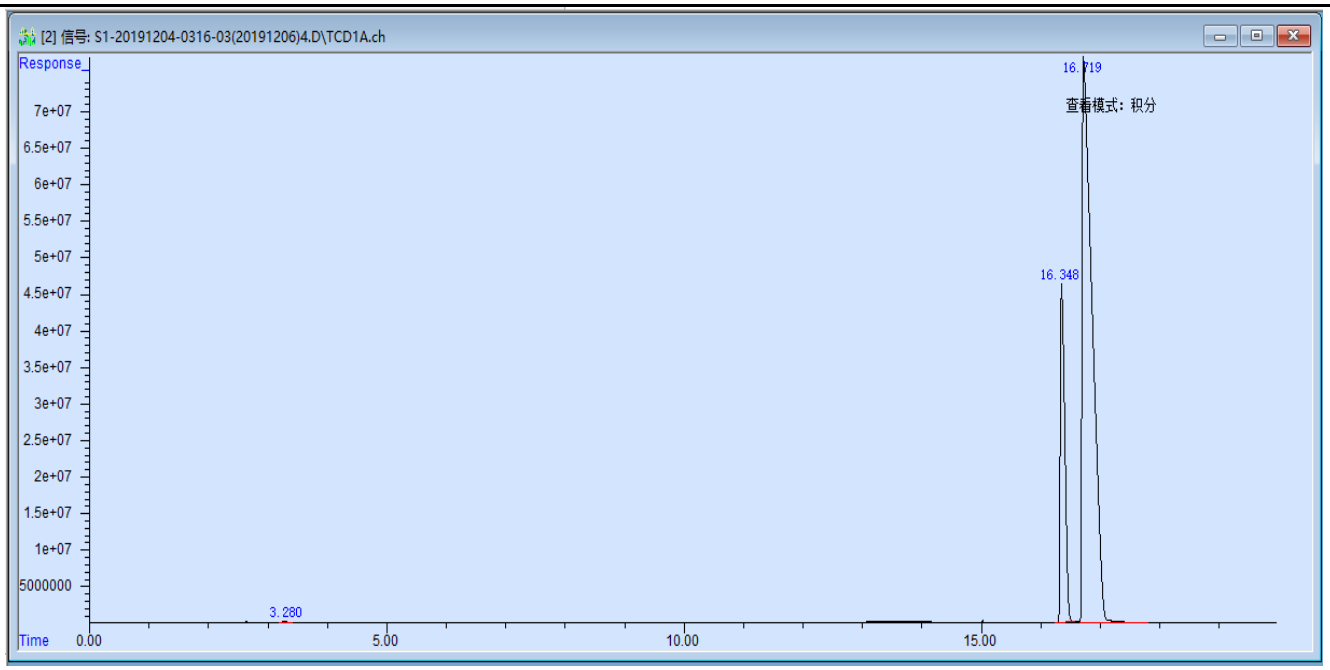

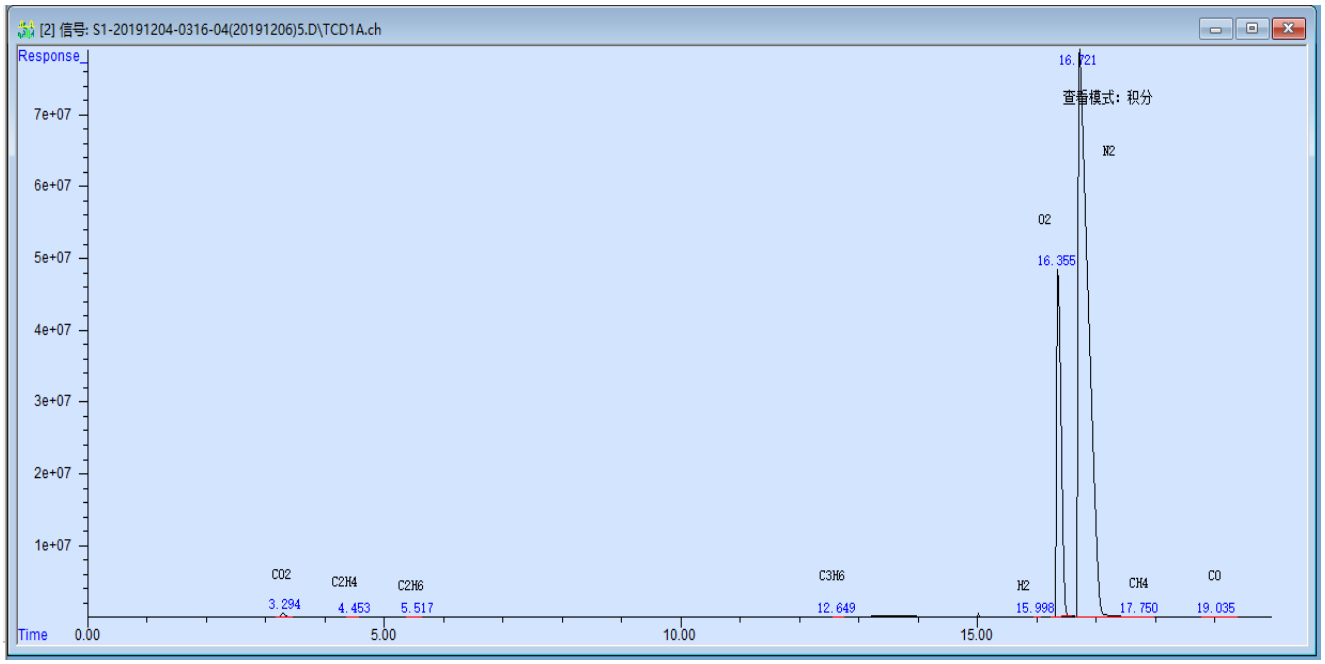

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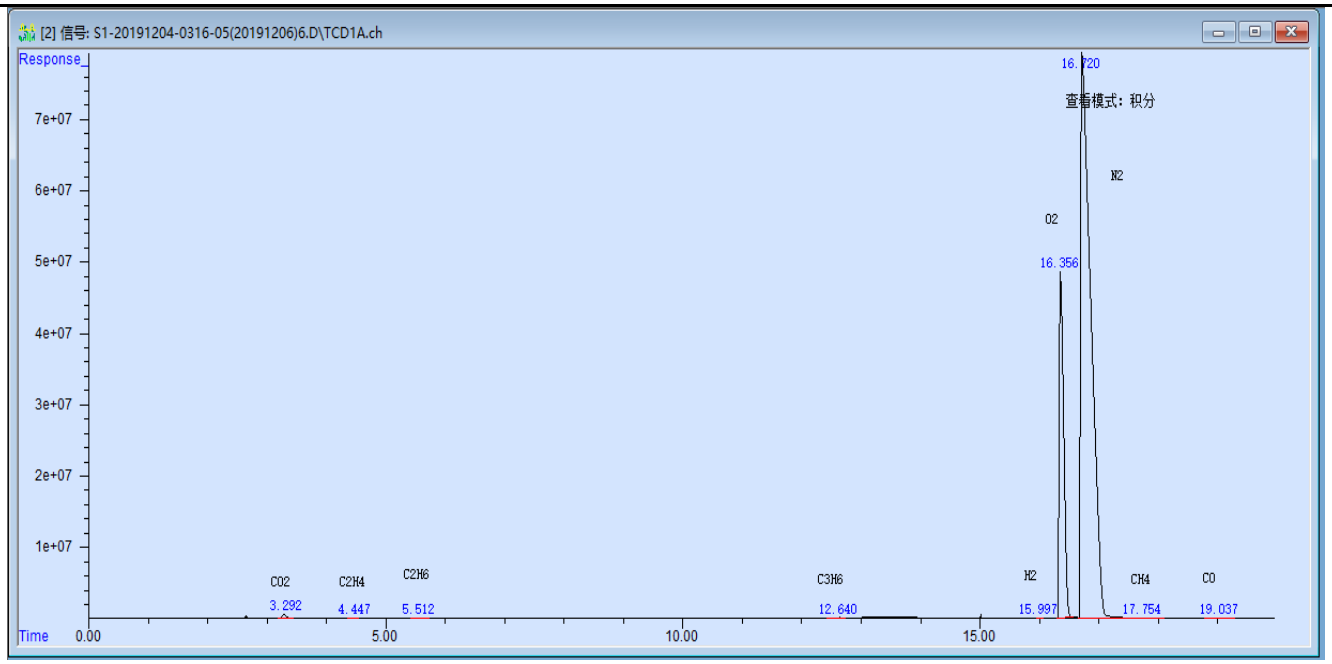

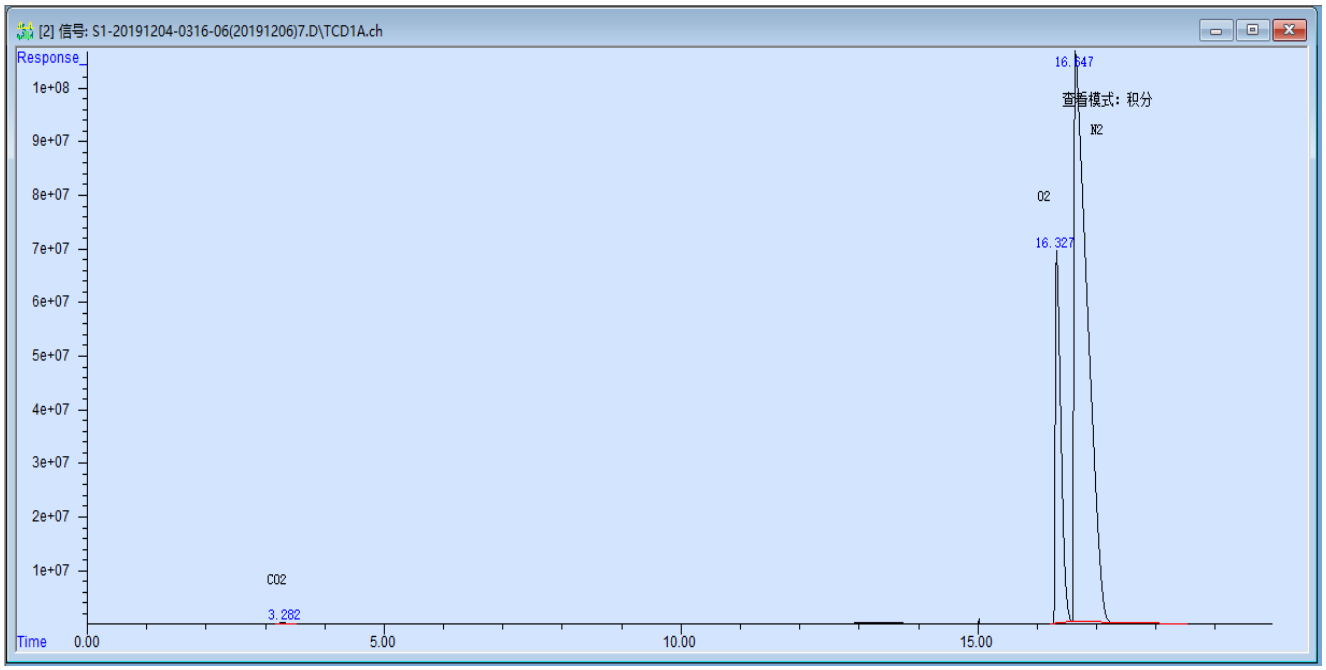

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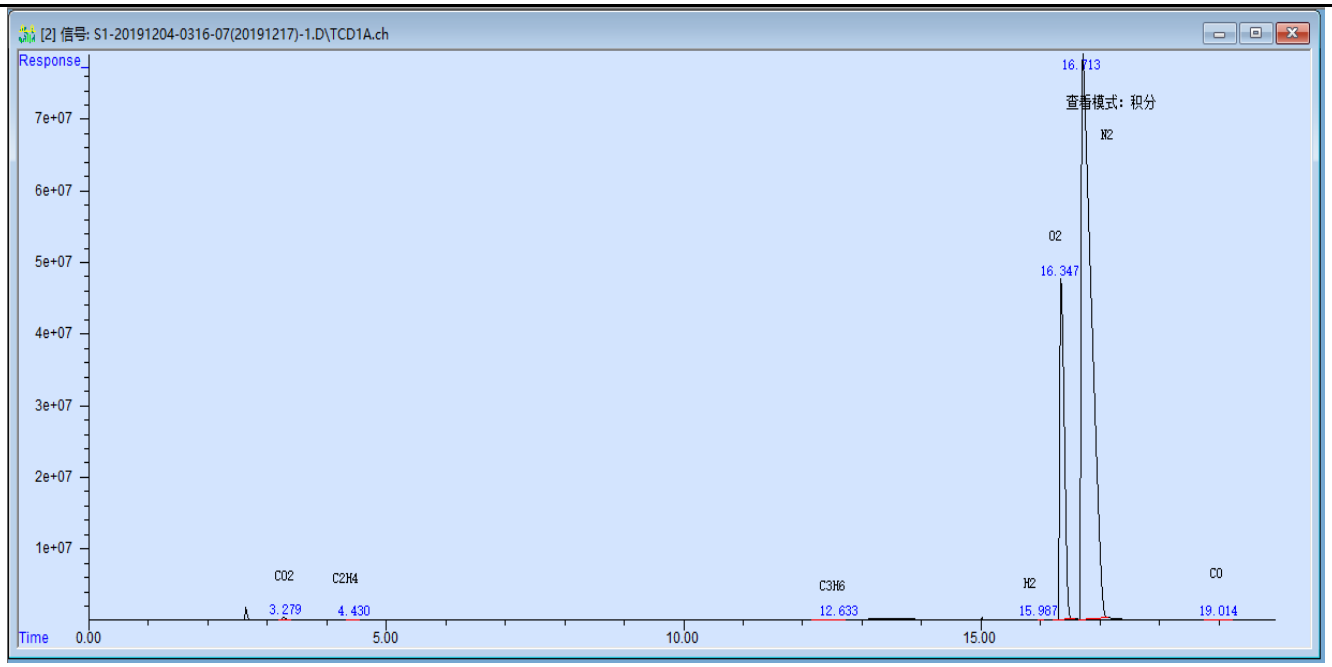

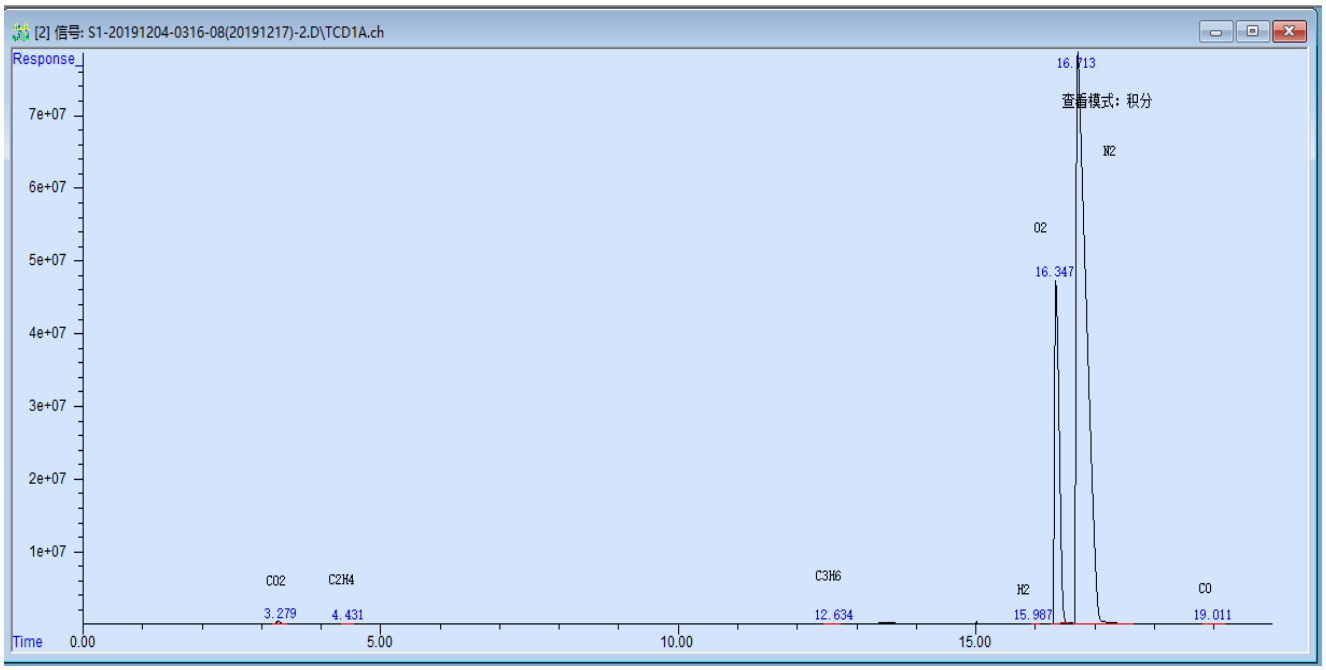

Equipment Used: Item no. 1,2,3,4,5,6
Date Start: 19/11/30 (YY/MM/DD)
Date End: 19/12/04 (YY/MM/DD)

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Test Equipment

Item No.	Inventory Code / ID	Description	Mfr	Model	Range Used	Calibration Date (YYYY-MM-DD)	Next Calibration Due Date (YYYY-MM-DD)
1	73B0E01460	Chamber	/	HTP-900-40-AW-D	-40~80℃	2019-02-20	2020-02-19
2	740TE01325	Battery Charge/Discharge System	Suoying	GBBT-110/300-2	10~110V, 5~300A	2019-02-19	2020-02-18
3	73TME00069	Data Logger	HIOKI	LR8401-21	-50~300℃	2019-07-12	2020-07-11
4	L108248/GACH0006	GC-MS	Agilent	5977-7890B	-	2018-10-19	2020-10-18
5	74MUE00013	Multi-Meter	Fluke	1587C	0～600Vdc	2019-08-15	2020-08-14
6	72BAQ00359	Scale	Shanghai Mingpai	XK3190-A12+E	0～400kg	2019-05-23	2020-05-22

---End of Report---

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Appendix N

EVE Power Battery Spacing Review Documentation

Appendix N

Prüfbericht-Nr.: *Test Report No.:*	**CN22GHM1 001**	**Auftrags-Nr.:** *Order No.:*	244427912	**Seite 1 von 51** *Page 1 of 51*
Kunden-Referenz-Nr.: *Client Reference No.:*	2182037	**Auftragsdatum:** *Order date.:*	Aug 06, 2022	
Auftraggeber: *Client:*	**Sungrow Energy Storage Technology Co.,Ltd.** No.788 Mingchuan Road, Boyan Technology Park, Hi-tech Zone, Hefei City, 230088 Anhui, P.R. China			
Prüfgegenstand: *Test item:*	Battery Rack			
Bezeichnung / Typ-Nr.: *Identification / Type No.:*	R286AL-141, R344AL-141, R573AL-143, R688AL-143			
Auftrags-Inhalt: *Order content:*	Test report			
Prüfgrundlage: *Test specification:*	UL 9540A: 2019 (Fourth Edition)			
Wareneingangsdatum: *Date of receipt:*	Aug 30, 2021			
Prüfmuster-Nr.: *Test sample No.:*	Engineering sample			
Prüfzeitraum: *Testing period:*	Sept 02, 2021 ~ Sept 17, 2022			
Ort der Prüfung: *Place of testing:*	See clause 1.1 of main report			
Prüflaboratorium: *Testing laboratory:*	See clause 1.1 of main report			
Prüfergebnis*: *Test result*:*	See main report			

geprüft von / *tested by:*			**kontrolliert von** / *reviewed by:*		
October 08, 2022	Simon Wang / Engineer		October 08, 2022	Bowen Dong / Reviewer	
Datum *Date*	**Name/Stellung** *Name/Position*	**Unterschrift** *Signature*	**Datum** *Date*	**Name/Stellung** *Name/Position*	**Unterschrift** *Signature*

Sonstiges / *Other:*

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

* Legende:	1 = sehr gut	2 = gut	3 = befriedigend	4 = ausreichend	5 = mangelhalt
	P(ass) = entspricht o.g. Prüfgrundlage(n)		F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
Legend:	1 = very good	2 = good	3 = satisfactory	4 = sufficient	5 = poor
	P(ass) = passed a.m. test specifications(s)		F(ail) = failed a.m. test specifications(s)	N/A = not applicable	N/T = not tested

Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht auszugsweise vervielfältigt werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens.

This test report only relates to the a. m. test sample. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.

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 do not 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.

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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 unit level tests of UL 9540A: 2019.

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.

Testing period: Sept 02, 2022 ~ Sept 17, 2022

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

Video records of the test from 2 different directions were provided in .mp4 format.
Complete records were provided in 6 separate documents, file number listed as below:

20220902 Sungrow unit UL9540A video ch02 (01-02).mp4;

20220902 Sungrow unit UL9540A video ch03 (01-04).mp4;

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 as 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 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

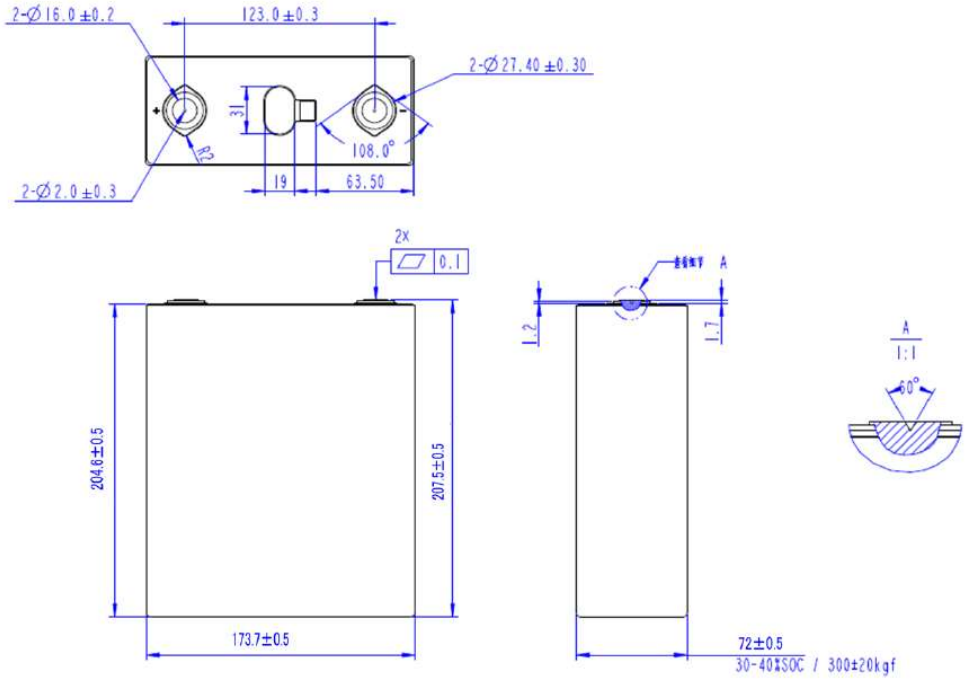
The product information and parameters were provided by the client as below.

2.1 Cell

2.1.1 Product information and parameters

Manufacturer ..... :	EVE POWER Co., Ltd.	
Model number ..... :	LF280K	
Chemistry ..... :	LiFePO4	
Physical configuration..... :	Prismatic	
	Weight:	5420±300 g
Electrical rating ..... :	Rated capacity:	280 Ah
	Nominal voltage:	3.2 V
Standard charge method ..... :	Charge current:	140 A
	End of charge voltage:	3.65 V
	Cut off current:	14 A
Standard discharge method ..... :	Discharge current:	140 A
	End of discharge voltage:	2.5 V

Diagram with overall dimension



2.1.2 Cell level test information

Cell level thermal runaway test information is from UL cell level test report 4789795626 provided by the client.

Thermal Runaway Methodology.....:	Two pieces 203.0 mm by 152.4 mm film heater for each sample
Cell Surface Temperature at Gas Venting...:	146.9°C
Cell Surface Temperature at Thermal Runaway .....:	147.7°C

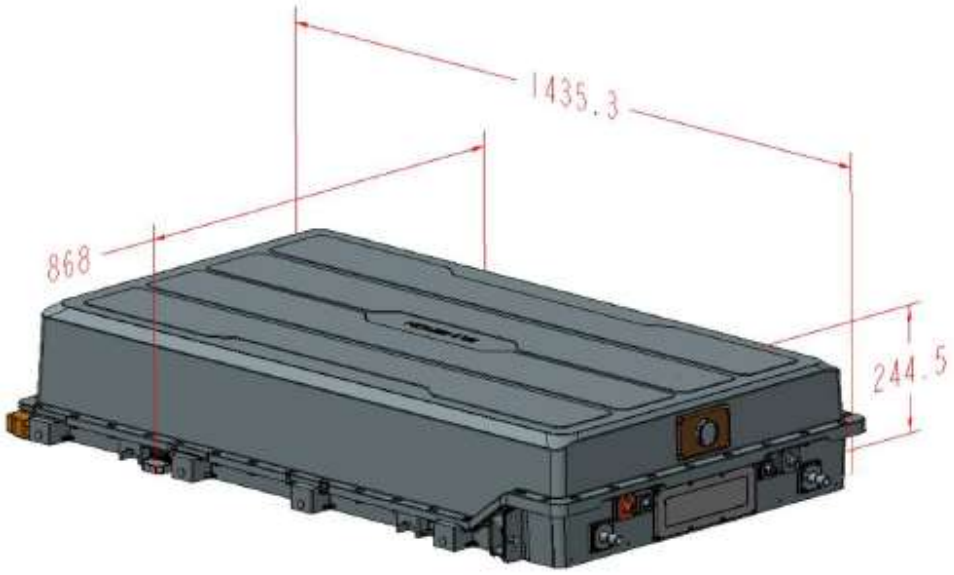
2.2 Module

2.2.1 Product information and parameters

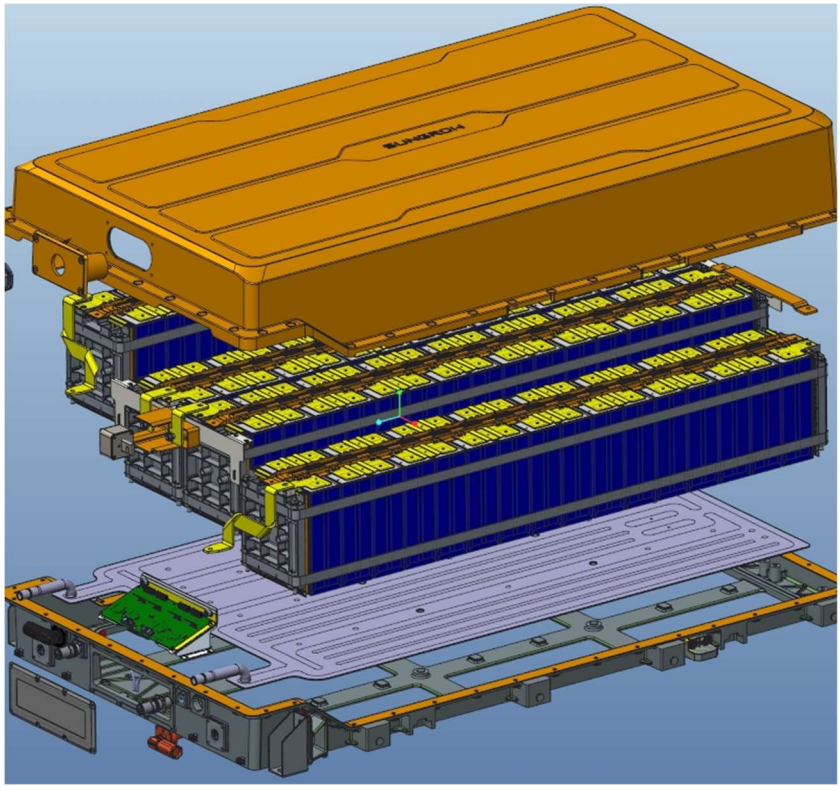
The product information and parameters are provided by the client as below.

Manufacturer name ..... :	SUNGROW ENERGY STORAGE TECHNOLOGY CO., LTD.
Type/Model..... :	P573AL-141, P573BL-141
Physical configuration..... :	Metal enclosure with plastic cover
	Weight: 400±12 kg
	Cells in series/parallel: 64 in series
Cooling method ..... :	Liquid Cooling
Separation between cells ..... :	0.45 mm separation between cells by air
Electrical rating..... :	Rated capacity: 280 Ah
	Nominal voltage: 204.8V
Standard charge method..... :	Charge current: 140 A
	End of charge voltage: 233.6 V
	Cut of current: 14 A
Standard discharge method ..... :	Discharge current: 140 A
	End of discharge voltage: 172.8 V
Compliance with UL 1973..... :	Under certification, not finished

2.2.2 Diagram with overall dimension

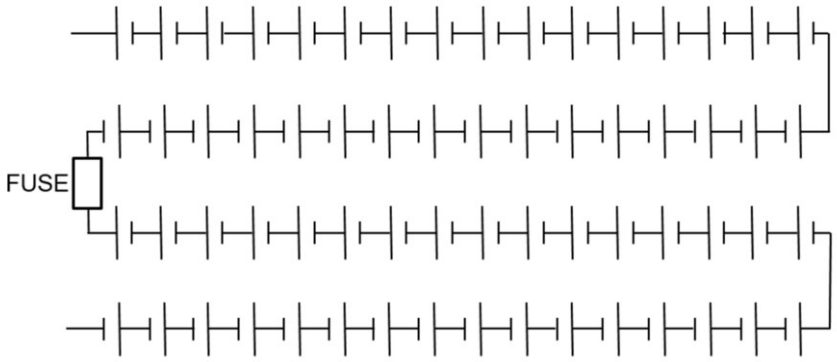


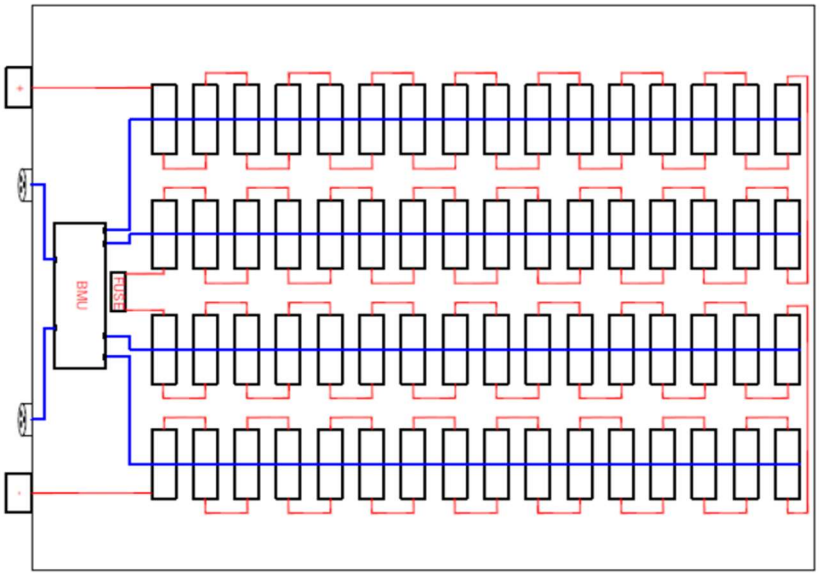
2.2.3 Layout of the module contents



2.2.4 Configuration diagram of the module

1P64S





2.3 Battery system (rack)

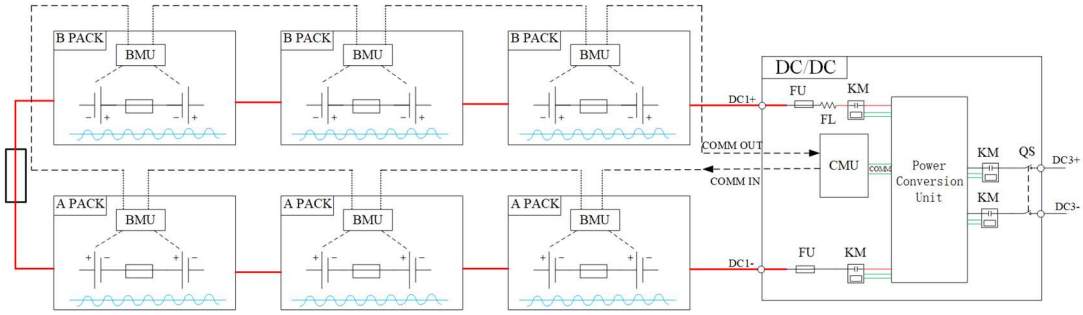
2.3.1 Manufacture information and model list

	Battery system	Battery system	Battery system	Battery system
Product	LFP Lithium Ion Energy Storage System	LFP Lithium Ion Energy Storage System	LFP Lithium Ion Energy Storage System	LFP Lithium Ion Energy Storage System
Type/model	R286AL-141	R344AL-141	R573AL-143	R688AL-143
Cell Capacity [Ah]	280	280	280	280
Cell Quantity	320	384	640	768
Battery structure	(64S)5S	(64S)6S	((64S)5S)2P	((64S)6S)2P
Nominal voltage [V]	1024	1228.8	1024	1228.8
Rated capacity [Wh]	286720	344064	573440	688128
Upper limit charging voltage [V]	1168	1401.6	1168	1401.6
Recommend charging current [A]	140	140	140	140
Maximum charging current [A]	140	160	140	140
Recommend discharging current [A]	140	140	140	140
Maximum discharging current [A]	140	160	140	140
Discharge cut-off voltage [V]	864	1036.8	864	1036.8
Temperature range for charging [°C]	0 to 50*	0 to 50*	0 to 50*	0 to 50*
Temperature range for discharging [°C]	-30 to 50*	-30 to 50*	-30 to 50*	-30 to 50*
Temperature threshold for protection	53	53	53	53
Overcharge protected voltage supply by battery system	≥3.65V /Cell	≥3.65V /Cell	≥3.65V /Cell	≥3.65V /Cell
Recommend charging method by manufacturer	Charge at constant current 140A until the voltage reaches 1168V, then switch to constant voltage 1168V till charge current drops to 14A	Charge at constant current 140A until the voltage reaches 1401.6V, then switch to constant voltage 1401.6V till charge current drops to 14A	Charge at constant current 140A until the voltage reaches 1168V, then switch to constant voltage 1168V till charge current drops to 14A	Charge at constant current 140A until the voltage reaches 1401.6V, then switch to constant voltage 1401.6V till charge current drops to 14A
Dimension [mm]	Rack:3117±10mm(W)×1474±10mm(D)×520±10mm(H) DC/DC:720±5mm(W)×788±5mm(D)×294±5mm(H)	Rack:3117±10mm(W)×1474±10mm(D)×520±10mm(H) DC/DC:720±5mm(W)×788±5mm(D)×294±5mm(H)	Rack:3117±10mm(W)×1474±10mm(D)×1040±10mm(H) DC/DC:720±5mm(W)×788±5mm(D)×294±5mm(H)	Rack:3117±10mm(W)×1474±10mm(D)×1040±10mm(H) DC/DC:720±5mm(W)×788±5mm(D)×294±5mm(H)
Weight [kg]	Rack: ≤2025kg DC/DC: 75kg	Rack: ≤2430kg DC/DC: 75kg	Rack: ≤4050kg DC/DC: 75kg	Rack: ≤4860kg DC/DC: 75kg
Ingress Protection (IP)	IP65	IP65	IP65	IP65
Protective Class	I	I	I	I
Cooling type	Liquid cooling	Liquid cooling	Liquid cooling	Liquid cooling
Altitude	4000m	4000m	4000m	4000m

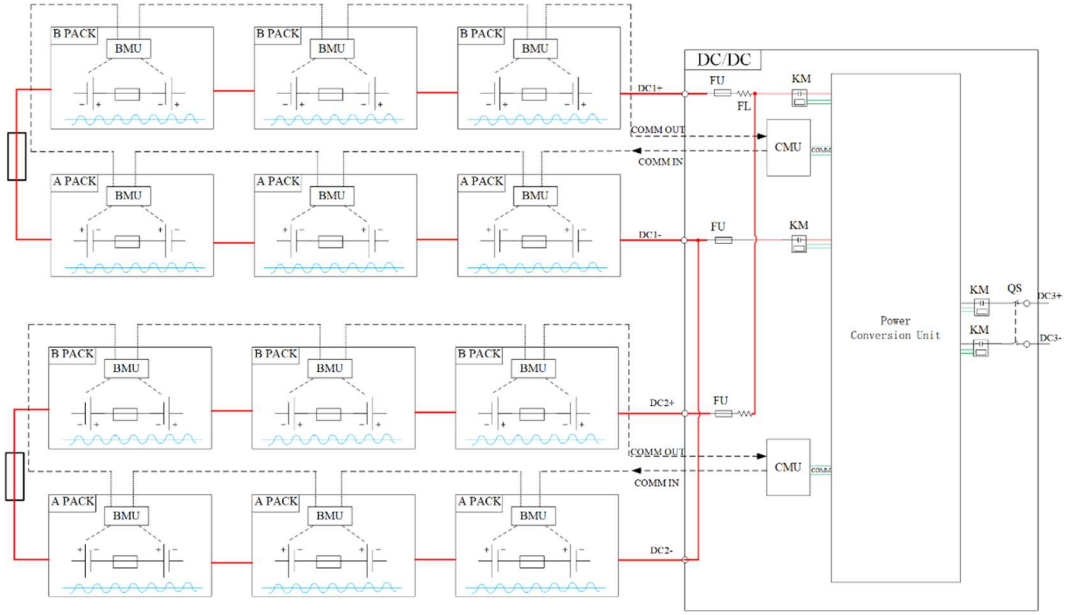
2.3.2 Product information

This product is used for Energy Storage System.
The EUTs covered by this report are 4 models of LFP lithium ion battery energy storage systems which include one DC-DC converter box and several battery packs in series(parallel) connection. The number of battery pack is 5, 6, 10,12 for model R286AL-141, R344AL-141, R573AL-143 and R688AL-143.

Block diagram for R344AL-141 is as below (R286AL-141 is the same except for one less pack) :



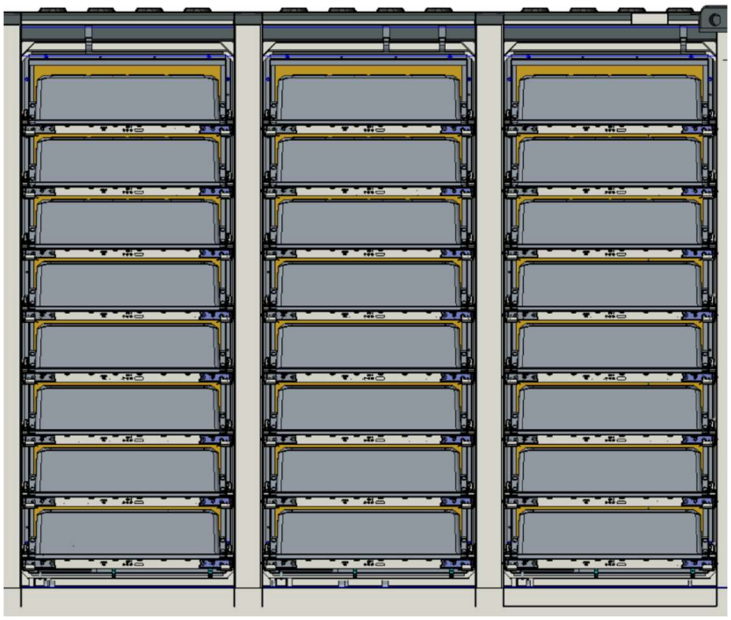
Block diagram for R688AL-143 is as below (R573AL-143 is the same except for two less packs) :

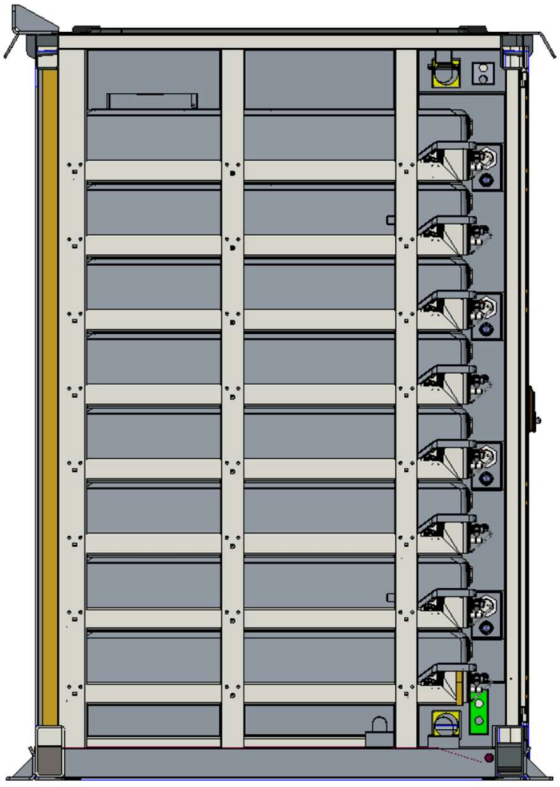


Each battery pack contains 64 cells in structure 64S. And it contain one BMU board for measuring and collecting the cell parameters and uploading the information of cell voltage and temperature to CMU in DC-DC converter box.
DC-DC box: Including CMU function and DC-DC converter which certified with UL 1741.
The EUTs are indoor type. The insulation between the DC circuit and the metal enclosure is basic insulation. And the insulation between the DC circuit and communication ports is reinforced insulation or double insulation.
BMS functional safety was evaluated according to IEC 60730-1 Annex H by TÜV Rheinland.

Compliance with UL9540..... :	without
Compliance with UL1973..... :	On-going
Integrated fire protection system in the unit..... :	No integrated fire protection system

Diagram with dimension of R688AL-143





2.4 Photo

Module

Battery Rack

3 Unit level test (section 8 of UL 9540A)

3.1 General

Unit level testing corresponds with the testing anticipated by fire codes and other codes impacting energy storage system installations to evaluate the large scale fire performance of BESS units installed in, on or adjacent to buildings or in other areas and their resultant performance to qualify for exceptions to limits in the codes imposed on these installations. The limitations where exceptions may be sought are limitations on the size of the individual BESS units, the total number of BESS units installed within a room, and the separation distances between BESS units and between BESS units and walls of the building.

In this test the initiating BESS unit is placed a set distance from target BESS units simulating BESS units identical to the initiating BESS unit, and from simulated walls representative on the installation. A thermal runaway is induced in cells, using the same approach as used in the module level testing within one of the modules in the initiating BESS, and a variety of measurements are taken. The results are intended to be used to verify that a fire within a single BESS unit will not spread to other units, nor breach the walls or the BESS enclosure (if provided), and there shall be no flying debris or explosive discharge of gases.

The test arrangement include the largest (energy) BESS unit for the installation to be represented by the test, and minimum spacing to adjacent walls and BESS units. The BESS may be tested with an internal fire suppression system provided by the manufacturer if that fire suppression system is required to be installed in the BESS. Optional internal fire suppression systems are not included in the unit level testing.

The test monitors the fire behavior of the BESS unit and measures heat release rates (convective and chemical); gas generation and composition; smoke release rate; maximum heat flux on the target BESS units, wall surfaces and within the accessible means of egress; maximum surface temperatures of the walls and modules within the target BESS units; and documents any explosions, deflagrations and flying debris from the BESS under test.

3.2 Unit sample preparation

The battery system is constructed with open rack without enclosure. Three columns and two rows of the racks with 6 complete modules was considered as a unit for purposes of the test.

All 6 module samples were conditioned together as a unit, through 3 charge/ discharge cycles per the manufacturer's instructions to verify that the module was functional.

The Charge/discharge was performed at 140A. Each cycle was defined as a charge to 100% SOC and allowed to rest 60 minutes and then discharged to an end of discharge voltage (EODV) determined by the module specification. Refer to section 2.2 for the end of the condition of charge and discharge.

Cycling was conducted on Sept 01, 2022 under ambient temperature 25°C ± 3°C and R.H. 70% ± 5%.

3.3 Setup of the test

3.3.1 Battery system installation information

The installation information was provided by the client as below.

Intended use location ..... :	☐ Residential	☒ Non-residential
	☐ Non-residential rooftop	
	☐ Non-residential open garage use	
Type of installation ..... :	☒ Indoor	☐ Outdoor
	☒ Floor/ground mounted	☐ Wall mounted
Row(s) of installation	☐ Single	☒ Multiple

3.3.2 Test site setup

Two instrumented walls with 3.8 m height and 3.55 m width form a right angle. Walls were constructed of 5/8 in gypsum painted flat black.

Three racks were used for the purpose of the test. As specified by the manufacture, the two target racks will be installed up and down of the initial unit. All racks were positioned facing instrumented wall A. See Figure 1 and 2 and photos on page 45.

The initiating unit (unit A) was positioned at the middle, adjacent to the two instrumented wall sections.

The minimum separation distance from the rack to wall and between racks were defined by the client. Subject to the actual conditions of the testing environment, there was 1cm tolerance in the actual setup.

Figure 1 was the test site setup diagram with separation distance.

The test side setup was located under the smoke collection hood of the calorimeter measurement system.

Figure 1. Test site setup diagram with separation distance. (Top view)

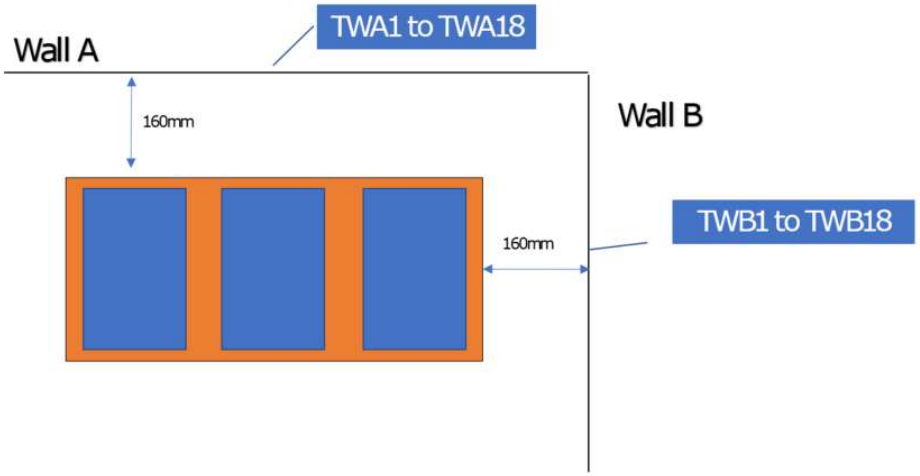
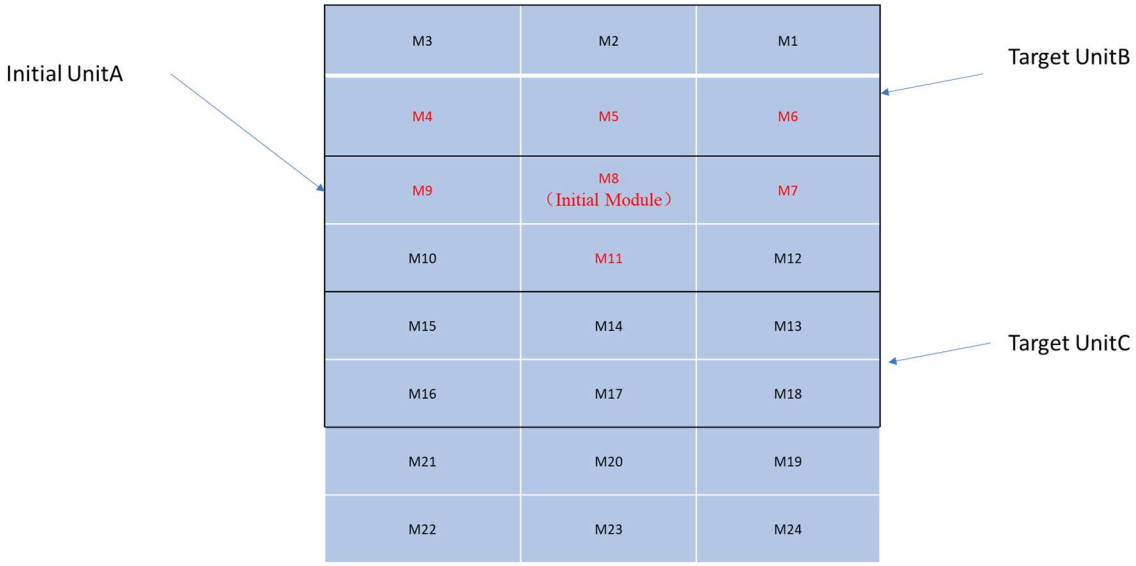


Figure 2. Test site setup diagram with separation distance. (Front view)



For the purpose of this test, the modules were numbered according to the electrical continuity.

In Initial Unit A, modules numbers from M7 to M12.

In Target Unit B, modules numbers from M1 to M6 which was the target unit situated above the Initial Unit A.

In Target Unit C, modules numbers from M13 to M18 which was the target unit situated below the Initial Unit A.

See Figure 3.

4 complete modules were used for unit A (M7 to M9 and M11).

3 complete modules were used for unit B (M4 to M6) to check the possible propagation form unit to unit.

Empty modules without cells were used for the other modules.

Figure 3. Module numbering in units showing fully populated modules in red.

M3	M2	M1
M4	M5	M6
M9	M8 （Initial Module）	M7
M10	M11	M12
M15	M14	M13
M16	M17	M18
M21	M20	M19
M22	M23	M24

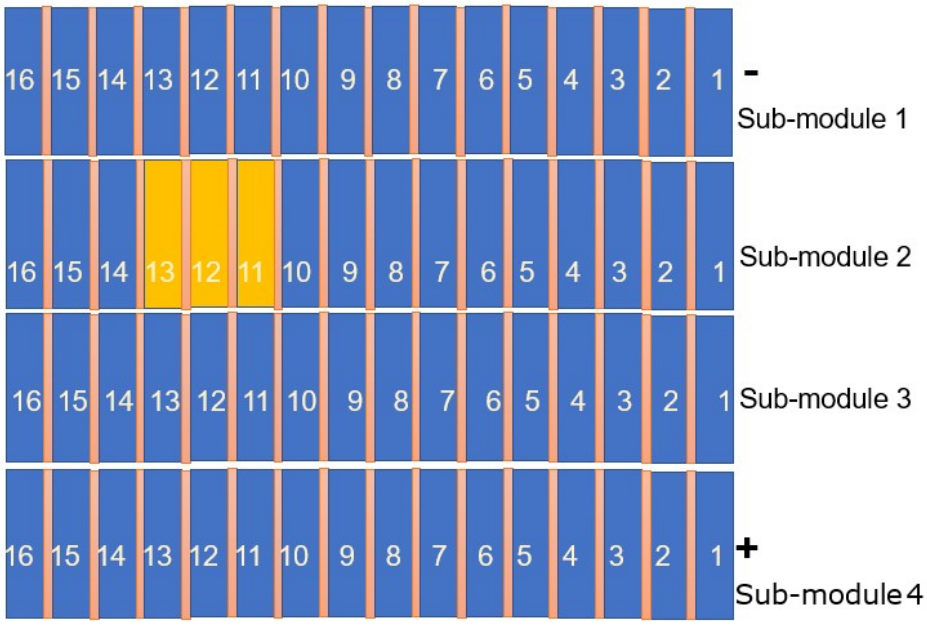
3.3.3 Thermal runaway setup

External heating method, agreed with the client, was used to initiate the thermal runaway within the module.

Module M8 was prepared with two heaters inside. Same as the method in module level test.

For convenient show the temperature condition of internal cells, numbering four lines cells from negative electrode to positive electrode for sub-module 1 to sub-module 4. Numbering cells in every sub-modules from electrodes side to another side for cell 1 to cell 16, see figure 4 for detail.

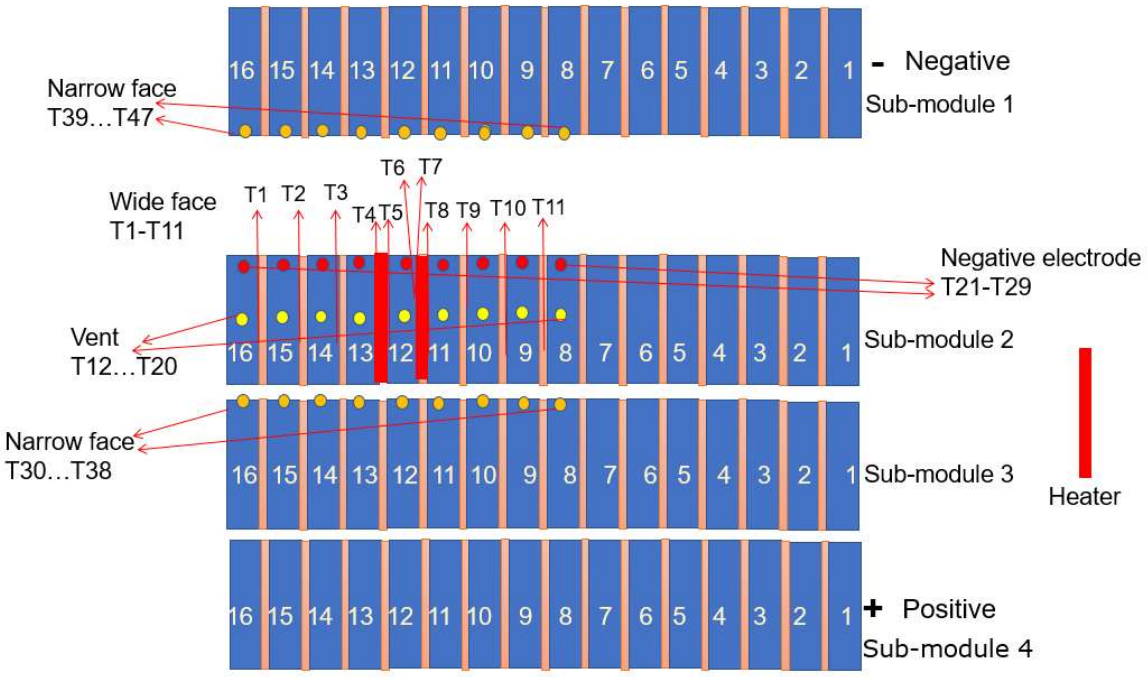
Figure 4. Cell numbering inside the initiating module



Consider the unit level installation and airflow of the liquid cooling in the module. #11, #12 and #13 cells of sub-module 2 were chosen as target cell to be forced into thermal runaway.

The cell #12 was heated by two external heater on each wide side, the cell #11 and cell#13 was heated by one external heater on wide near cell #12. The heater is rated 220VAC/500 W (size 207*174*4mm).

Figure 5. Thermocouples on initiating module M8



In sub-module 1,

9 glass fiber thermocouples (#39-#47) Type K, 24AWG were attached on the #16-#8 cells center of narrow surface near sub-module 2, used to check the possible propagation form cell to cell.

In sub-module 2,

1 glass fiber thermocouples (#T7) Type K, 14AWG was attached on the center of wide surface of #12 cell under heater used to feedback the temperature to the heater controller.

4 glass fiber thermocouples (#T4, #T5, #T6, #T8) were attached on the center of wide surface of #13, #12 and #10 cells under heater used to determine the thermal runaway of initiating cells.

6 glass fiber thermocouples (#1-#3, #9-#11) were attached on the center of wide surface of #16-#14, #10-#8 cells under heater used to check the possible propagation from cell to cell.

8 glass fiber thermocouples (#12-#20) were attached above the vent of #16-#8 cells used to record the venting time.

8 glass fiber thermocouples (#21-#29) were attached on the negative electrode of #16-#8 cells used to observe the temperature change.

In sub-module 3,

9 glass fiber thermocouples (#30-#38) Type K, 24AWG were attached on the #16-#8 cells center of narrow surface near sub-module 2, used to check the possible propagation form cell to cell.

The initiating module M8, Internal voltage sample wire and signal wire covered by glass fiber tube. The BMS control board disabled during test.

Manual control the voltage supply to the heater and maintain a 4°C/min to 7°C/min heating rate. When heater temperature reached to 150°C (T-set), hold about 30min (10:13 to 10:43), then continue to heat and maintain a 4°C/min to 7°C/min heating rate.

Once thermal runaway was observed, the heaters were immediately de-energized.
One thermocouple located below the heater at the center of #12 cell surface was used to feedback the temperature to the controller.

Voltage of the module are monitored during test.

The units was located under the smoke collection hood of the calorimeter measurement system.

3.4 Observations and records

Before the test, the initiating module was 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.

The ambient condition at the initiation of the test was 25°C, 66% RH.

The voltage of the modules was recorded as below:

Figure 6: Voltage record of cells during the test

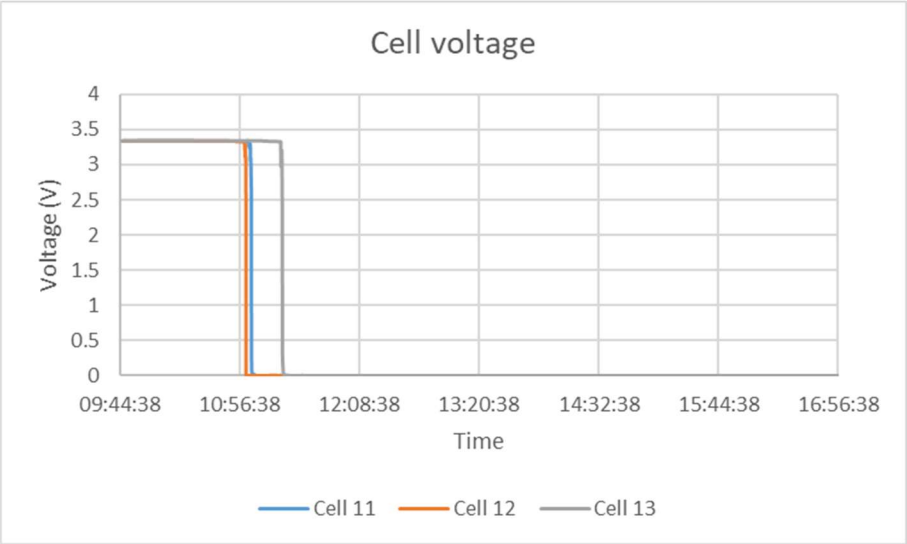
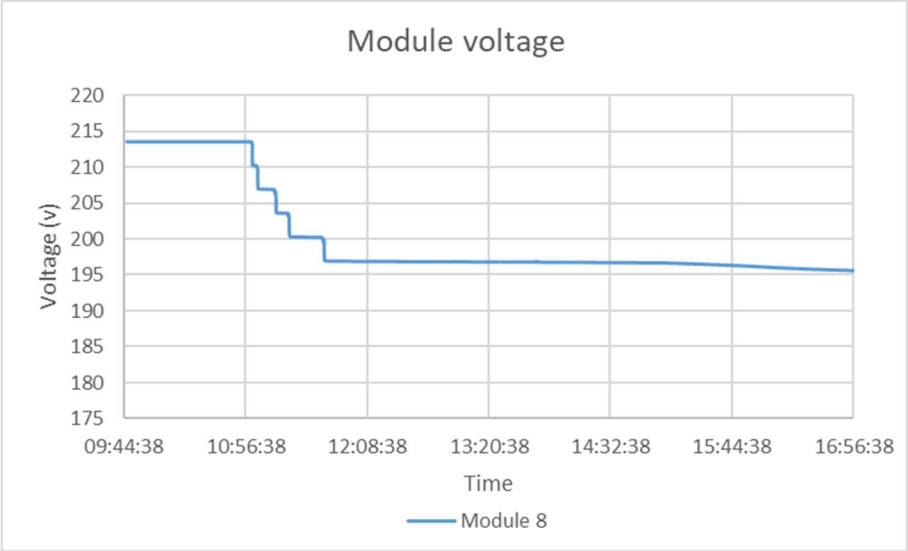


Figure 7: Voltage record of modules during the test



Tests were performed on Sep 02, 2022, started at 09:50 AM.

Observations during the test:

Audible pop was heard on 10:55 AM (the pressure relief valve burst), followed by smoke release after several seconds.

A large amount of white smoke was observed after thermal runaway.

Cell to cell propagation was observed in the initial model.

Module to module propagation was not observed.

No flying debris or explosive discharge of gases observed during test.

No sparks, electrical arcs, or other electrical events observed during test.

No external flaming was observed during the test.

Observations after the test:

No damage and contamination on the instrument walls.

No damage and contamination on the modules of target units.

The plastic top enclosure near the initial cell of module M8 was melted and significantly damaged. Module voltage of M8 was 194.8 Vdc.

Five cells inside the initial module M8 were damaged. Cell to cell propagation were observed on cells #14, #15 of sub-module 2 after receiving thermal energy from cell #13. Voltage measured on each remaining undamaged in other sub-modules were 3.33Vdc.

Weight loss of the initiating module was 1.5 kg (before test 401.5kg, after test 400.0kg)

See photos in page 44~49.

3.5 Temperature measurements

3.5.1 Temperature measurement of initiating cells

Surface temperature of cells #8 - #16 of sub-module 1 to sub-module 3 was recorded during the test. Cell to cell propagation occurred during the test. See Figure 8 for the temperature vs time curve.

Cell thermal runaway occurred on cell #12, #13, #11 in turn at around 11:00, 11:03, 11:12 Maximum temperature 566.7°C, 555.1°C, 449.0°C were measured on the cell #12, #13, #11 surface.

Cell to cell thermal runaway propagation occurred on cell #14, #15. Maximum temperature 587.5°C, 512.3°C were measured on the cell #14, #15 surface.

Figure 8. Surface temperatures of thermal runaway cells on module M8 (sub-module 2)

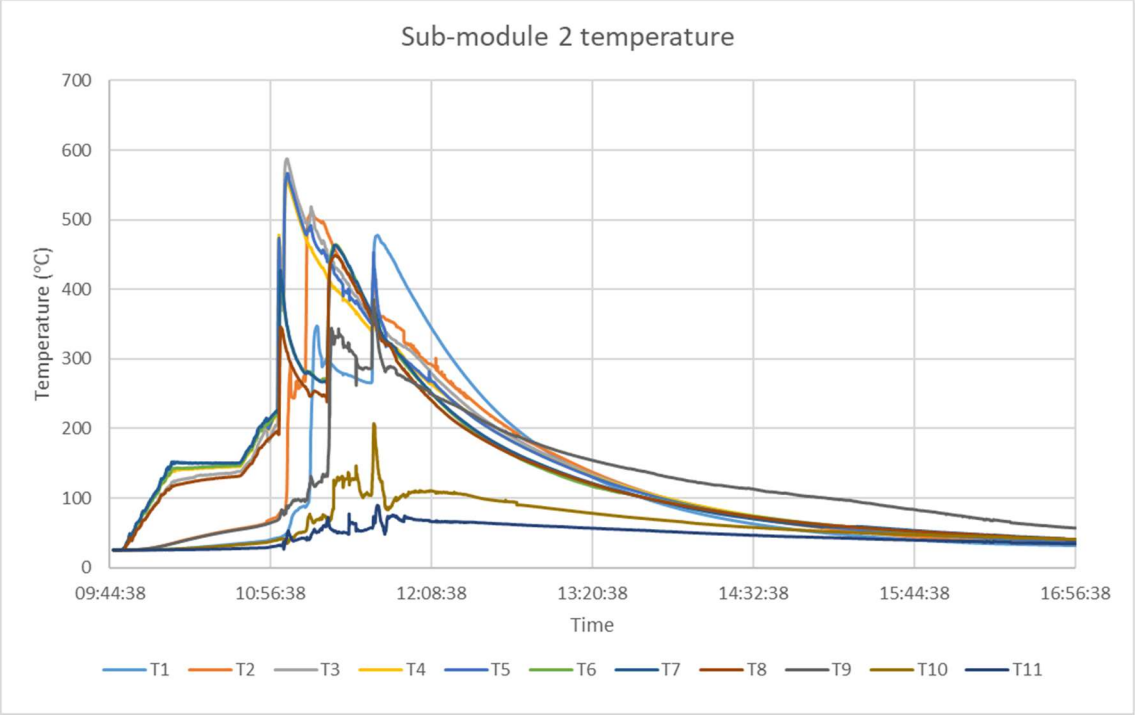


Table 1 Maximum temperature of sub-module 2 cells

Thermocouple no.	Location	Maximum temp.(℃)
T1	Wide surface of Cell #16	477. 9
T2	Wide surface of Cell #15	512. 3
T3	Wide surface of Cell #14	587. 5
T4	Wide surface of Cell #13	555.1
T5	Wide surface of Cell #12	566. 7
T6	Wide surface of Cell #12	464. 7
T7	Wide surface of Cell #12 for feedback	463. 2

T8	Wide surface of Cell #11	449. 0
T9	Wide surface of Cell #10	385. 0
T10	Wide surface of Cell #9	207. 2
T11	Wide surface of Cell #8	89. 9

Cells thermal runaway in sub-module 1 did not occur, maximum temperature see table 2 for detail.

Figure 9. Surface temperatures of no thermal runaway cells on sub-module 1 of module M8

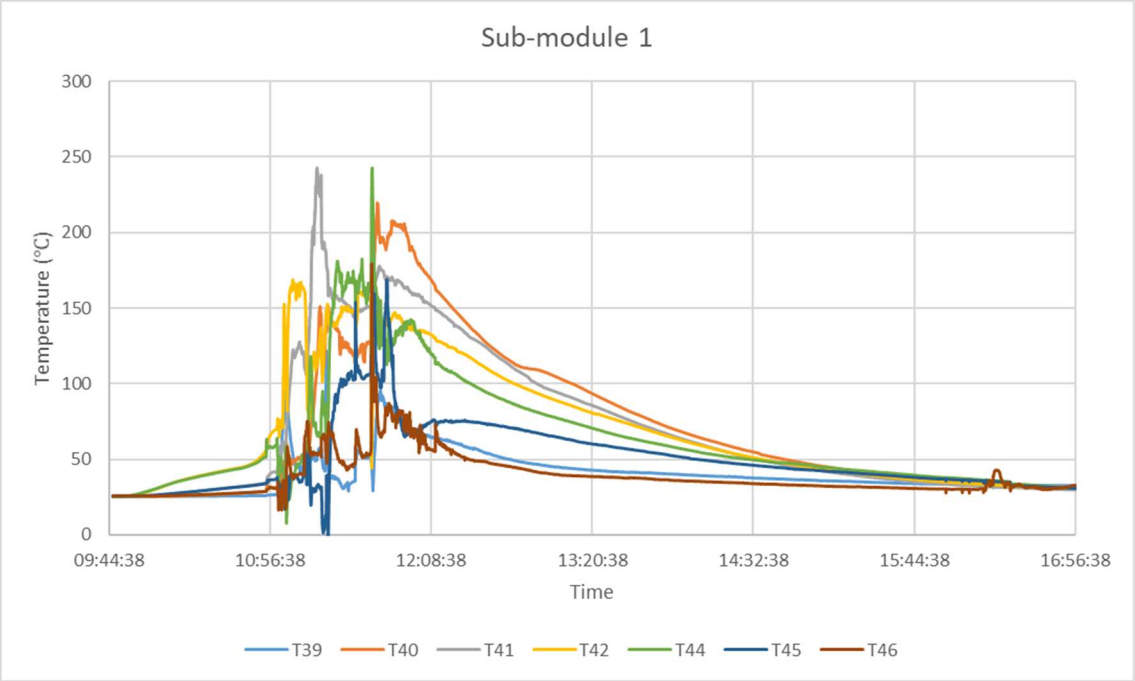


Table 2 Maximum temperature of sub-module 1 cells

Thermocouple no.	Location	Maximum temp.(℃)
T39	Narrow surface of cell #16	120.7
T40	Narrow surface of cell #15	219.6
T41	Narrow surface of cell #14	242.8
T42	Narrow surface of cell #13	168.8
T43	Narrow surface of cell #12	--
T44	Narrow surface of cell #11	242.7
T45	Narrow surface of cell #10	169.0
T46	Narrow surface of cell #9	179.2
T47	Narrow surface of cell #8	-

Note: #T43, 47 thermocouples may be damaged during test.

Cells thermal runaway in sub-module 3 did not occur, maximum temperature see table 3 for detail.

Figure 10. Surface temperatures of no thermal runaway cells on sub-module 3 of module M8

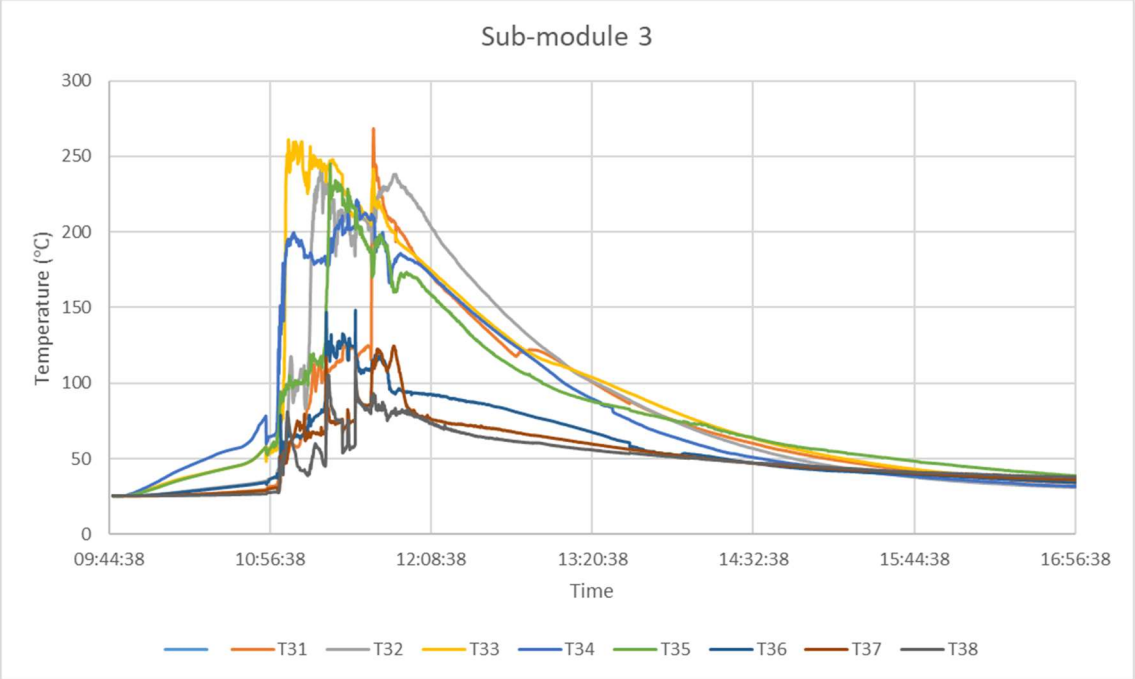


Table 3 Maximum temperature of sub-module 3 cells

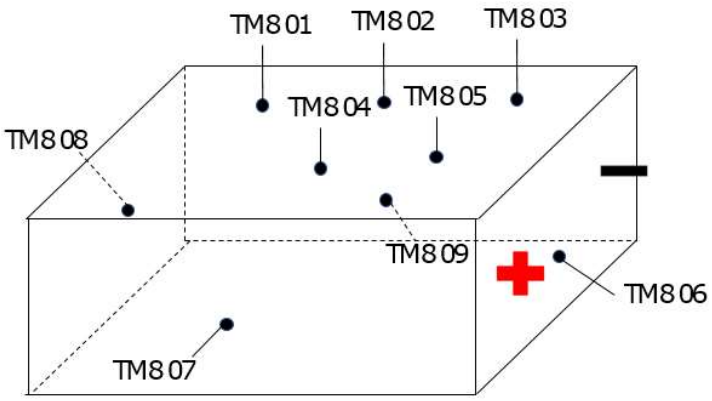
Thermocouple no.	Location	Maximum temp.(℃)
T30	Narrow surface of cell #16	--
T31	Narrow surface of cell #15	268.4
T32	Narrow surface of cell #14	241.5
T33	Narrow surface of cell #13	261.0
T34	Narrow surface of cell #12	221.3
T35	Narrow surface of cell #11	244.7
T36	Narrow surface of cell #10	148.3
T37	Narrow surface of cell #9	124.5
T38	Narrow surface of cell #8	116.7

Note: #T30 thermocouples may be damaged during test.

3.5.2 Temperature measurement of units

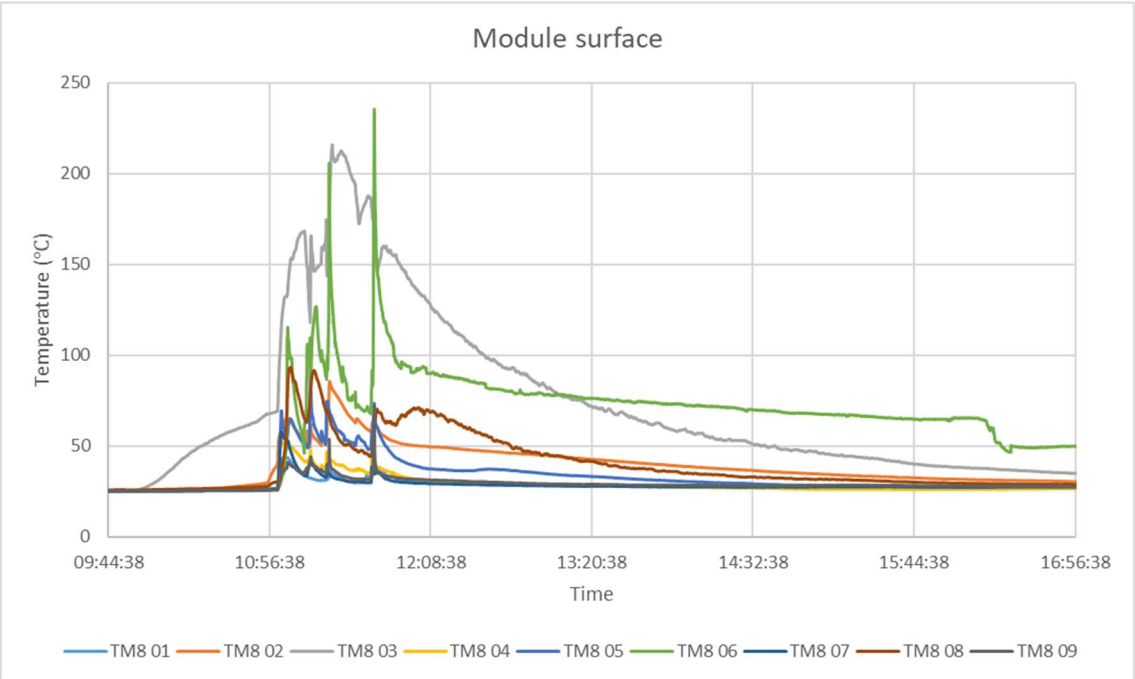
9 glass fiber insulated thermocouples (TM8 01~TM8 09), Type K, 24 AWG was attached on the external surface of module M8, as below Figure 8.

Figure 11. Thermocouple of module M8 surface



TM8 01~TM8 03 located on top surface above cell in sub-module2. TM8 04, TM8 05 located on top surface above cell in sub-module 3. TM8 06 located on front of module (electrode side), TM8 07 located on the left side surface, TM8 08 located on the rear side, TM8 09 located on the right side surface. Maximum temperature 235.5°C was measured on top of the module near #12 cell.

Figure 12. Surface temperatures of initiating module M8

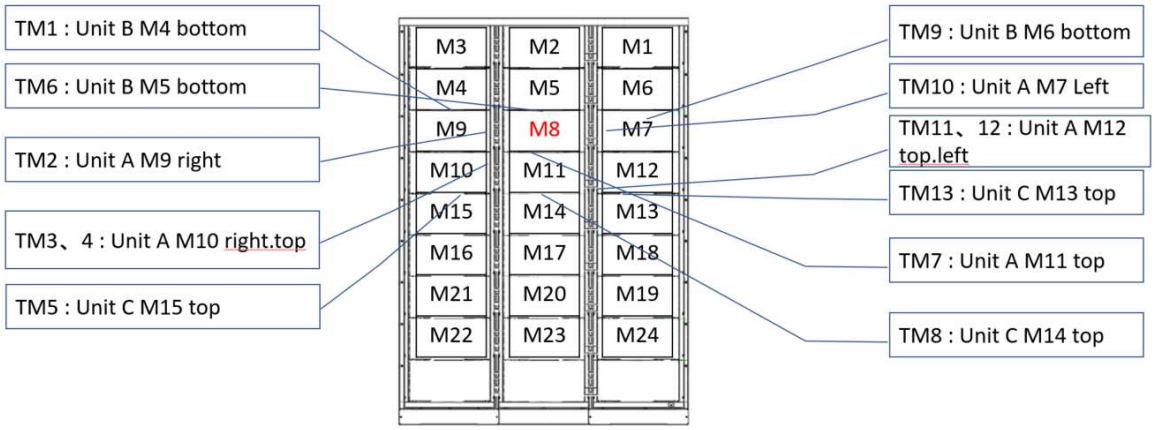


13 glass fiber insulated thermocouples (TM1 to TM13), Type K, 24 AWG were attached to the center of the top surface of modules M4 to M15.

Maximum temperature 30.5°C was measured on bottom surface of the module M5 of Unit B.

Maximum temperature 30.8°C was measured on top surface of the module M14 of Unit C.

Figure 13. Thermocouple location on modules in units A,B,C (Rack 1)



View direction: towards instrument wall A with reference to Figure 2

Figure 14. Surface temperatures of modules from M4 to M15

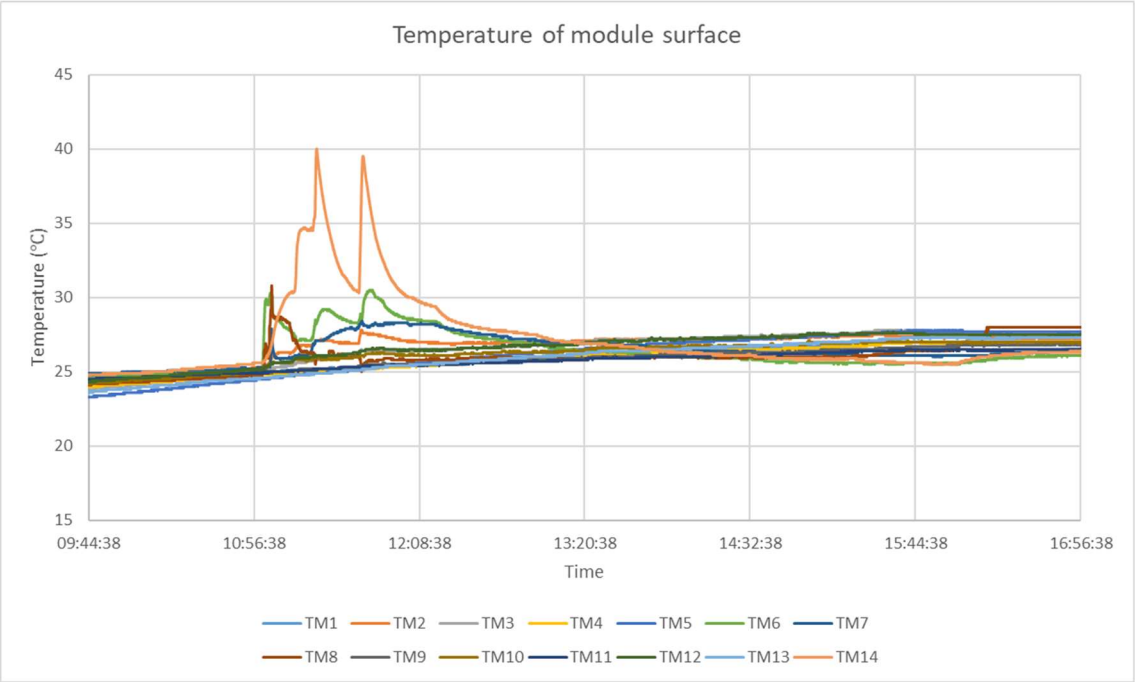


Figure 15. Thermocouple location on the back side of Wall A

View direction: from instrument wall A with reference to Figure 2

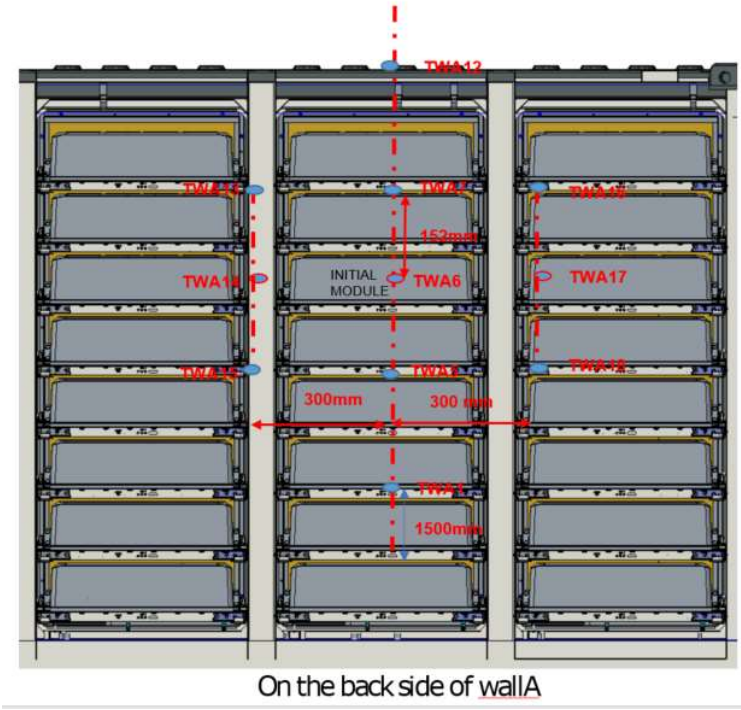
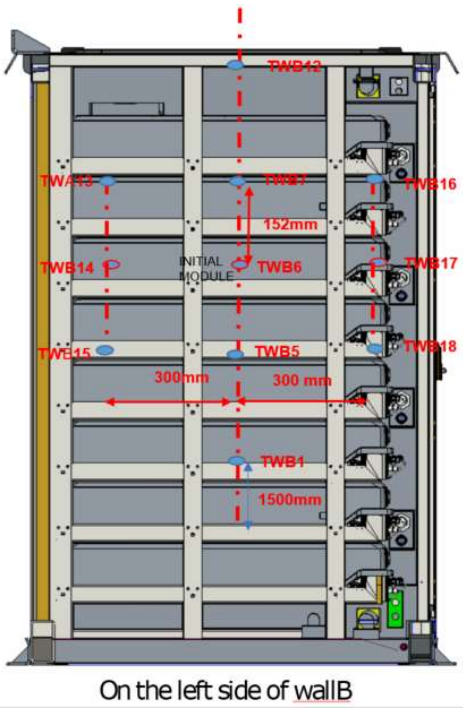


Figure 16. Thermocouple location on the left side of wall B

View direction: towards instrument wall B with reference to Figure 2



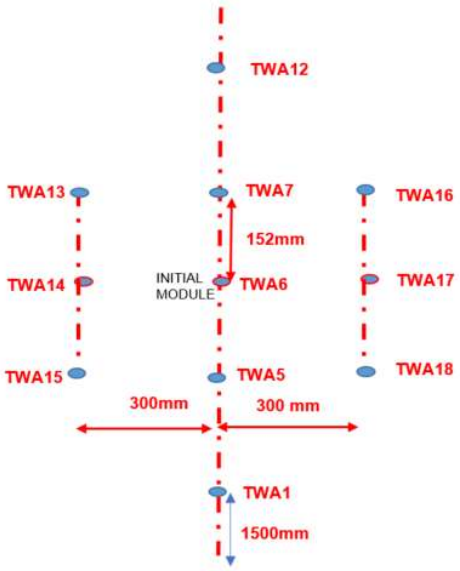
3.5.3 Temperature measurement of instrumented walls

Wall surface temperatures were measured in vertical arrays at 152 mm intervals for the full height of the instrumented wall sections using Type K, 30 AWG thermocouple. The thermocouple arrays were collinear with the centre line of Initial Unit A. The red line in Figure 12 shows the thermocouple arrays on the wall.

The first thermocouple starts from 1500 mm from ground. Total 36 thermocouples were used for each array. The thermocouples were numbered from low to high as TWA1 to TWA18 for wall A and TWB1 to TWB18 for wall B.

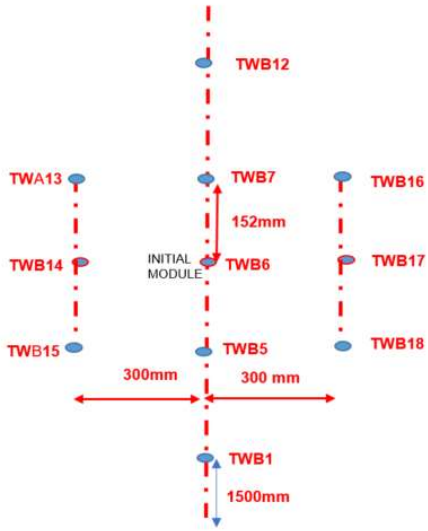
Figure 17. Vertical position of the thermocouples on the wall

Instrumented wall A



View direction: towards instrument wall A with reference to Figure 2

Instrumented wall B



View direction: towards instrument wall B with reference to Figure 2

Additional 6 thermocouples were positioned horizontally near the initial module M8 300 mm away from the vertical array each side, on instrumented wall A and wall B. See Figure 18.

Maximum temperature measured on instrument wall A was 24.3°C at TWA13, temperature curve see figure 19 for detail.

Maximum temperature measured on instrument wall B was 23.9°C at TWB3, temperature curve see figure 20 for detail.

Figure 18. Horizontal position of the thermocouples on the wall A and wall B

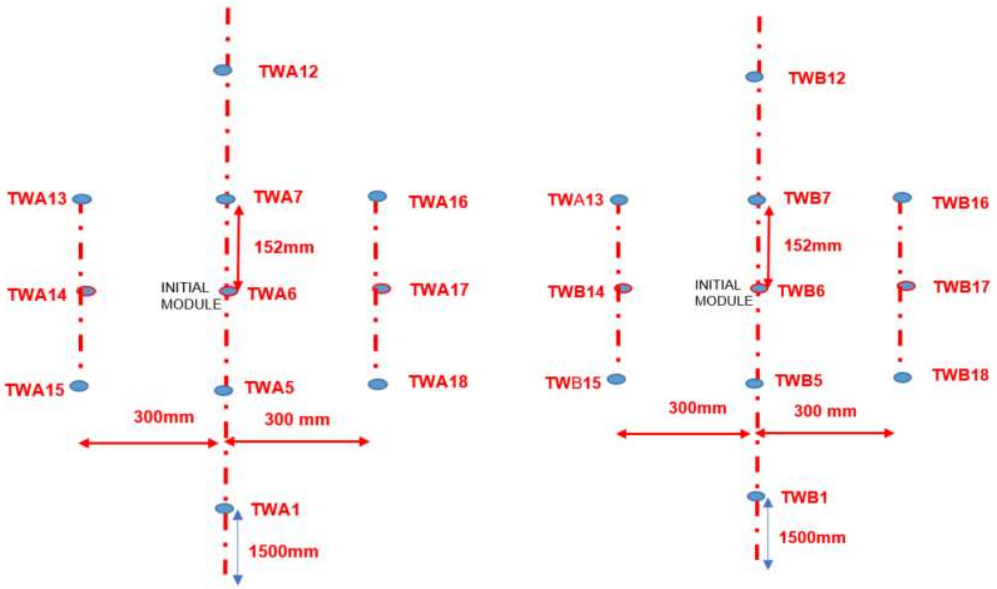


Figure 19. Temperatures on instrument wall A.

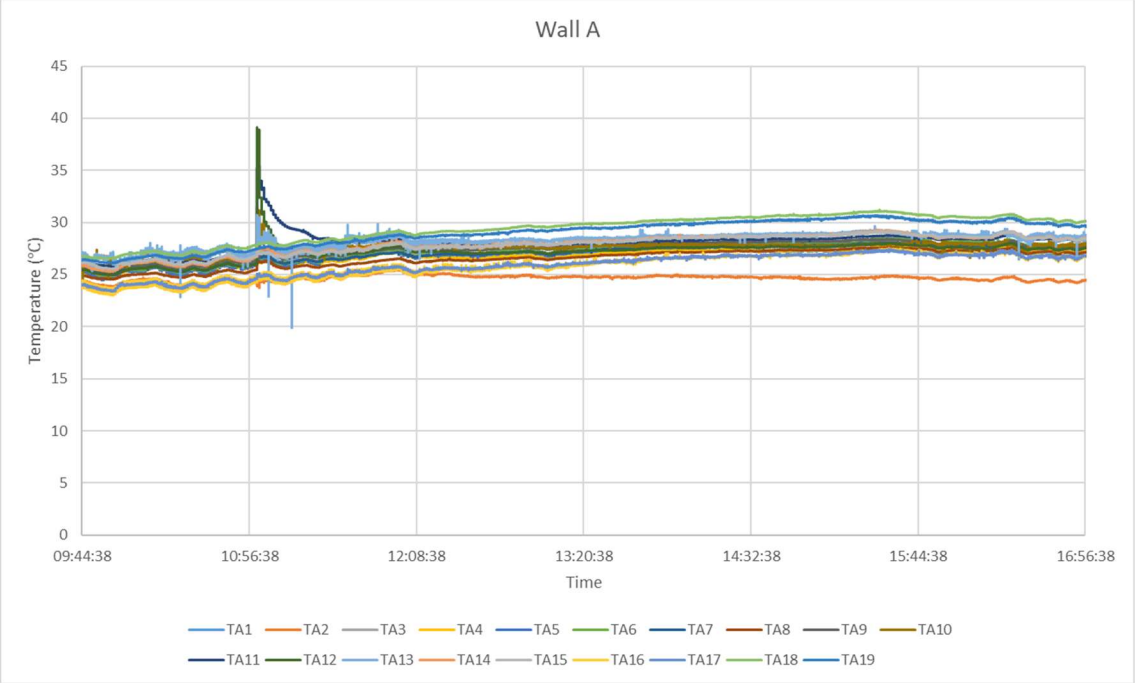
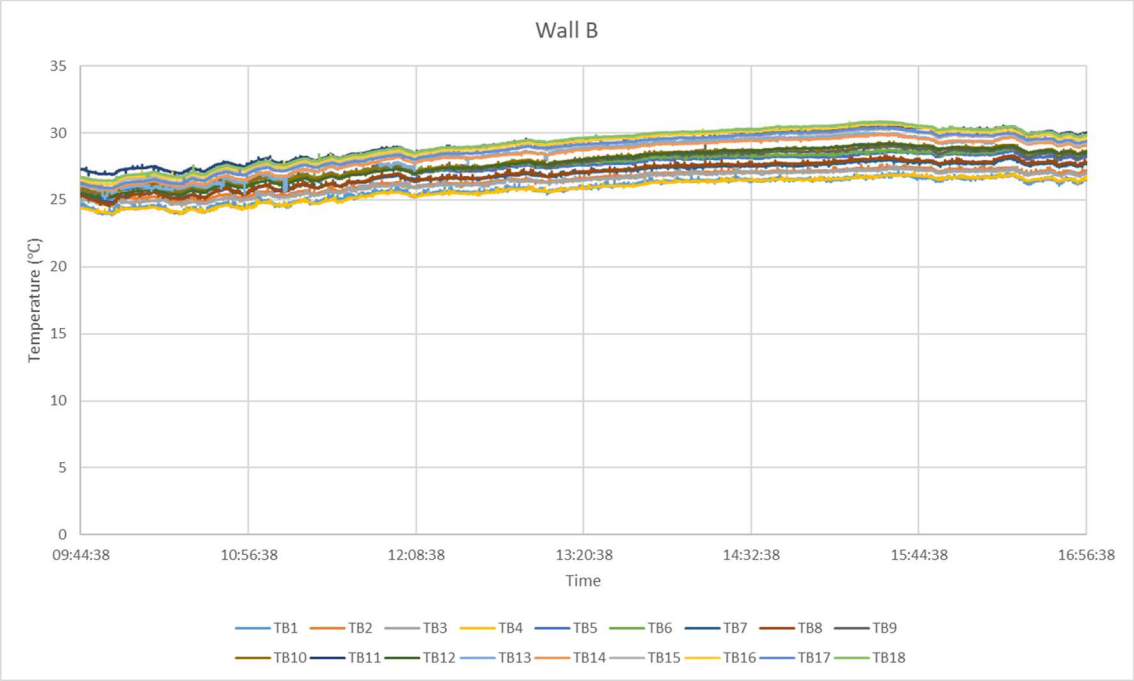


Figure 20. Temperatures on instrument wall B.



3.6 Heat flux measurement

Two sensors were placed on the surface of instrumented wall A, wall B and adjacent unit A that faces the initiating unit.

The sensors were collinear with the vertical thermocouple array. One was positioned at the height equivalent to module M8 top edge, which was estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating unit. Another was positioned at the height equivalent to module M11 top edge, which was estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating unit.

Figure 21 shows the positions of the sensors. Sensor H1 & H2 were positioned at unit A; H3&H4 were positioned at wall A, H5&H6 were positioned at wall B, All sensors were numbered from low to high.

Measured heat flux of target wall and target units are zero.

Figure 21. Heat flux sensor locations on unit

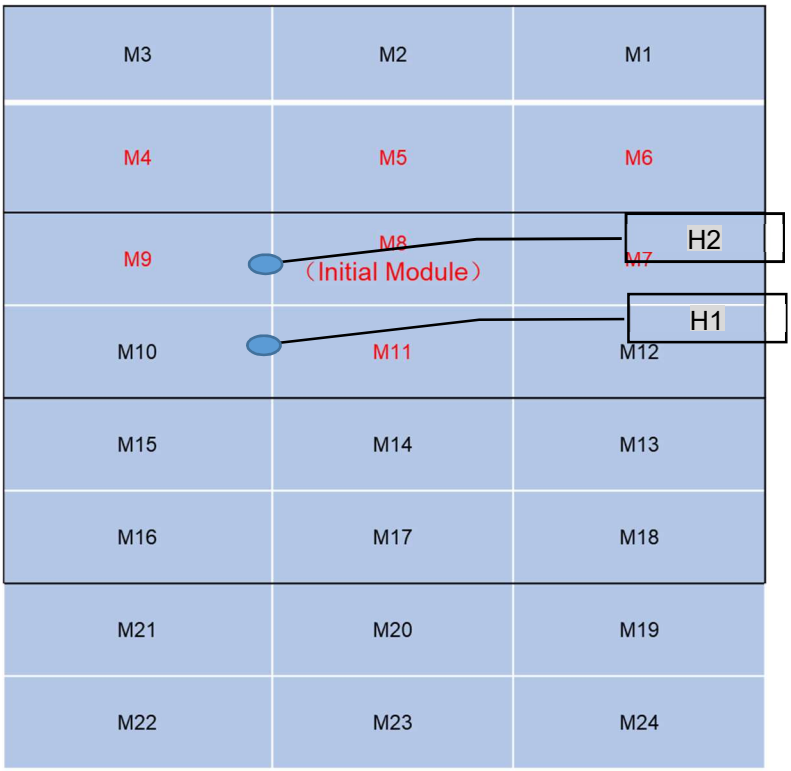
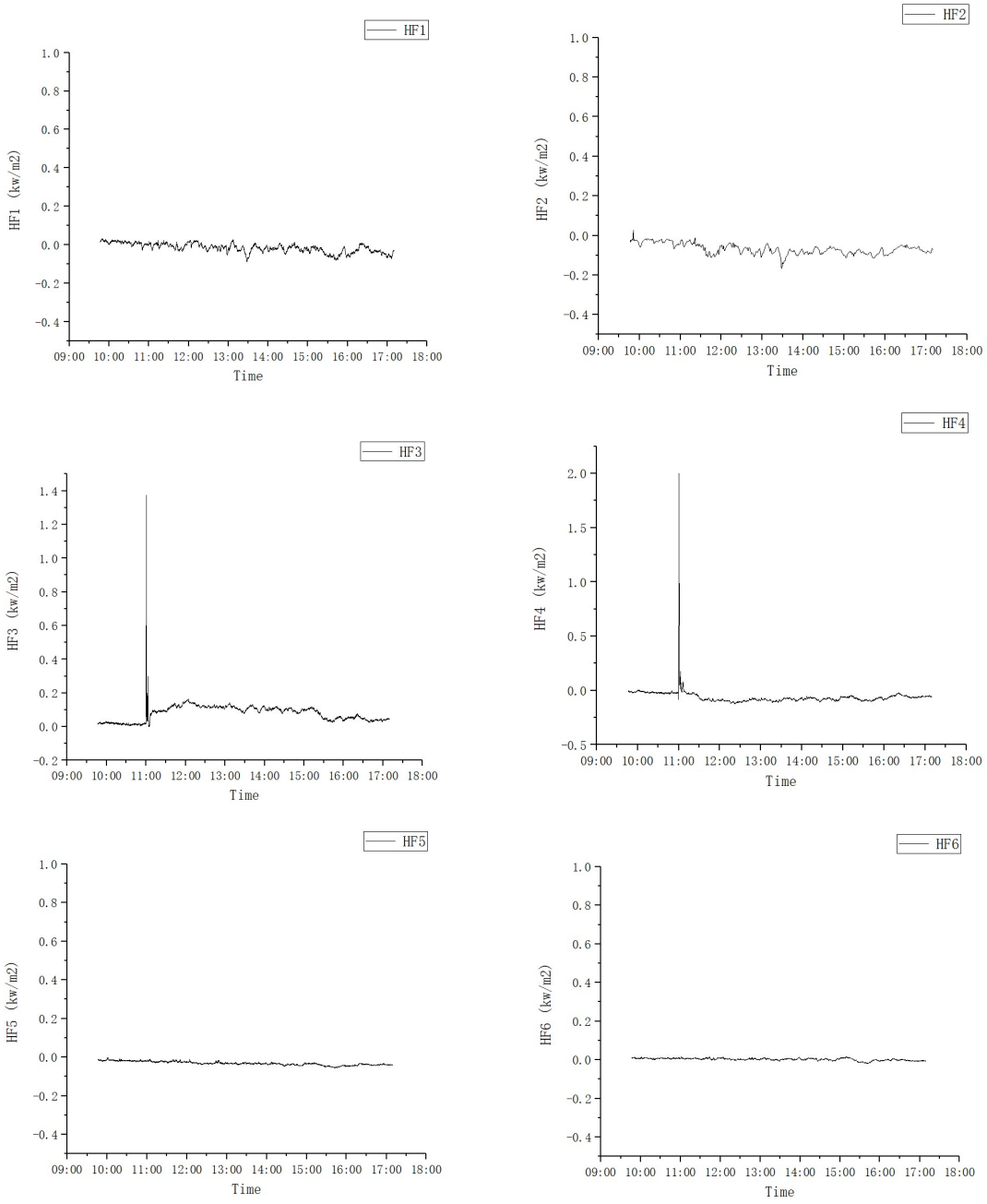


Figure 22. Measured heat flux of target wall and target units



3.7 Chemical heat release rate measurement

The chemical heat release rates were measured by an oxygen consumption calorimeter measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple.

The instrumentations are located in the exhaust duct of the heat release rate calorimeter.

The chemical heat release rate was calculated at each of the flows as follows:

$$HRR_1 = \left[E \times \varphi - (E_{co} - E) \times \frac{1-\varphi}{2} \times \frac{X_{co}}{X_{O_2}}\right] \times \frac{\dot{m}_e}{1+\varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^o_{H_2O}) \times X^o_{O_2}$$

In which:

HRR_t = *total heat release rate, as a function of time (kW)*

E = *Net heat released for complete combustion per unit of oxygen consumed (adjusted for oxygen contained within cell chemistry, 13,100 kJ/kg)*

E_{CO} = *Net heat released for complete combustion per unit of oxygen consumed, for CO (adjusted for oxygen contained within cell chemistry, 17,600 kJ/kg)*

φ = *Oxygen depletion factor (non-dimensional), where:*

$$\varphi = \frac{X^o_{O_2} \times [1 - X_{CO_2} - X_{CO}] - X_{O_2} \times [1 - X^o_{CO_2}]}{X^o_{O_2} \times [1 - X_{O_2} - X_{CO_2} - X_{CO}]}$$

X_{CO} = *Measured mole fraction of CO in exhaust flow (non-dimensional)*

X_{CO_2} *Measured mole fraction of* CO_2 *in exhaust flow (non-dimensional)*

$X°_{CO_2}$ = *Measured mole fraction of* CO_2 *in incoming air (non-dimensional)*

$X°_{H_2O}$ = *Measured mole fraction of* H_2O *in incoming air (non-dimensional)*

X_{O_2} = *Measured mole fraction of* O_2 *in exhaust flow (non-dimensional)*

$X°_{O_2}$ = *Measured mole fraction of* O_2 *in incoming air (non-dimensional)*

α = *Combustion expansion factor (non-dimensional; normally a value of 1.105)*

M_a = *Molecular weight of incoming and exhaust air (29 kg/kmol)*

M_{O_2} = *Molecular weight of oxygen (32 kg/kmol)*

$\dot{m}_e$ = *Mass flow rate in exhaust duct (kg/s), in which:*

$$\dot{m}_e = C \times \sqrt{\frac{\Delta p}{T_e}}$$

or

$$\dot{m}_e = 26.54 \times \frac{A \times k_c}{f(\mathrm{Re})} \times \sqrt{\frac{\Delta p}{T_e}}$$

C = Orifice plate coefficient (in $kg^{1/2}m^{1/2}K^{1/2}$)

Δp = Pressure drop across orifice plate or bidirectional probe (Pa)

T_e = Combustion gas temperature at orifice plate or bidirectional probe (K)

A = Cross sectional area of the duct (m^2)

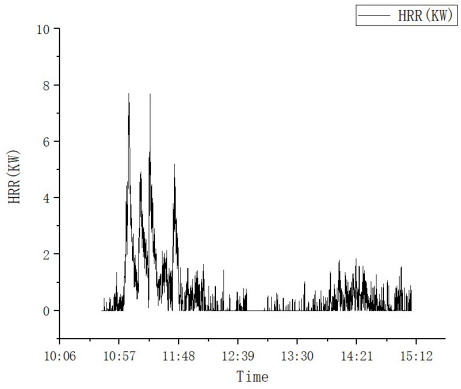
k_c = Velocity profile shape factor (non-dimensional)

$f(Re)$ = Reynolds number correction (non-dimensional)

The heat release rate measurement system was calibrated at 50kW and 70kW heat release rate using a standard propane burner before the test. The calibrations were performed using flows of 1078mg/s and 1510mg/s of propane.

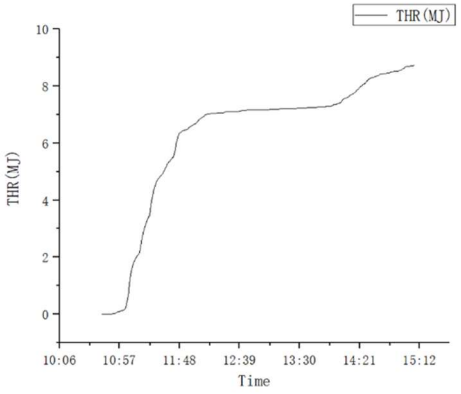
Measured peak chemical heat release rate HRR_t was 7.713kW

Figure 23. HRRt curve



Measured total heat release THR through the test was 8.736 MJ

Figure 24. THR curve



3.8 Convective heat release rate measurement

The convective heat release rate was measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct.
The convective heat release rate was calculated at each of the flows as follows:

$$HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$$

Where:

HRR_c = The convective heat release rate (kW)

V_e = The exhaust velocity (m/s)

A = The exhaust duct cross sectional area (m^2)

T_e = The temperature at the location where exhaust velocity is measured (K)

$353.22/T_e$ = The density of air at the velocity measurement location (kg/m^3)

T_o = The ambient temperature (K) in the test room

T = The thermopile temperature (K)

$$\int_{T_o}^{T} C_p dT = A_0(T - T_o) + A_1/2(T^2 - T_o^2) + A_2/3(T^3 - T_o^3) + A_3/4(T^4 - T_o^4)$$

Cp = Specific heat of air (kJ/kg-K), given as $C_p = A_0 + A_1T + A_2T^2 + A_3T^3$, where:

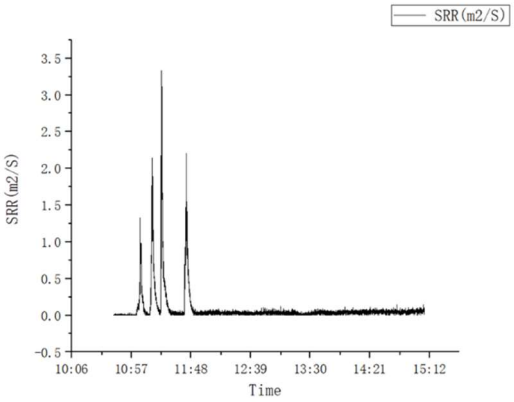
A_0 = 0.9950

A_1 = -5.29933E-05

A_2 = 3.21022E-07

A_3 = -1.22004E-10

Figure 25. Peak smoke release rate SRR: 3.339 m2/s



3.9 Gas generation measurement

The composition, velocity and temperature of the vent gases were measured within the calorimeter's exhaust duct.

Gas compositions were measured using a Fourier-Transform Infrared Spectrometer with a resolution of 1 cm^{-1} and a path length of 4.2 m within the calorimeter's exhaust duct.

The total hydrocarbon content of the vent gas was measured using flame ionization detection.

Hydrogen gas was measured with electrochemical method.

Composition, velocity and temperature measurement instrumentation were collocated with heat release rate calorimetry instrumentation.

3.9.1 Total gas release

The flow rates of various gases were integrated over the test duration and the total cumulative volume of gas calculated for the total test duration (09:50 ~ 16:53) was presented in the below table.

The total cumulative volume of gases before cell venting (09:50 ~ 10:55) was also presented in the table for reference. Which may be considered as ambient gases background before the test.

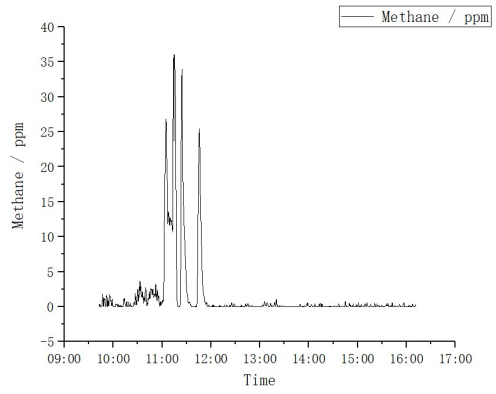
Gas type	Gas components		Total volume of gas (L)	
			Before cell venting	Throughout the test
Hydrocarbon species	Methane	CH_4	1.40	54.56
	Acetylene	C_2H_2	0.90	4.10
	Ethylene	C_2H_4	0.87	35.04
	Ethane	C_2H_6	0.33	20.06
	Propane	C_3H_8	0.18	32.23
Hydrogen halide species	Hydrogen Cyanide	HCN	0.04	3.80
	Hydrogen Fluoride	HF	0.00	4.43
Nitrogen containing species	Nitrogen Monoxide	NO	0.1	29.1
	Nitrous Oxide	N_2O	1.34	21.62
Others	Carbon Monoxide	CO	0.00	115.10
	Carbon Dioxide [2)]	CO_2	896.00	6112.00
	Hydrogen	H_2	0.00	71.39
	Oil as octane	--	0	25.3
	Formaldehyde	CH_2O	0.01	0.37
	Methanol	CH_4O	0.46	10.27
Total Hydrocarbons (equivalent to C_3H_8, measured by FID)				1547.57

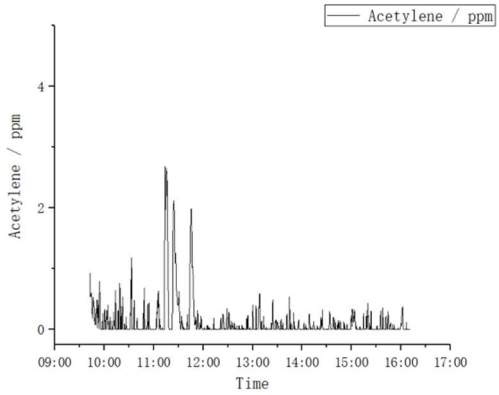
Note:
1) The collection time is from 09:50 to 16:53;
2) The carbon dioxide in the air during this period1) was also counted;
3) 3) The Hydrogen was measured by palladium nickel thin film solid state sensor.

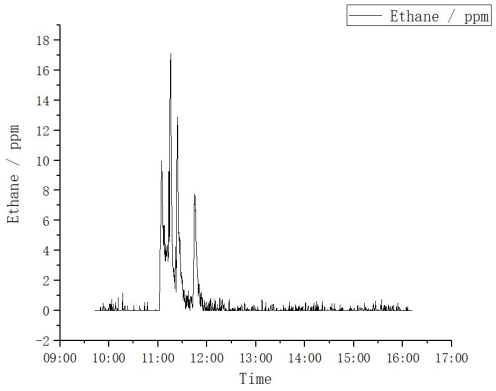
3.9.2 Gas components

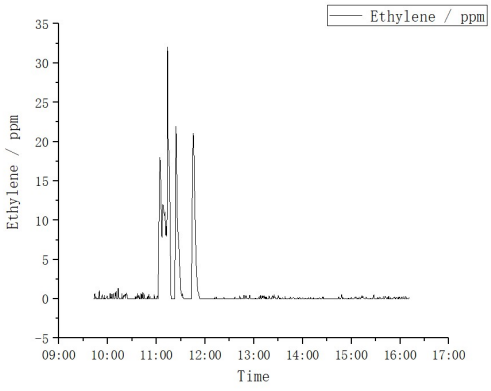
Concentrations of the gases were scaled based on the measured flow rate of the exhaust system and were presented in the standard volume flow rate of gas ventilated in below figures.

Figure 26. Hydrocarbon species









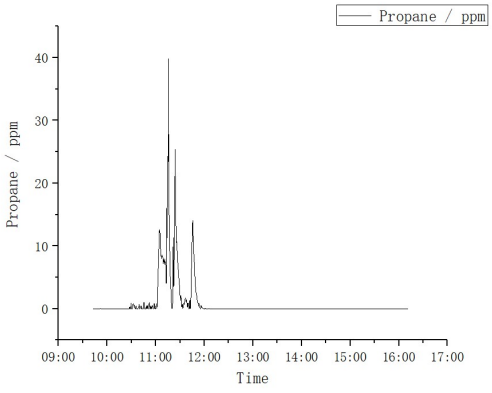


Figure 27. Hydrogen halide species

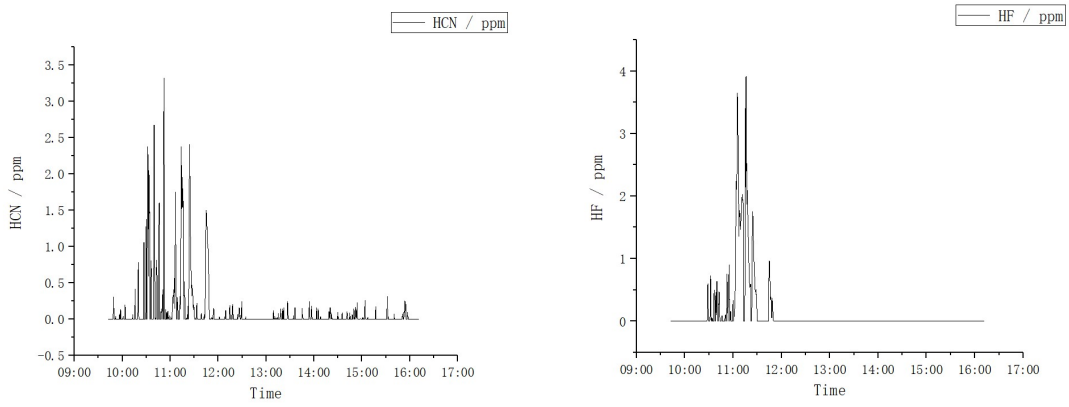


Figure 28. Nitrogen containing species

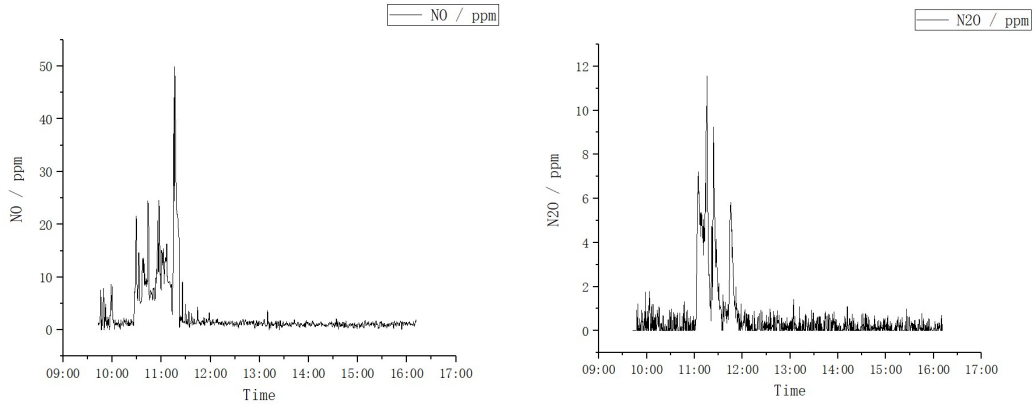


Figure 29. H_2 containing species

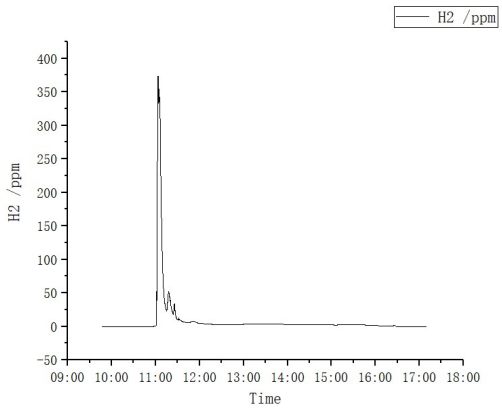
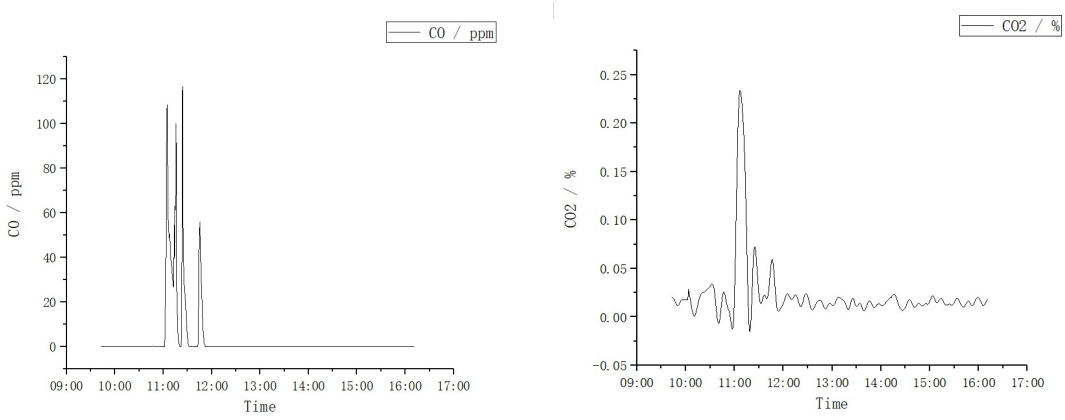


Figure 30. CO, CO_2 containing species

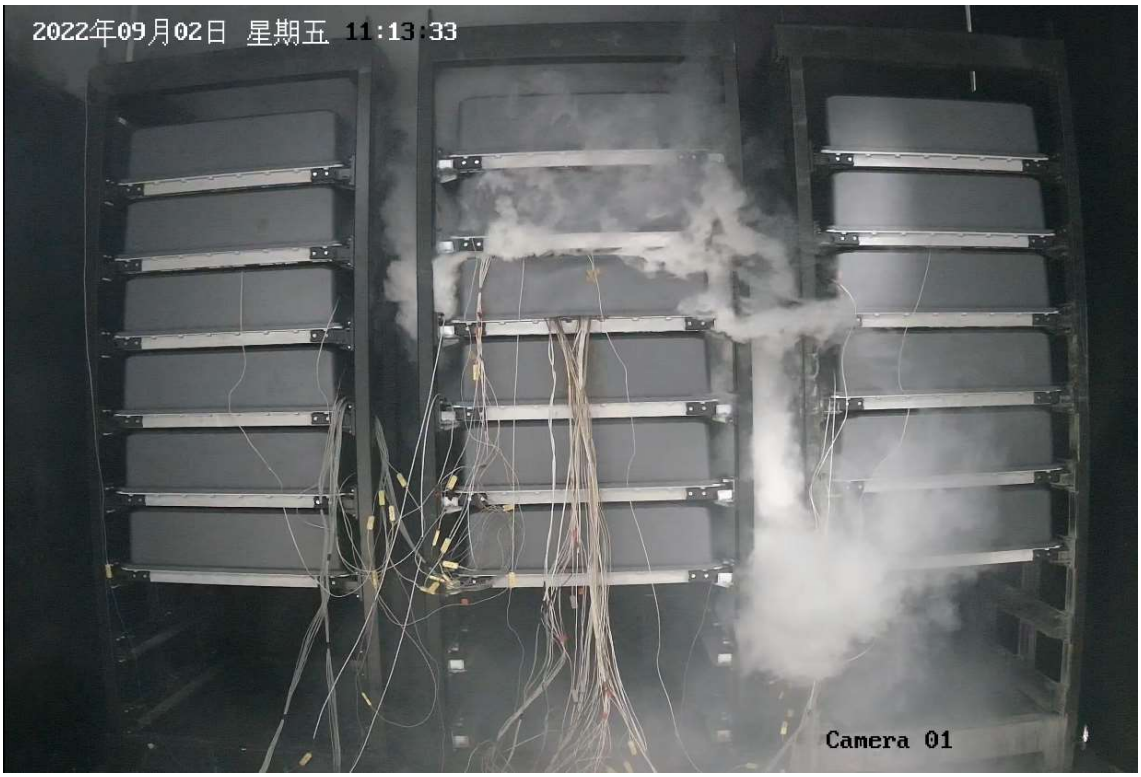


3.10 Photos

Initial module

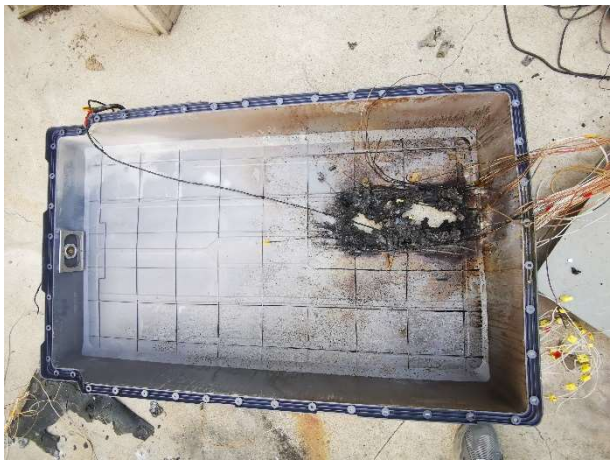
Test setup

Smoke release during the test



Photos after the test

Initial module after test



4 List of Test and Measurement Instruments

No.	Equipment	Model	Rating	Inventory no.	Last Cal. date
1	Ambient temperature and humidity	HWP01-10S	-30℃~50℃, 20%RH~100%RH	12005577	2022.5.16
2	Data acquisition equipment	DAQ970A	3-slot cardcage with 6½ digit (22 bit) internal DMM 0.004%, accuracy 0.06% Vac	TY2020000138	2022.3.5
3	Electronic scale	CHAOOUC1	0-500KG	65960494169	2022.3.9
4	Paramagnetic oxygen analyser	SERVOMEX4100	O2: paramagnetic sensor, range 0-25%, accuracy 0.02%, response time T90 < 7S	ZY2020000018-1	2022.3.9
5	Velocity probe	2671-25L-D-11-G2-E-N	4-20mA output, range 0-250pa, accuracy ± 1% F.S	ZY2020000018-2	2022.4.12
6	Photo detector	PDA36A2	Thorlabs optical receiver, wavelength range (350-1000) mm, gain adjustable, voltage output (0-10) V, instability < 0.1%	ZY2020000018-3	2022.4.12
7	Fourier-Transform Infrared Spectrometer	atmosFIR	Spectral scanning range: 485 - 7500cm-1; Spectral repeatability: < 0.1cm-1	ZY2020000018-5	2022.4.12
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	2022.3.9
9	Palladium-nickel thin-film solid state sensor	MODEL 2000	Range: 0-2000ppm, temperature less than 100 C, -90~110kPa	ZY2021000210	2022.4.30
10	Flame ionization detector	3010	Accuracy: 2.0%	19937	2022.3.10

11	Heat flux measurement equipment	MW88-JTC08C	0 ~ ± 99999 w / m2, - 250 ~ 980 ℃, accuracy 5%, response time less than 0.1s,	ZY2020000010	2022.4.13
12	Thermopile	RS-WD-HW-1	0-200 ℃, 4-20mA, response speed < 0.15s	28348141942	2022.4.12
13	Ambient temperature and humidity	HWP01-10S	-30℃~50℃, 20%RH~100%RH	12005577	2022.5.16

End of Test Report

Appendix O

Ruipu Energy Battery Spacing Review Documentation

Prüfbericht-Nr.: *Test Report No.:*	**CN22216G 001**	**Auftrags-Nr.:** *Order No.:*	244371117	**Seite 1 von 54** *Page 1 of 54*
Kunden-Referenz-Nr.: *Client Reference No.:*	2182037	**Auftragsdatum:** *Order date.:*	Nov 01, 2021	
Auftraggeber: *Client:*	Sungrow Energy Storage Technology Co.,Ltd. No.788 Mingchuan Road, Boyan Technology Park, Hi-tech Zone, Hefei City, 230088 Anhui, P.R. China			
Prüfgegenstand: *Test item:*	Battery Rack			
Bezeichnung / Typ-Nr.: *Identification / Type No.:*	R286AL-121, R344AL-121, R573AL-123, R688AL-123			
Auftrags-Inhalt: *Order content:*	Test report			
Prüfgrundlage: *Test specification:*	UL 9540A: 2019 (Fourth Edition)			
Wareneingangsdatum: *Date of receipt:*	Dec 06, 2021			
Prüfmuster-Nr.: *Test sample No.:*	Engineering sample			
Prüfzeitraum: *Testing period:*	Dec 09, 2021 ~ Dec 11, 2021			
Ort der Prüfung: *Place of testing:*	See clause 1.1 of main report			
Prüflaboratorium: *Testing laboratory:*	See clause 1.1 of main report			
Prüfergebnis*: *Test result*:*	See main report			

geprüft von / *tested by:*

March 19, 2022	David Zhou / Engineer	
Datum *Date*	**Name/Stellung** *Name/Position*	**Unterschrift** *Signature*

kontrolliert von / *reviewed by:*

March 19, 2022	Bowen Dong / Reviewer	
Datum *Date*	**Name/Stellung** *Name/Position*	**Unterschrift** *Signature*

Sonstiges / *Other:*

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

* Legende:	1 = sehr gut P(ass) = entspricht o.g. Prüfgrundlage(n)	2 = gut	3 = befriedigend F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	4 = ausreichend N/A = nicht anwendbar	5 = mangelhalt N/T = nicht getestet
Legend:	1 = very good P(ass) = passed a.m. test specifications(s)	2 = good	3 = satisfactory F(ail) = failed a.m. test specifications(s)	4 = sufficient N/A = not applicable	5 = poor N/T = not tested

Dieser Prüfbericht bezieht sich nur auf das o.g. Prüfmuster und darf ohne Genehmigung der Prüfstelle nicht auszugsweise vervielfältigt werden. Dieser Bericht berechtigt nicht zur Verwendung eines Prüfzeichens.

This test report only relates to the a. m. test sample. Without permission of the test center this test report is not permitted to be duplicated in extracts. This test report does not entitle to carry any test mark.

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 do not 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.

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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 unit level tests of UL 9540A: 2019.

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.

Testing period: Dec 09, 2021 ~ Dec 11, 2021

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

Video records of the test from 2 different directions were provided in .mp4 format.
Complete records were provided in 2 separate documents, file number listed as below:

20211210 Sungrow unit UL9540A video 001.mp4;

20211210 Sungrow unit UL9540A video 002.mp4;

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 as 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 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

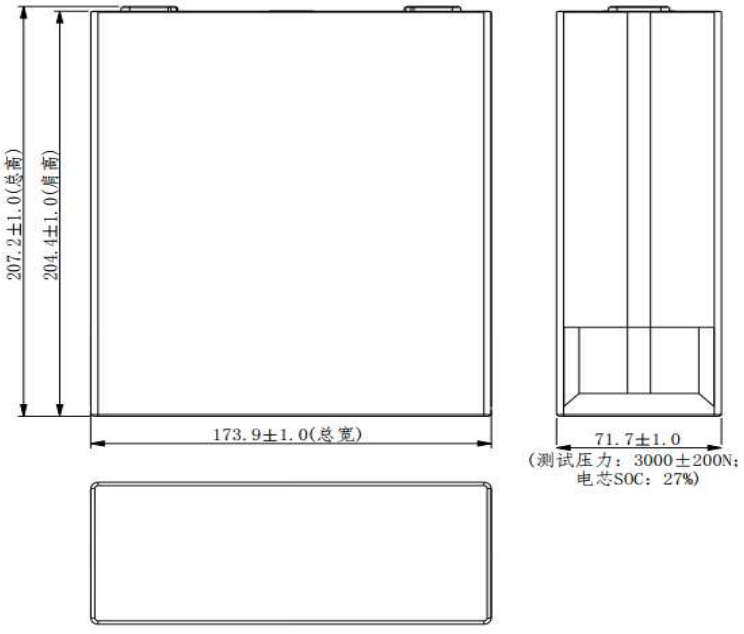
The product information and parameters were provided by the client as below.

2.1 Cell

2.1.1 Product information and parameters

Manufacturer ..... :	Ruipu Energy Co., Ltd.	
Model number ..... :	CB71173204EB	
Chemistry ..... :	LiFePO4	
Physical configuration..... :	Prismatic	
	Weight:	5340±150 g
Electrical rating ..... :	Rated capacity:	280 Ah
	Nominal voltage:	3.2 V
Standard charge method ..... :	Charge current:	280 A
	End of charge voltage:	3.65 V
	Cut off current:	14 A
Standard discharge method ..... :	Discharge current:	280 A
	End of discharge voltage:	2.5 V

Diagram with overall dimension



2.1.2 Cell level test information

Cell level thermal runaway test information is from TUV Rheinland cell level test report CN215HG7 002 provided by the client.

Thermal Runaway Methodology ..... :	External heating method with aluminum heater 1 PCS, rated 220VAC/800W, size 200mm*200mm*20 mm
Average Cell Surface Temperature at Gas Venting..... :	166.08°C
Average Cell Surface Temperature at Thermal Runaway ..... :	299.83°C

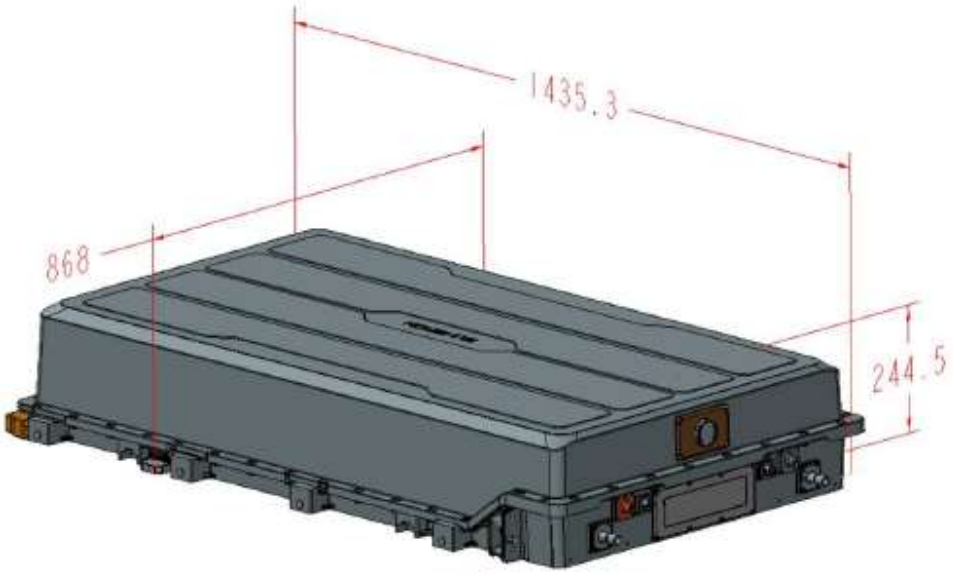
2.2 Module

2.2.1 Product information and parameters

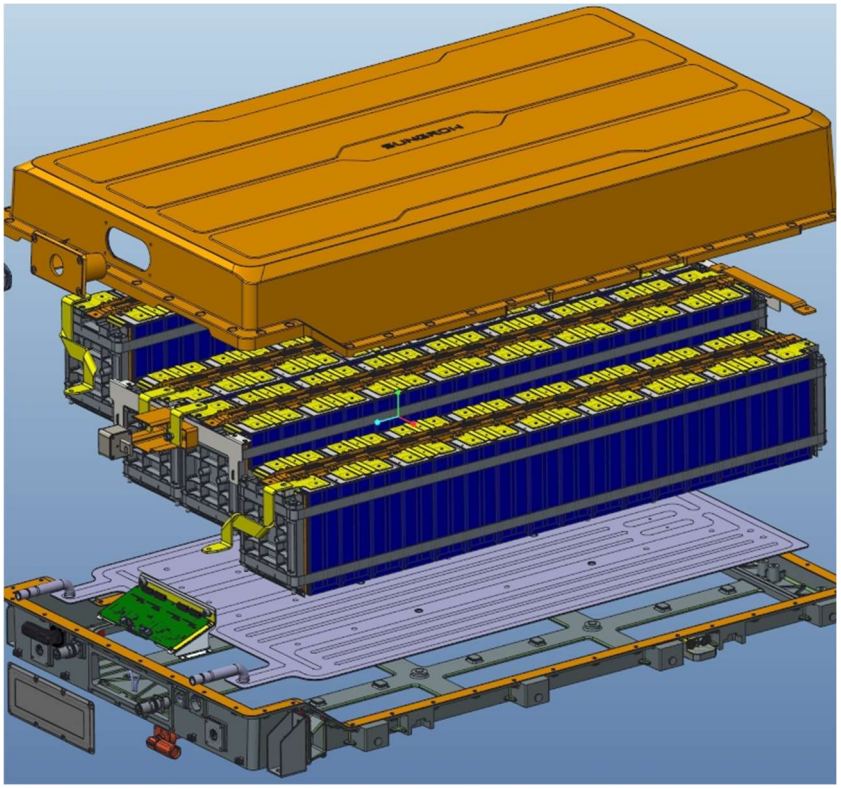
The product information and parameters are provided by the client as below.

Manufacturer name ..... :	SUNGROW ENERGY STORAGE TECHNOLOGY CO., LTD.
Type/Model..... :	P573AL-121, P573BL-121
Physical configuration..... :	Metal enclosure with plastic cover
	Weight: ≤400kg
	Cells in series/parallel: 64 in series
Cooling method ..... :	Liquid Cooling
Separation between cells ..... :	0.45 mm separation between cells by air
Electrical rating..... :	Rated capacity: 280 Ah
	Nominal voltage: 204.8V
Standard charge method ..... :	Charge current: 280 A
	End of charge voltage: 233.6 V
	Cut of current: 14 A
Standard discharge method ..... :	Discharge current: 280 A
	End of discharge voltage: 172.8 V
Compliance with UL 1973..... :	Under certification, not finished

2.2.2 Diagram with overall dimension

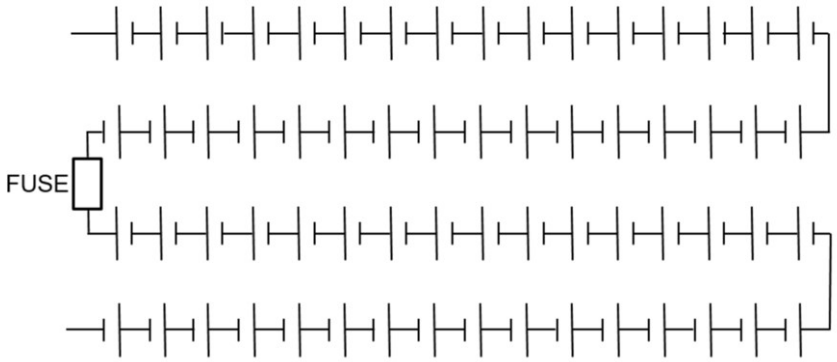


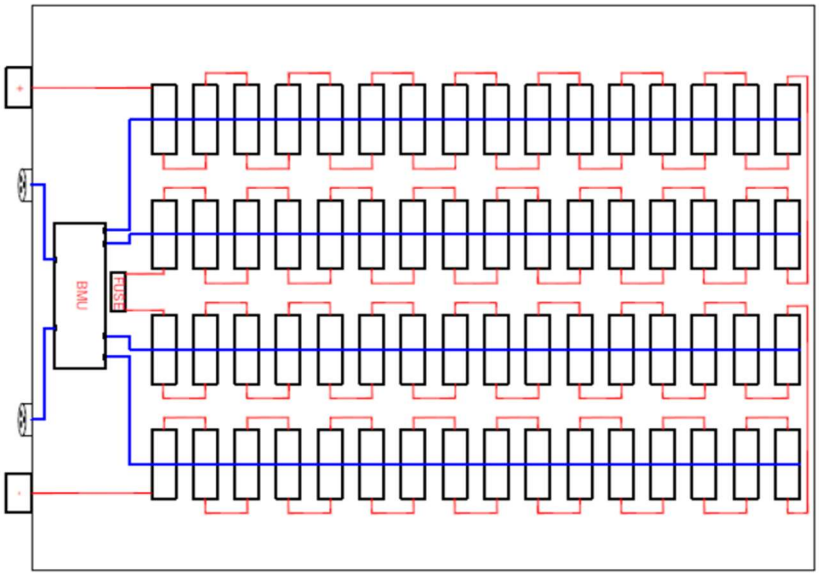
2.2.3 Layout of the module contents



2.2.4 Configuration diagram of the module

1P64S





2.3 Battery system (rack)

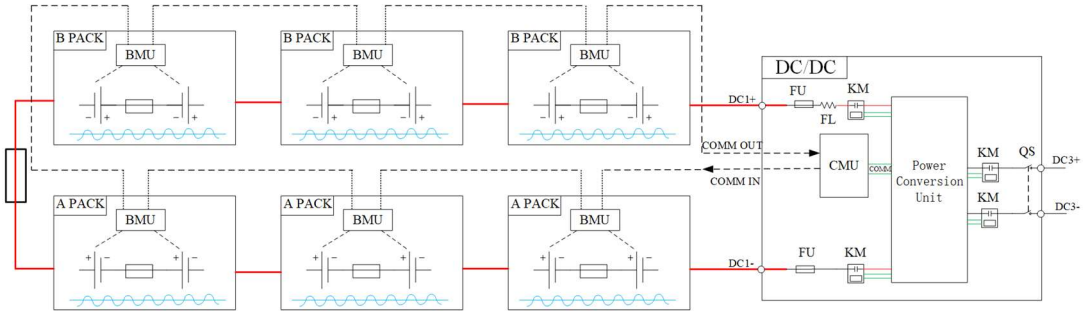
2.3.1 Manufacture information and model list

	Battery system	Battery system	Battery system	Battery system
Product	LFP Lithium Ion Energy Storage System	LFP Lithium Ion Energy Storage System	LFP Lithium Ion Energy Storage System	LFP Lithium Ion Energy Storage System
Type/model	R286AL-121	R344AL-121	R573AL-123	R688AL-123
Cell Capacity [Ah]	280	280	280	280
Cell Quantity	320	384	640	768
Battery structure	(64S)5S	(64S)6S	((64S)5S)2P	((64S)6S)2P
Nominal voltage [V]	1024	1228.8	1024	1228.8
Rated capacity [Wh]	286720	344064	573440	688128
Upper limit charging voltage [V]	1168	1401.6	1168	1401.6
Recommend charging current [A]	140	140	140	140
Maximum charging current [A]	140	160	140	140
Recommend discharging current [A]	140	140	140	140
Maximum discharging current [A]	140	160	140	140
Discharge cut-off voltage [V]	864	1036.8	864	1036.8
Temperature range for charging [°C]	0 to 50*	0 to 50*	0 to 50*	0 to 50*
Temperature range for discharging [°C]	-30 to 50*	-30 to 50*	-30 to 50*	-30 to 50*
Temperature threshold for protection	58	58	58	58
Overcharge protected voltage supply by battery system	≥3.65V /Cell	≥3.65V /Cell	≥3.65V /Cell	≥3.65V /Cell
Recommend charging method by manufacturer	Charge at constant current 140A until the voltage reaches 1168V, then switch to constant voltage 1168V till charge current drops to 14A	Charge at constant current 140A until the voltage reaches 1401.6V, then switch to constant voltage 1401.6V till charge current drops to 14A	Charge at constant current 140A until the voltage reaches 1168V, then switch to constant voltage 1168V till charge current drops to 14A	Charge at constant current 140A until the voltage reaches 1401.6V, then switch to constant voltage 1401.6V till charge current drops to 14A
Dimension [mm]	Rack:3117±10mm(W)×1474±10mm(D)×520±10mm(H) DC/DC:720±5mm(W)×788±5mm(D)×294±5mm(H)	Rack:3117±10mm(W)×1474±10mm(D)×520±10mm(H) DC/DC:720±5mm(W)×788±5mm(D)×294±5mm(H)	Rack:3117±10mm(W)×1474±10mm(D)×1040±10mm(H) DC/DC:720±5mm(W)×788±5mm(D)×294±5mm(H)	Rack:3117±10mm(W)×1474±10mm(D)×1040±10mm(H) DC/DC:720±5mm(W)×788±5mm(D)×294±5mm(H)
Weight [kg]	Rack: ≤2000kg DC/DC: 75kg	Rack: ≤2400kg DC/DC: 75kg	Rack: ≤4000kg DC/DC: 75kg	Rack: ≤4800kg DC/DC: 75kg
Ingress Protection (IP)	IP65	IP65	IP65	IP65
Protective Class	I	I	I	I
Cooling type	Liquid cooling	Liquid cooling	Liquid cooling	Liquid cooling
Altitude	4000m	4000m	4000m	4000m

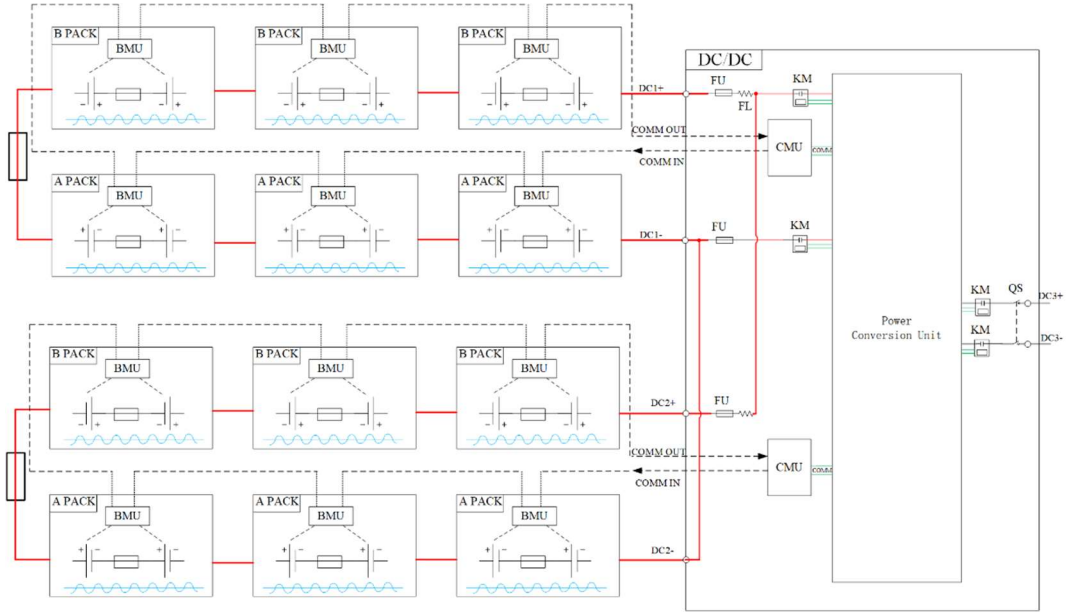
2.3.2 Product information

This product is used for Energy Storage System.
The EUTs covered by this report are 4 models of LFP lithium ion battery energy storage systems which include one DC-DC converter box and several battery packs in series(parallel) connection. The number of battery pack is 5, 6, 10,12 for model R286AL-121, R344AL-121, R573AL-123 and R688AL-123.

Block diagram for R344AL-121 is as below (R286AL-121 is the same except for one less pack) :



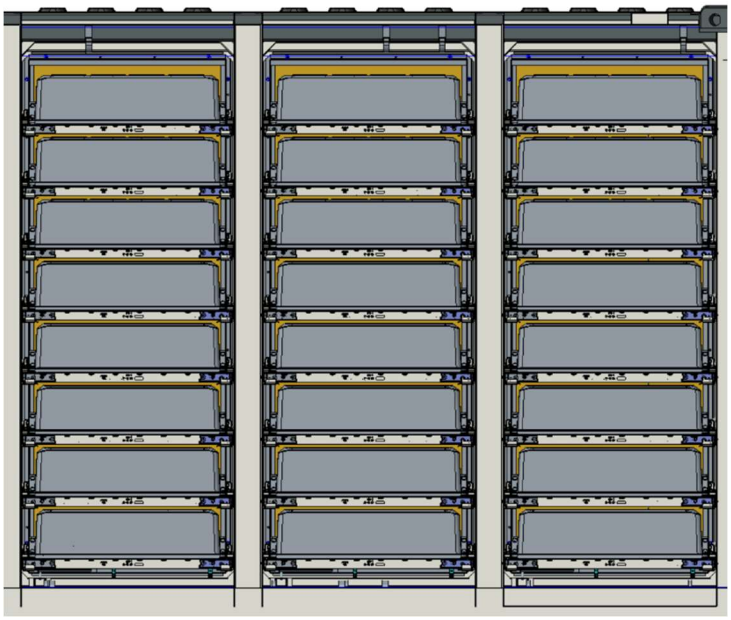
Block diagram for R688AL-123 is as below (R573AL-123 is the same except for two less packs) :

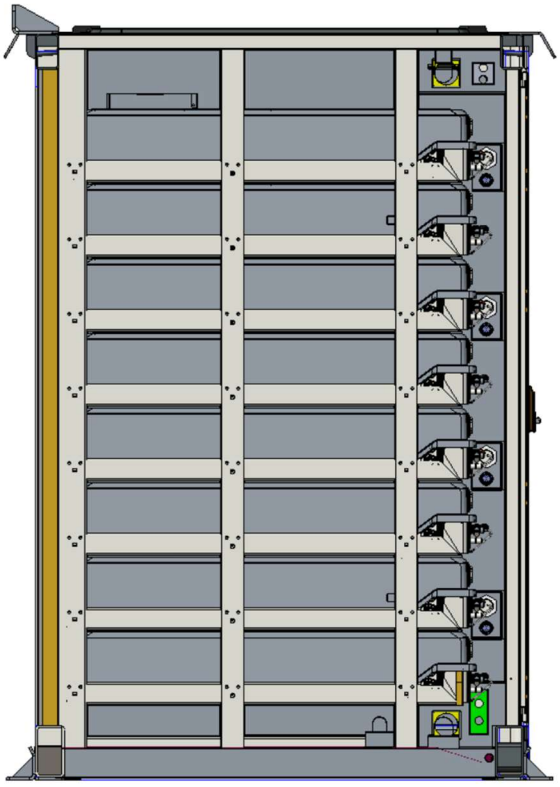


Each battery pack contains 64 cells in structure 64S. And it contain one BMU board for measuring and collecting the cell parameters and uploading the information of cell voltage and temperature to CMU in DC-DC converter box.
DC-DC box: Including CMU function and DC-DC converter which certified with UL 1741.
The EUTs are indoor type. The insulation between the DC circuit and the metal enclosure is basic insulation. And the insulation between the DC circuit and communication ports is reinforced insulation or double insulation.
BMS functional safety was evaluated according to IEC 60730-1 Annex H by TÜV Rheinland.

Compliance with UL9540..... :	without
Compliance with UL1973..... :	Yes, (repot number: CN22626J 001)
Integrated fire protection system in the unit..... :	No integrated fire protection system

Diagram with dimension of R688AL-123





2.4 Photo

Module

Battery Rack

3 Unit level test (section 8 of UL 9540A)

3.1 General

Unit level testing corresponds with the testing anticipated by fire codes and other codes impacting energy storage system installations to evaluate the large scale fire performance of BESS units installed in, on or adjacent to buildings or in other areas and their resultant performance to qualify for exceptions to limits in the codes imposed on these installations. The limitations where exceptions may be sought are limitations on the size of the individual BESS units, the total number of BESS units installed within a room, and the separation distances between BESS units and between BESS units and walls of the building.

In this test the initiating BESS unit is placed a set distance from target BESS units simulating BESS units identical to the initiating BESS unit, and from simulated walls representative on the installation. A thermal runaway is induced in cells, using the same approach as used in the module level testing within one of the modules in the initiating BESS, and a variety of measurements are taken. The results are intended to be used to verify that a fire within a single BESS unit will not spread to other units, nor breach the walls or the BESS enclosure (if provided), and there shall be no flying debris or explosive discharge of gases.

The test arrangement include the largest (energy) BESS unit for the installation to be represented by the test, and minimum spacing to adjacent walls and BESS units. The BESS may be tested with an internal fire suppression system provided by the manufacturer if that fire suppression system is required to be installed in the BESS. Optional internal fire suppression systems are not included in the unit level testing.

The test monitors the fire behavior of the BESS unit and measures heat release rates (convective and chemical); gas generation and composition; smoke release rate; maximum heat flux on the target BESS units, wall surfaces and within the accessible means of egress; maximum surface temperatures of the walls and modules within the target BESS units; and documents any explosions, deflagrations and flying debris from the BESS under test.

3.2 Unit sample preparation

The battery system is constructed with open rack without enclosure. One column of the rack with 9 complete modules was considered as a unit for purposes of the test.

All 9 module samples were conditioned together as a unit, through 3 charge/ discharge cycles per the manufacturer's instructions to verify that the module was functional.

The Charge/discharge was performed at 140A. Each cycle was defined as a charge to 100% SOC and allowed to rest 60 minutes and then discharged to an end of discharge voltage (EODV) determined by the module specification. Refer to section 2.2 for the end of the condition of charge and discharge.

Cycling was conducted on Dec 3, 2021 under ambient temperature 25°C ± 3°C and R.H. 70% ± 5%.

3.3 Setup of the test

3.3.1 Battery system installation information

The installation information was provided by the client as below.

Intended use location ..... :	☐ Residential	☒ Non-residential
	☐ Non-residential rooftop	
	☐ Non-residential open garage use	
Type of installation ..... :	☒ Indoor	☐ Outdoor
	☒ Floor/ground mounted	☐ Wall mounted
Row(s) of installation	☐ Single	☒ Multiple

3.3.2 Test site setup

Two instrumented walls with 3.8 m height and 3.55 m width form a right angle. Walls were constructed of 5/8 in gypsum painted flat black.

Three racks were used for the purpose of the test. As specified by the manufacture, the two target racks will be installed up and down of the initial unit. All racks were positioned facing instrumented wall A. See Figure 1 and 2 and photos on page 47.

The initiating unit (unit A) was positioned at the middle, adjacent to the two instrumented wall sections.

The minimum separation distance from the rack to wall and between racks were defined by the client. Subject to the actual conditions of the testing environment, there was 1cm tolerance in the actual setup.

Figure 1 was the test site setup diagram with separation distance.

The test side setup was located under the smoke collection hood of the calorimeter measurement system.

Figure 1. Test site setup diagram with separation distance. (Top view)

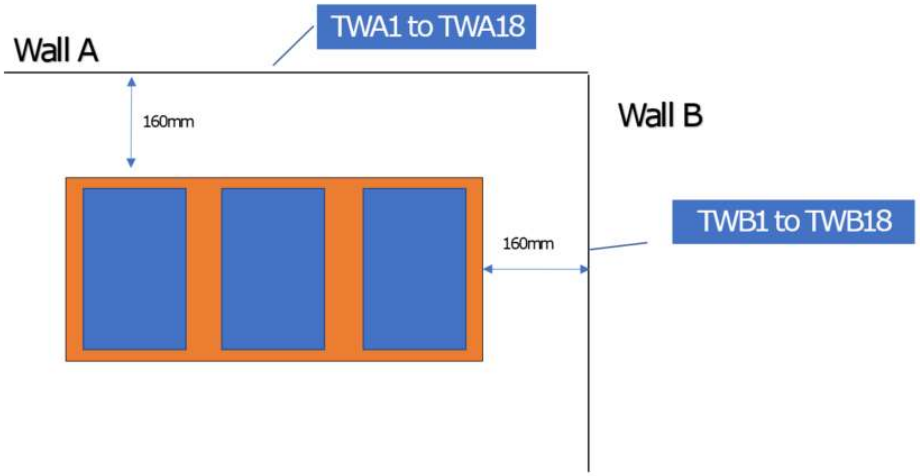
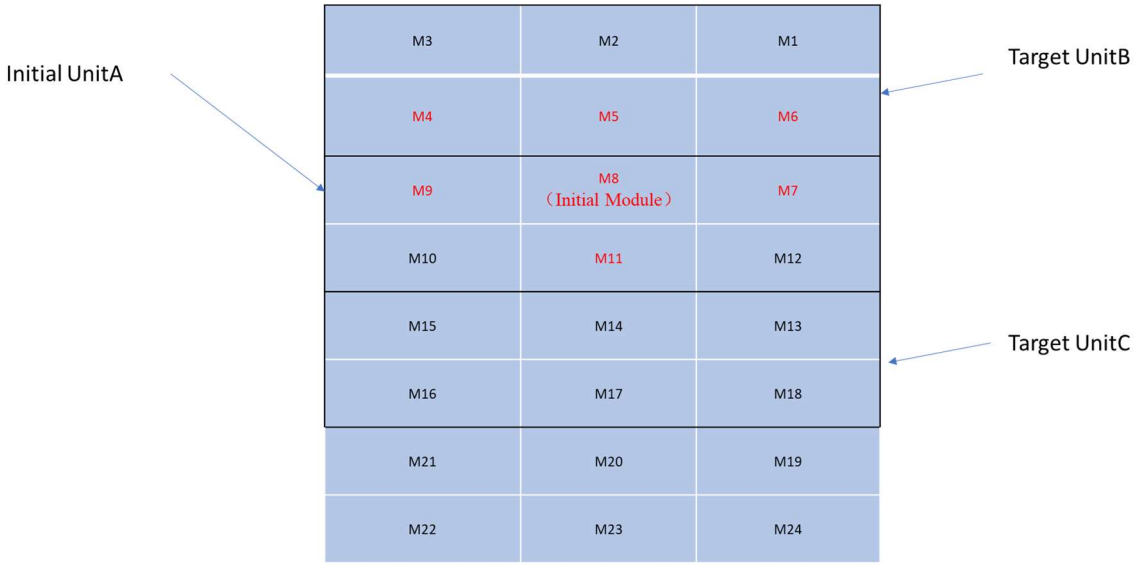


Figure 2. Test site setup diagram with separation distance. (Front view)



For the purpose of this test, the modules were numbered according to the electrical continuity.

In Initial Unit A, modules numbers from M7 to M12.

In Target Unit B, modules numbers from M1 to M6 which was the target unit situated above the Initial Unit A.

In Target Unit C, modules numbers from M13 to M18 which was the target unit situated below the Initial Unit A.

See Figure 3.

4 complete modules were used for unit A (M7 to M9 and M11).

3 complete modules were used for unit B (M4 to M6) to check the possible propagation form unit to unit.

Empty modules without cells were used for the other modules.

Figure 3. Module numbering in units showing fully populated modules in red.

M3	M2	M1
M4	M5	M6
M9	M8 （Initial Module）	M7
M10	M11	M12
M15	M14	M13
M16	M17	M18
M21	M20	M19
M22	M23	M24

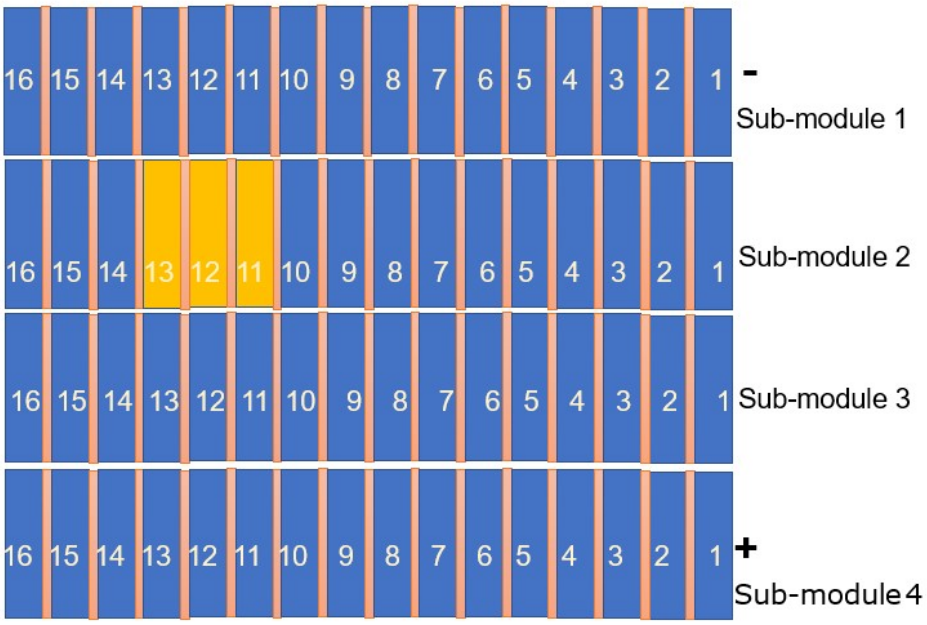
3.3.3 Thermal runaway setup

External heating method, agreed with the client, was used to initiate the thermal runaway within the module.

Module M8 was prepared with two heaters inside. Same as the method in module level test.

For convenient show the temperature condition of internal cells, numbering four lines cells from negative electrode to positive electrode for sub-module 1 to sub-module 4. Numbering cells in every sub-modules from electrodes side to another side for cell 1 to cell 16, see figure 4 for detail.

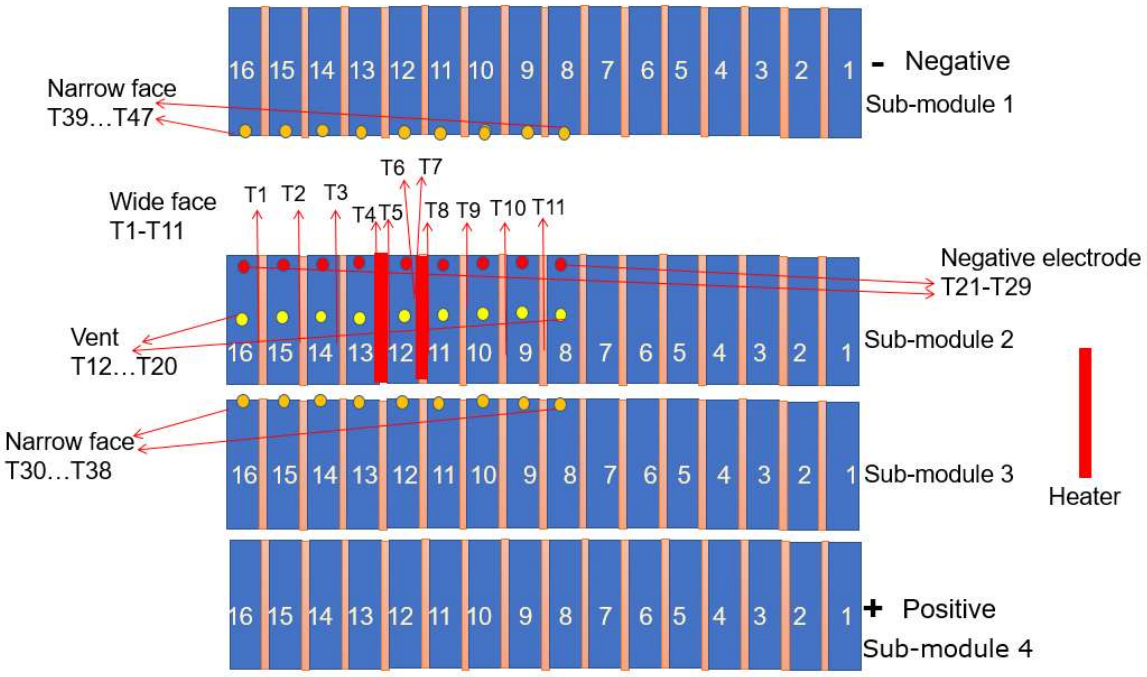
Figure 4. Cell numbering inside the initiating module



Consider the unit level installation and airflow of the liquid cooling in the module. #11, #12 and #13 cells of sub-module 2 were chosen as target cell to be forced into thermal runaway.

The cell #12 was heated by two external heater on each wide side, the cell #11 and cell#13 was heated by one external heater on wide near cell #12. The heater is rated 220VAC/500 W (size 207*174*4mm).

Figure 5. Thermocouples on initiating module M8



In sub-module 1,

9 glass fiber thermocouples (#39-#47) Type K, 24AWG were attached on the #16-#8 cells center of narrow surface near sub-module 2, used to check the possible propagation form cell to cell.

In sub-module 2,

1 glass fiber thermocouples (#T7) Type K, 14AWG was attached on the center of wide surface of #12 cell under heater used to feedback the temperature to the heater controller.

4 glass fiber thermocouples (#T4, #T5, #T6, #T8) were attached on the center of wide surface of #13, #12 and #10 cells under heater used to determine the thermal runaway of initiating cells.

6 glass fiber thermocouples (#1-#3, #9-#11) were attached on the center of wide surface of #16-#14, #10-#8 cells under heater used to check the possible propagation from cell to cell.

8 glass fiber thermocouples (#12-#20) were attached above the vent of #16-#8 cells used to record the venting time.

8 glass fiber thermocouples (#21-#29) were attached on the negative electrode of #16-#8 cells used to observe the temperature change.

In sub-module 3,

9 glass fiber thermocouples (#30-#38) Type K, 24AWG were attached on the #16-#8 cells center of narrow surface near sub-module 2, used to check the possible propagation form cell to cell.

The initiating module M8, Internal voltage sample wire and signal wire covered by glass fiber tube. The BMS control board disabled during test.

A PID controller was used to control the voltage supply to the heater and maintain a 4°C/min to 7°C/min heating rate. When heater temperature reached to 150°C (T-set), hold about 93min (11:04 to 12:37), then continue to heat and maintain a 4°C/min to 7°C/min heating rate.

Once thermal runaway was observed, the heaters were immediately de-energized.
One thermocouple located below the heater at the center of #12 cell surface was used to feedback the temperature to the controller.

Voltage of the module are monitored during test.

The units was located under the smoke collection hood of the calorimeter measurement system.

3.4 Observations and records

Before the test, the initiating module was 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.

The ambient condition at the initiation of the test was 25°C, 66% RH.

The voltage of the modules was recorded as below:

Figure 6: Voltage record of cells during the test

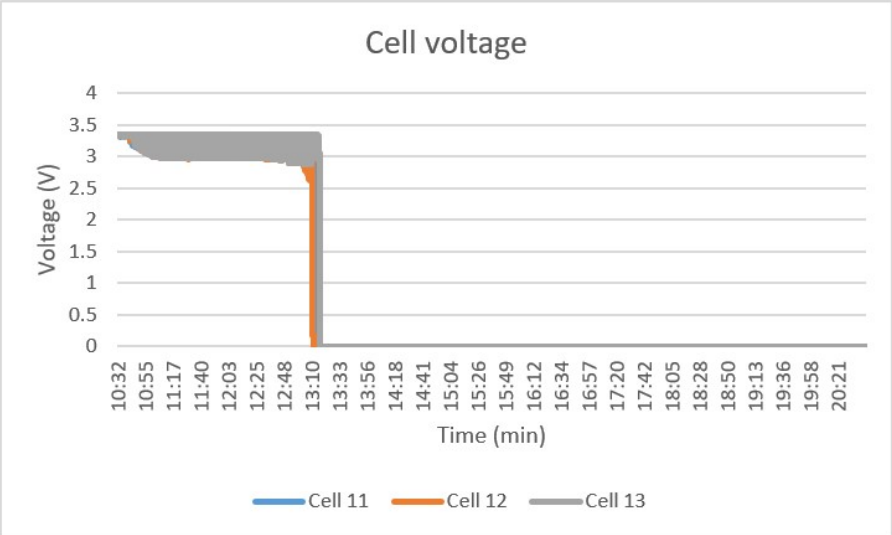
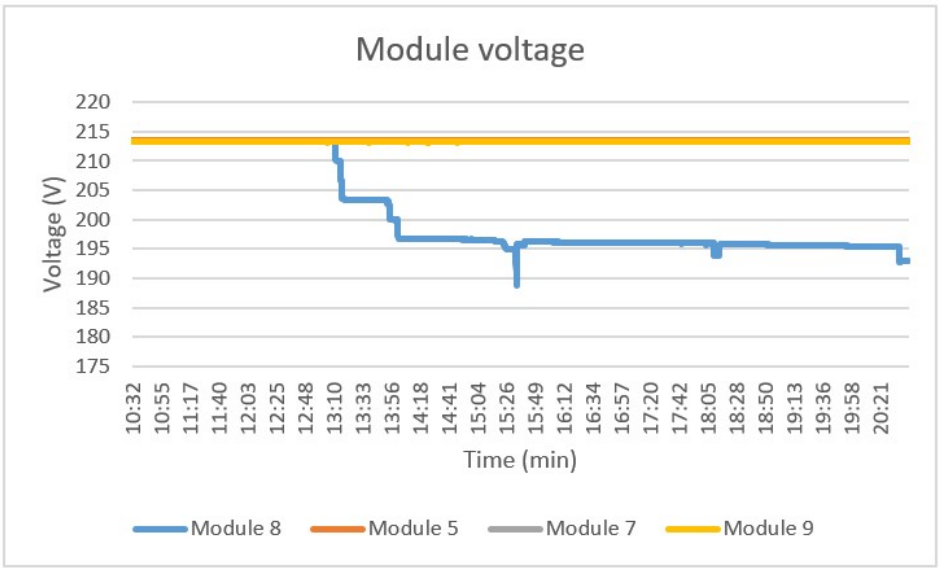


Figure 7: Voltage record of Modules during the test



Tests were performed on Sep 16, 2021, started at 09:40 AM.

Observations during the test:

Audible pop was heard on 12:46 AM (the pressure relief valve burst), followed by smoke release after several seconds.

A large amount of white smoke was observed after thermal runaway.

Cell to cell propagation was observed in the initial model.

Module to module propagation was not observed.

No flying debris or explosive discharge of gases observed during test.

No sparks, electrical arcs, or other electrical events observed during test.

No external flaming was observed during the test.

Observations after the test:

Leakage outside the initiating module enclosure was observed. See photos in page 47~52.

No damage and contamination on the instrument walls.

No damage and contamination on the modules of target units.

The plastic top enclosure near the initial cell of module M8 was melted and significantly damaged. Module voltage of M8 was 193.3 Vdc.

Six cells inside the initial module M8 were damaged. Cell to cell propagation were observed on cells #14, #15, #10 of sub-module 1 after receiving thermal energy from cell #13. Voltage measured on each remaining undamaged in other sub-modules were 3.33Vdc.

Weight loss of the initiating module was 2.0 kg (before test 406.5kg, after test 404.5kg)

See photos in page 47~52.

3.5 Temperature measurements

3.5.1 Temperature measurement of initiating cells

Surface temperature of cells #8 - #16 of sub-module 1 to sub-module 3 was recorded during the test. Cell to cell propagation occured during the test. See Figure 8 for the temperature vs time curve.

Cell thermal runaway occurred on cell #12, #13, #11 in turn at around 13:11, 13:14, 13:15 Maximum temperature 604.2°C, 643.2°C, 730.1°C were measured on the cell #12, #13, #11 surface.

Cell to cell thermal runaway propagation occurred on cell #14, #15, #10. Maximum temperature 471.0°C, 547.1°C, 468.5°C were measured on the cell #14, #15, #10 surface.

Figure 8. Surface temperatures of thermal runaway cells on module M8 (sub-module 2)

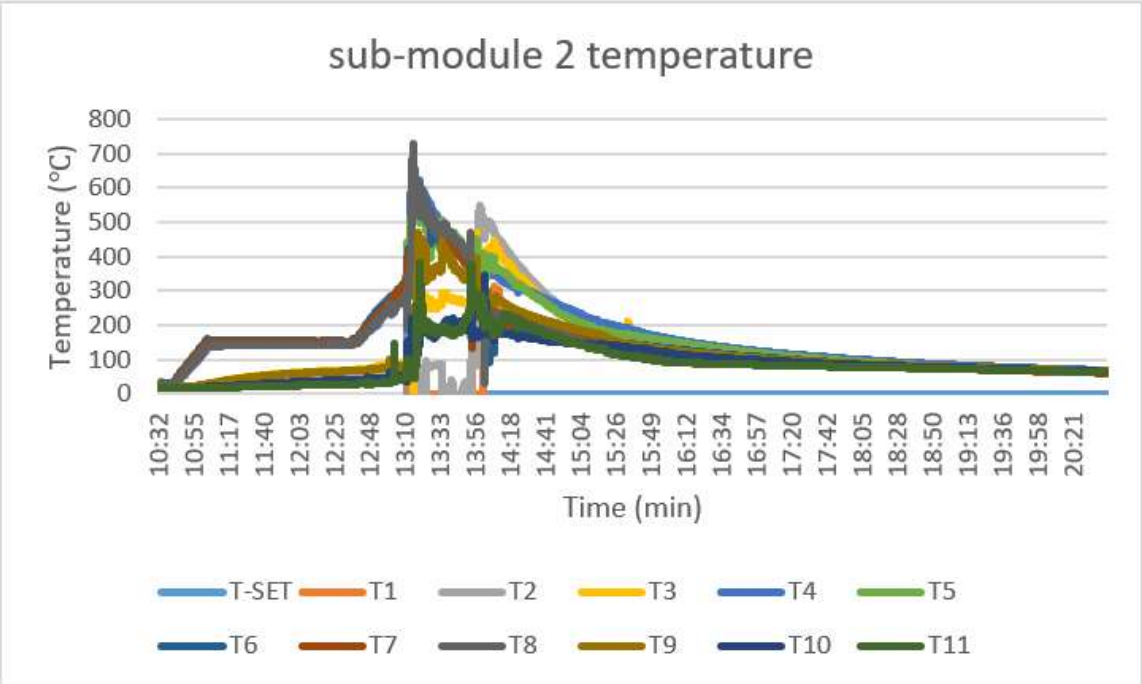


Table 1 Maximum temperature of sub-module 2 cells

Thermocouple no.	Location	Maximum temp.(℃)
T1	Wide surface of Cell #16	314.9
T2	Wide surface of Cell #15	547.1
T3	Wide surface of Cell #14	471.0
T4	Wide surface of Cell #13	643.2
T5	Wide surface of Cell #12	581.8
T6	Wide surface of Cell #12	595.4
T7	Wide surface of Cell #12 for feedback	604.2
T8	Wide surface of Cell #11	730.1
T9	Wide surface of Cell #10	468.5
T10	Wide surface of Cell #9	368.5
T11	Wide surface of Cell #8	382.1

Cells in sub-module 1 not happened thermal runaway, maximum temperature see table 2 for detail.

Figure 9. Surface temperatures of no thermal runaway cells on sub-module 1 of module M8

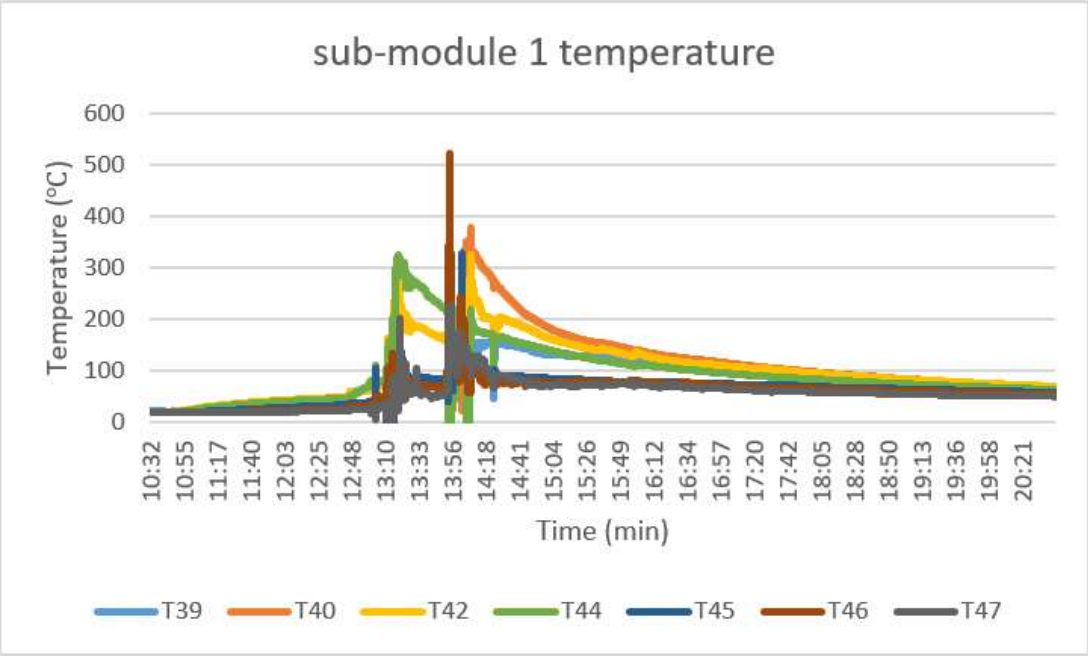


Table 2 Maximum temperature of sub-module 2 cells

Thermocouple no.	Location	Maximum temp.(℃)
T39	Narrow surface of cell #16	176.6
T40	Narrow surface of cell #15	378.5
T41	Narrow surface of cell #14	--
T42	Narrow surface of cell #13	326.9
T43	Narrow surface of cell #12	--
T44	Narrow surface of cell #11	324.4
T45	Narrow surface of cell #10	327.0
T46	Narrow surface of cell #9	523.2
T47	Narrow surface of cell #8	226.1

Cell in sub-module 3 not happened thermal runaway, maximum temperature see table 3 for detail.

Figure 10. Surface temperatures of no thermal runaway cells on sub-module 3 of module M8

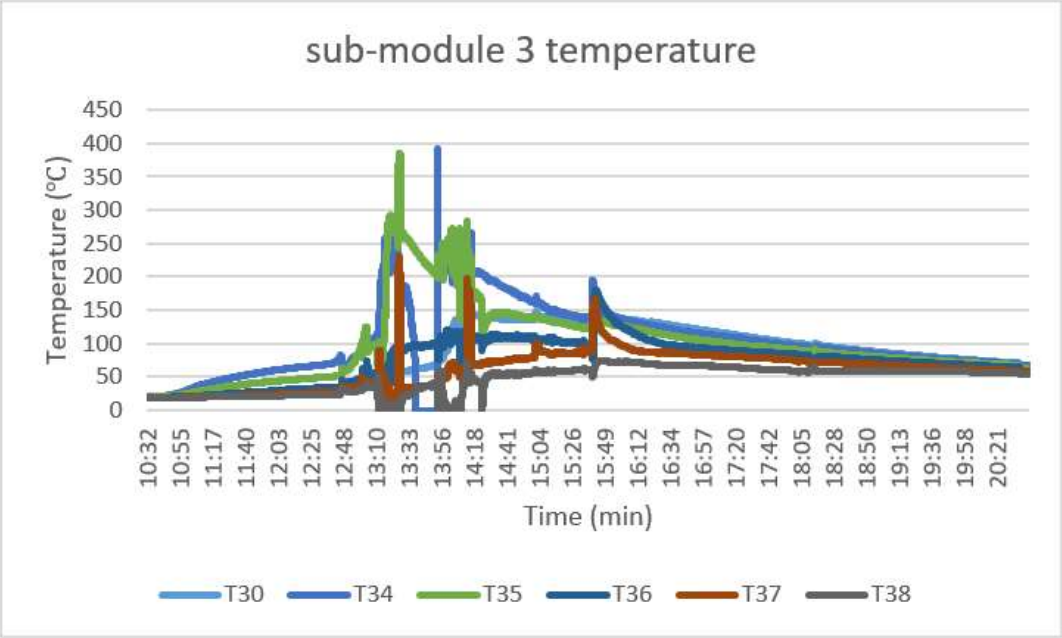


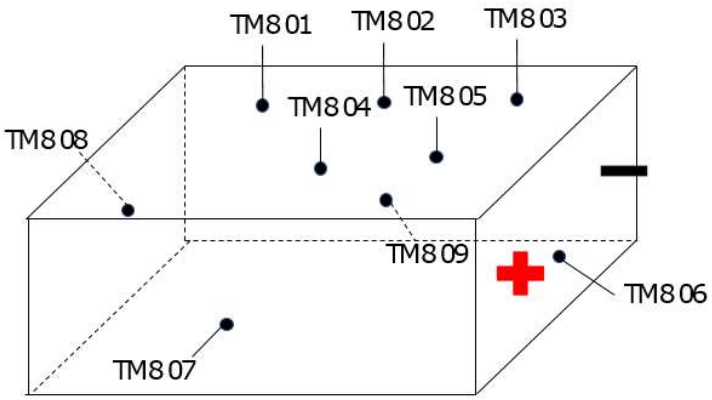
Table 3 Maximum temperature of sub-module 3 cells

Thermocouple no.	Location	Maximum temp.(℃)
T30	Narrow surface of cell #16	245.1
T31	Narrow surface of cell #15	--
T32	Narrow surface of cell #14	--
T33	Narrow surface of cell #13	--
T34	Narrow surface of cell #12	391.6
T35	Narrow surface of cell #11	384.9
T36	Narrow surface of cell #10	187.4
T37	Narrow surface of cell #9	231.2
T38	Narrow surface of cell #8	75.2

3.5.2 Temperature measurement of units

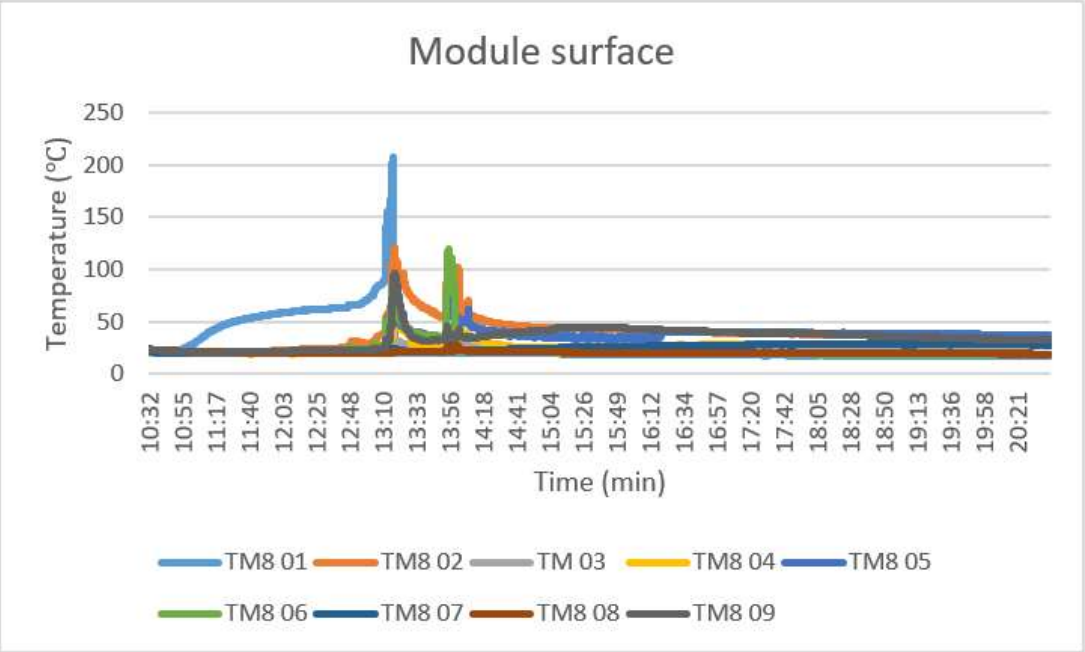
9 glass fiber insulated thermocouples (TM8 01~TM8 09), Type K, 24 AWG was attached on the external surface of module M8, as below Figure 8.

Figure 11. Thermocouple of module M8 surface



TM8 01~TM8 03 located on top surface above cell in sub-module2. TM8 04, TM8 05 located on top surface above cell in sub-module 3. TM8 06 located on front of module (electrode side), TM8 07 located on the left side surface, TM8 08 located on the rear side, TM8 09 located on the right side surface. Maximum temperature 208°C was measured on top of the module near #12 cell.

Figure 12. Surface temperatures of initiating module M8

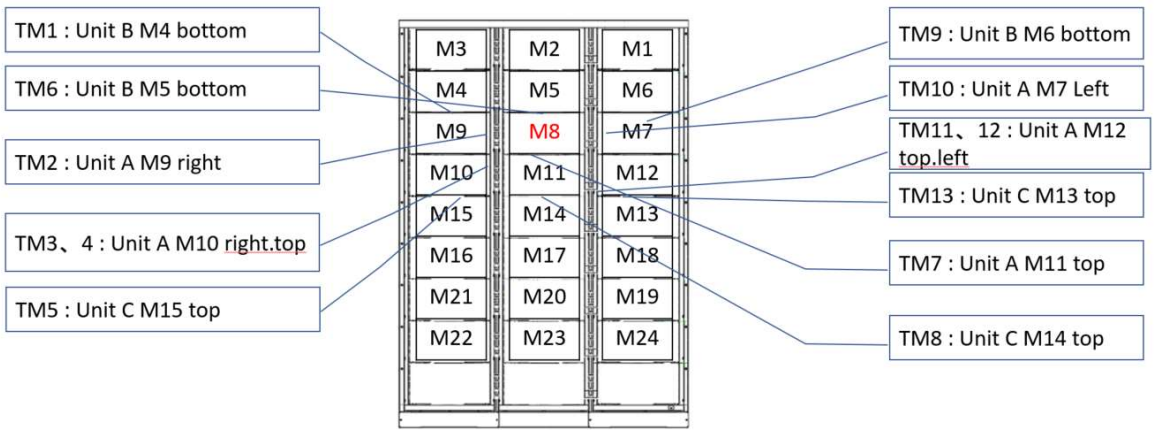


13 glass fiber insulated thermocouples (TM1 to TM13), Type K, 24 AWG were attached to the center of the top surface of modules M4 to M15.

Maximum temperature 31.4°C was measured on bottom surface of the module M5 of Unit B.

Maximum temperature 26.5°C was measured on top surface of the module M13 of Unit C.

Figure 13. Thermocouple location on modules in units A,B,C (Rack 1)



View direction: towards instrument wall A with reference to Figure 2

Figure 14. Surface temperatures of modules from M4 to M15

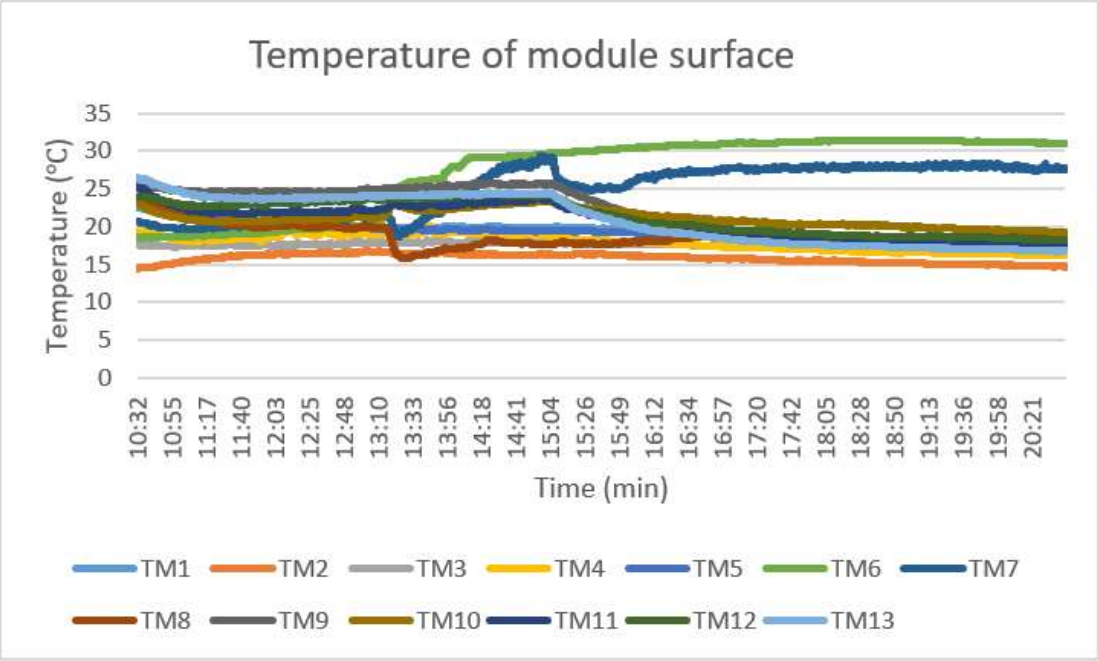


Figure 15. Thermocouple location on the back side of Wall A

View direction: from instrument wall A with reference to Figure 2

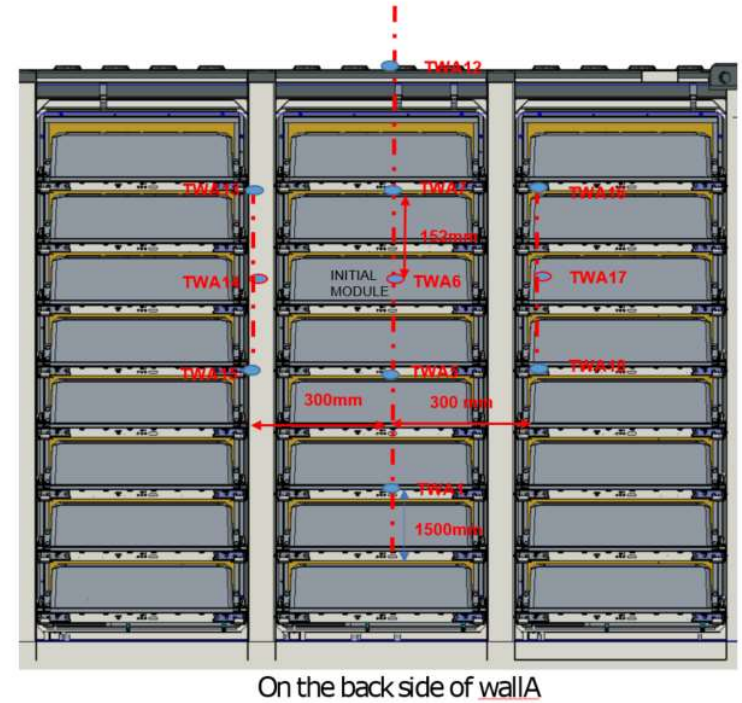
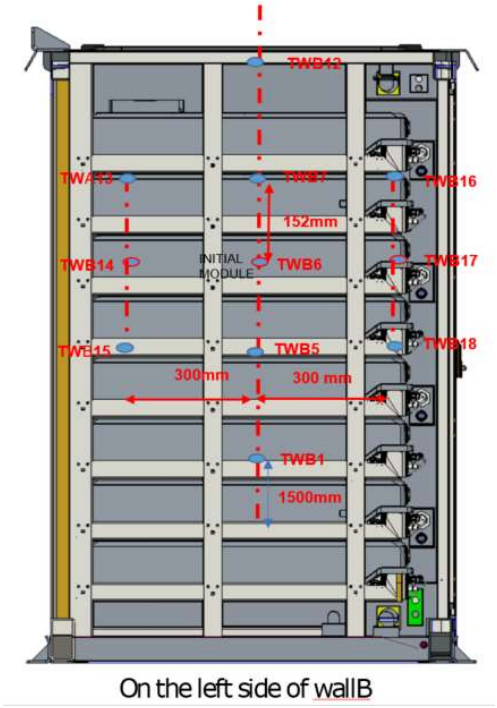


Figure 16. Thermocouple location on the left side of wall B



View direction: towards instrument wall B with reference to Figure 2

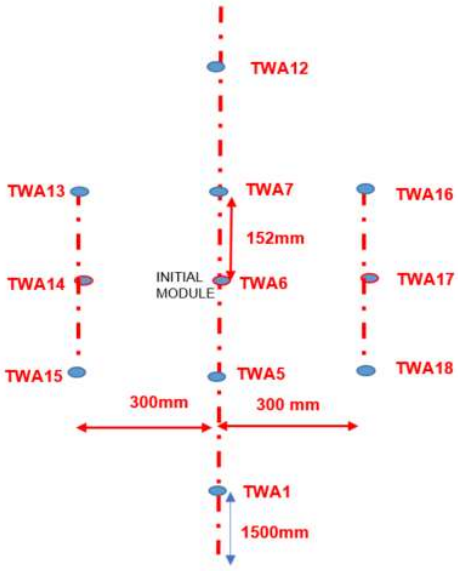
3.5.3 Temperature measurement of instrumented walls

Wall surface temperatures were measured in vertical arrays at 152 mm intervals for the full height of the instrumented wall sections using Type K, 30 AWG thermocouple. The thermocouple arrays were collinear with the centre line of Initial Unit A. The red line in Figure 12 shows the thermocouple arrays on the wall.

The first thermocouple starts from 1500 mm from ground. Total 36 thermocouples were used for each array. The thermocouples were numbered from low to high as TWA1 to TWA18 for wall A and TWB1 to TWB18 for wall B.

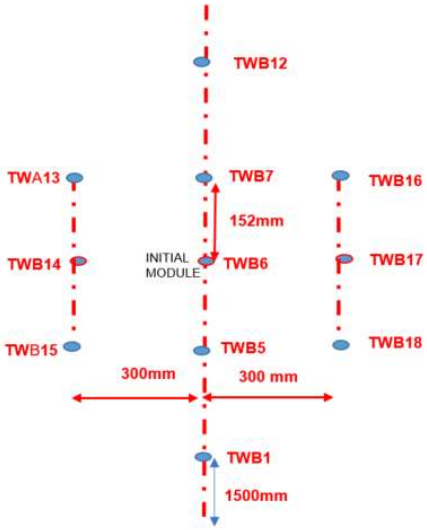
Figure 17. Vertical position of the thermocouples on the wall

Instrumented wall A



View direction: towards instrument wall A with reference to Figure 2

Instrumented wall B



View direction: towards instrument wall B with reference to Figure 2

Additional 6 thermocouples were positioned horizontally near the initial module M8 300 mm away from the vertical array each side, on instrumented wall A and wall B. See Figure 18.

Maximum temperature measured on instrument wall A was 24.3°C at TWA13, temperature curve see figure 19 for detail.

Maximum temperature measured on instrument wall B was 23.9°C at TWB3, temperature curve see figure 20 for detail.

Figure 18. Horizontal position of the thermocouples on the wall A and wall B

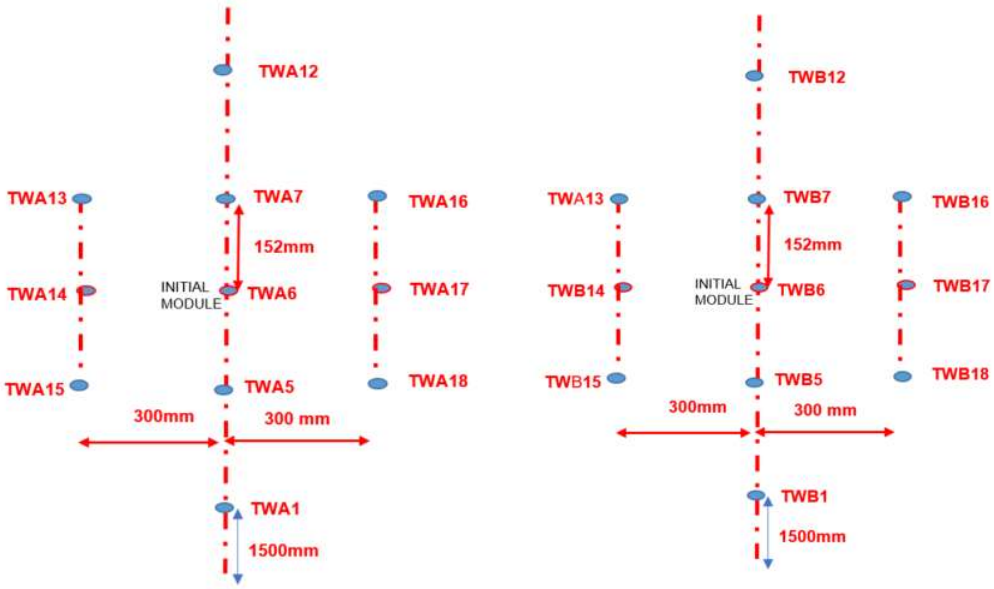


Figure 19. Temperatures on instrument wall A.

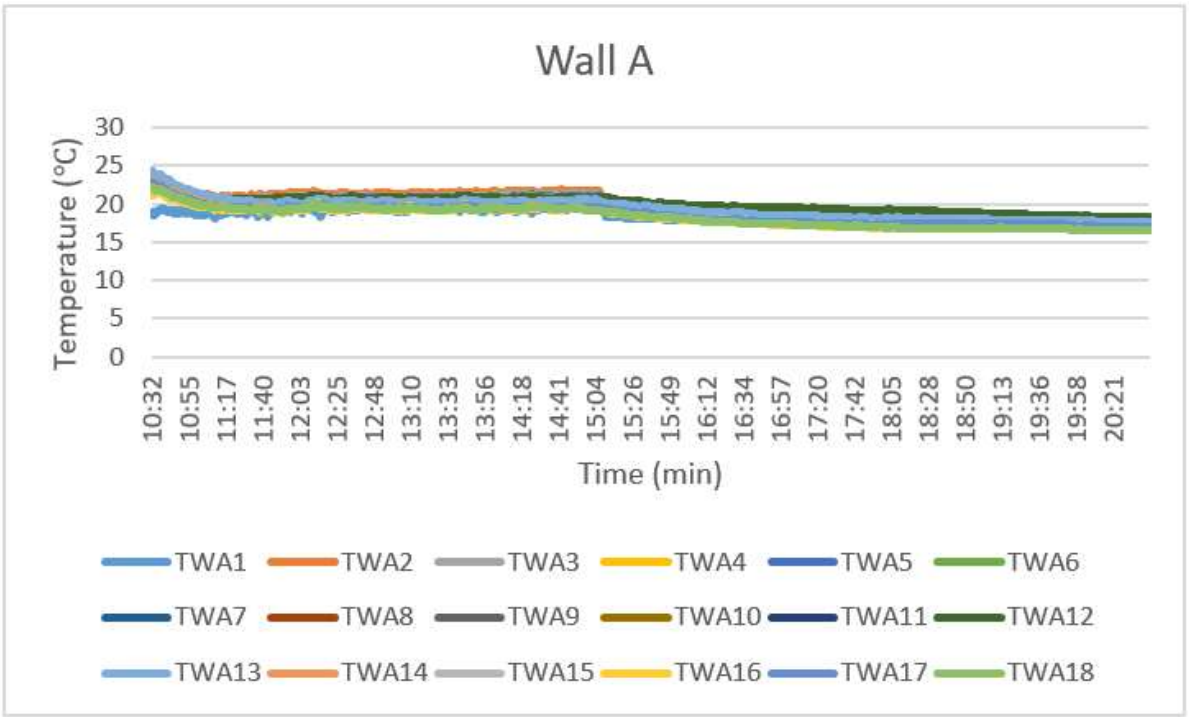
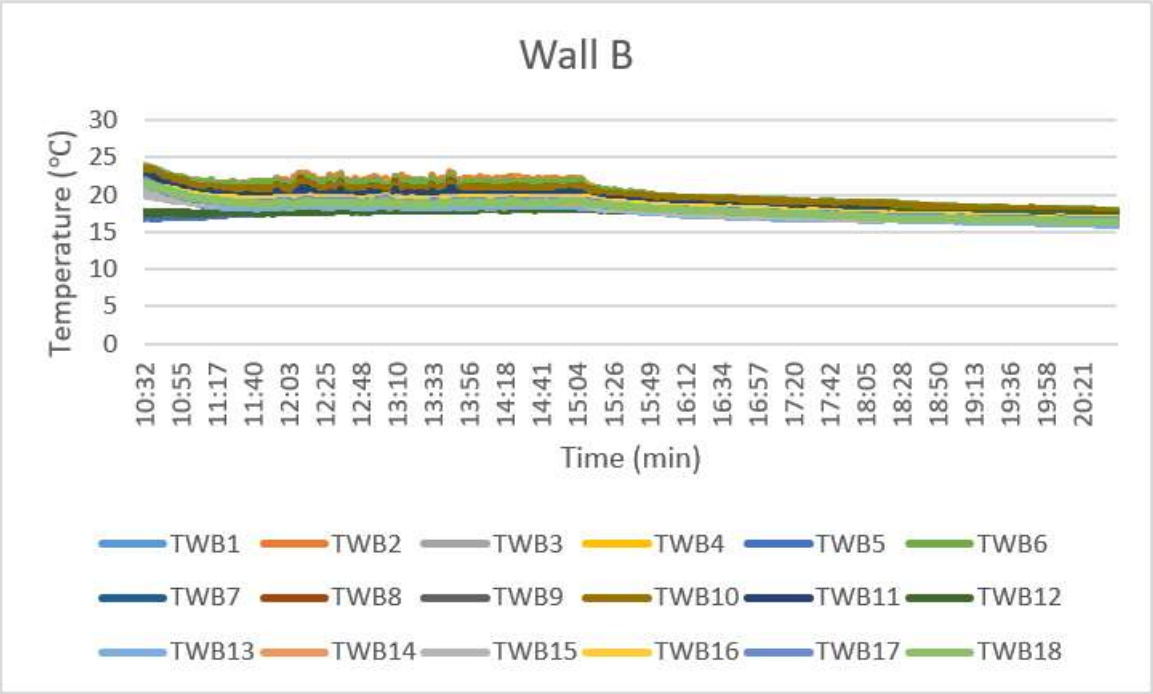


Figure 20. Temperatures on instrument wall B.



3.6 Heat flux measurement

Two sensors were placed on the surface of instrumented wall A, wall B and adjacent unit A that faces the initiating unit.

The sensors were collinear with the vertical thermocouple array. One was positioned at the height equivalent to module M8 top edge, which was estimated to receive the greatest heat flux due to the thermal runaway of the initiating module within the initiating unit. Another was positioned at the height equivalent to module M11 top edge, which was estimated to receive the greatest surface heat flux due to the thermal runaway of the initiating unit.

Figure 21 shows the positions of the sensors. Sensor H1 & H2 were positioned at unit A; H3&H4 were positioned at wall A, H5&H6 were positioned at wall B, All sensors were numbered from low to high.

Measured heat flux of target wall and target units are zero.

Figure 21. Heat flux sensor locations on unit

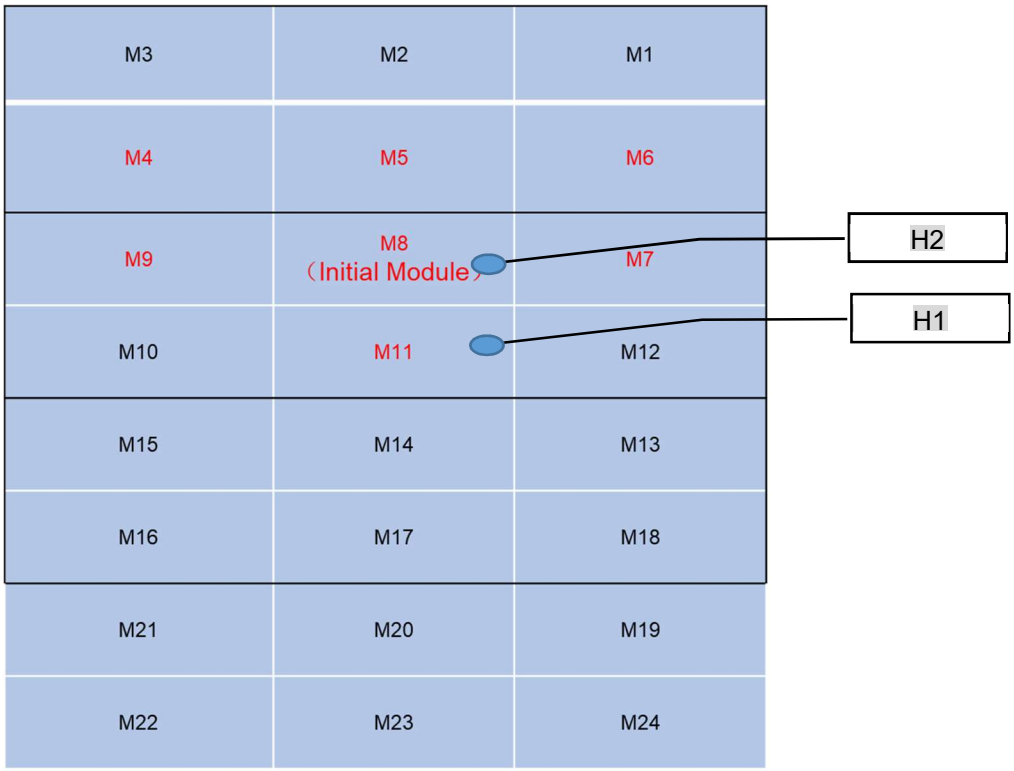
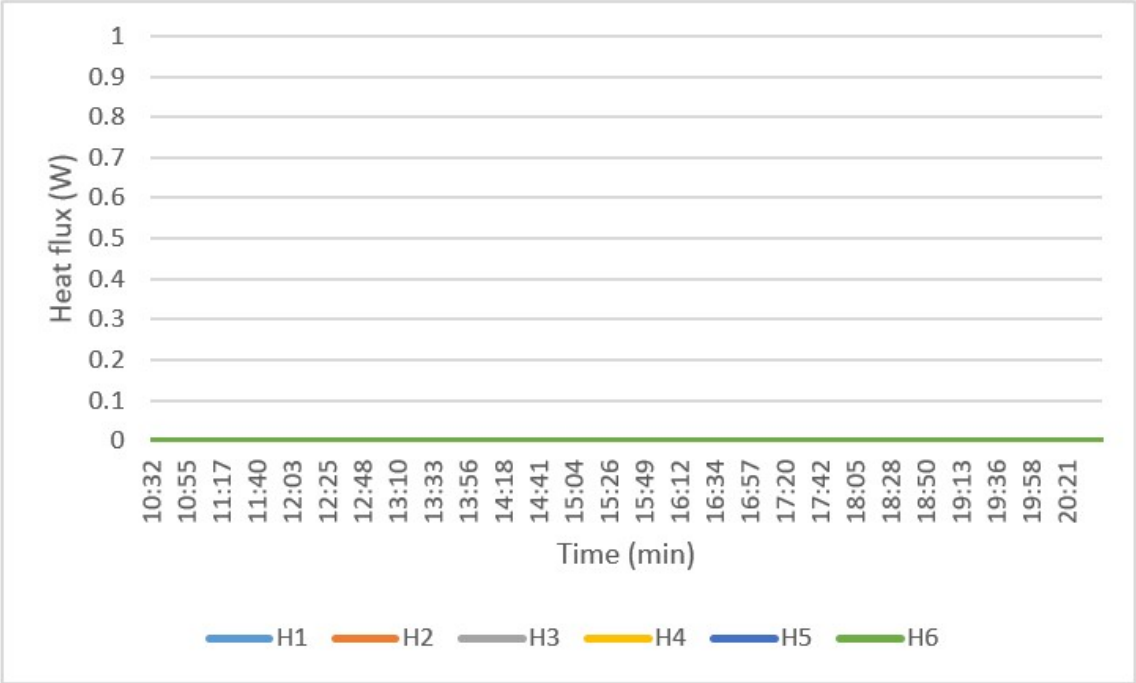


Figure 22. Measured heat flux of target wall and target units



3.7 Chemical heat release rate measurement

The chemical heat release rates were measured by an oxygen consumption calorimeter measurement system consisting of a paramagnetic oxygen analyzer, non-dispersive infrared carbon dioxide and carbon monoxide analyzer, velocity probe, and a Type K thermocouple.

The instrumentations are located in the exhaust duct of the heat release rate calorimeter.

The chemical heat release rate was calculated at each of the flows as follows:

$$HRR_1 = \left[E \times \varphi - (E_{co} - E) \times \frac{1-\varphi}{2} \times \frac{X_{co}}{X_{O_2}}\right] \times \frac{\dot{m}_e}{1+\varphi \times (\alpha - 1)} \times \frac{M_{O_2}}{M_a} \times (1 - X^o_{H_2O}) \times X^o_{O_2}$$

In which:

HRR_t = total heat release rate, as a function of time (kW)

E = Net heat released for complete combustion per unit of oxygen consumed (adjusted for oxygen contained within cell chemistry, 13,100 kJ/kg)

E_{CO} = Net heat released for complete combustion per unit of oxygen consumed, for CO (adjusted for oxygen contained within cell chemistry, 17,600 kJ/kg)

φ = Oxygen depletion factor (non-dimensional), where:

$$\varphi = \frac{X^o_{O_2} \times [1 - X_{CO_2} - X_{CO}] - X_{O_2} \times [1 - X^o_{CO_2}]}{X^o_{O_2} \times [1 - X_{O_2} - X_{CO_2} - X_{CO}]}$$

X_{CO} = Measured mole fraction of CO in exhaust flow (non-dimensional)

X_{CO_2} Measured mole fraction of CO_2 in exhaust flow (non-dimensional)

$X°_{CO_2}$ = Measured mole fraction of CO_2 in incoming air (non-dimensional)

$X°_{H_2O}$ = Measured mole fraction of H_2O in incoming air (non-dimensional)

X_{O_2} = Measured mole fraction of O_2 in exhaust flow (non-dimensional)

$X°_{O_2}$ = Measured mole fraction of O_2 in incoming air (non-dimensional)

α = Combustion expansion factor (non-dimensional; normally a value of 1.105)

M_a = Molecular weight of incoming and exhaust air (29 kg/kmol)

M_{O_2} = Molecular weight of oxygen (32 kg/kmol)

$\dot{m}_e$ = Mass flow rate in exhaust duct (kg/s), in which:

$$\dot{m}_e = C \times \sqrt{\frac{\Delta p}{T_e}}$$

or

$$\dot{m}_e = 26.54 \times \frac{A \times k_c}{f(\mathrm{Re})} \times \sqrt{\frac{\Delta p}{T_e}}$$

C = Orifice plate coefficient (in $kg^{1/2}m^{1/2}K^{1/2}$)

Δp = Pressure drop across orifice plate or bidirectional probe (Pa)

T_e = Combustion gas temperature at orifice plate or bidirectional probe (K)

A = Cross sectional area of the duct (m^2)

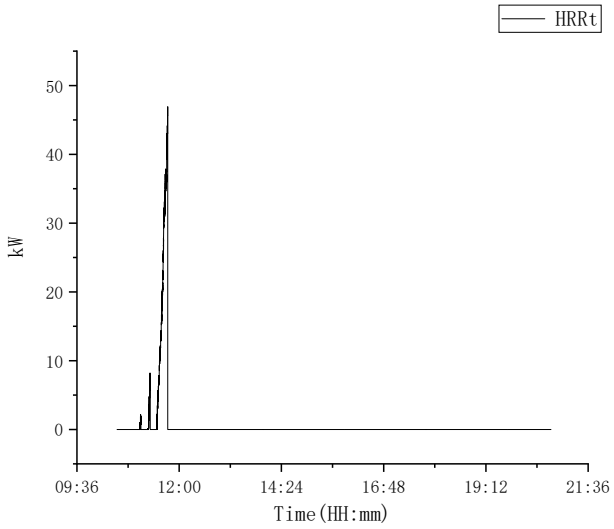
k_c = Velocity profile shape factor (non-dimensional)

$f(Re)$ = Reynolds number correction (non-dimensional)

The heat release rate measurement system was calibrated at 50kW and 70kW heat release rate using a standard propane burner before the test. The calibrations were performed using flows of 1078mg/s and 1510mg/s of propane.

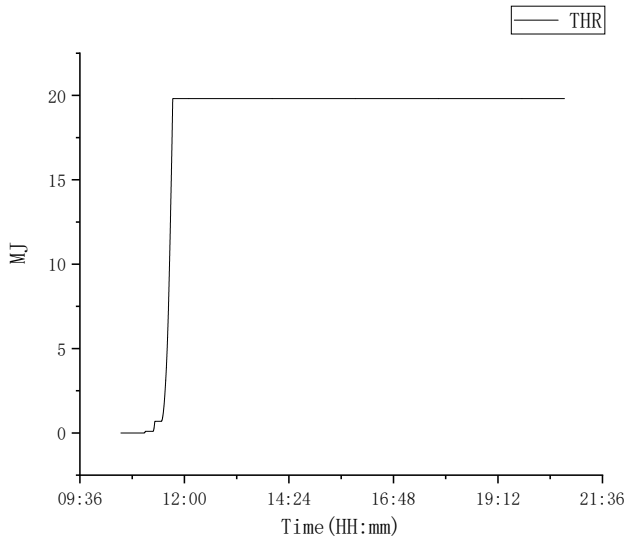
Measured peak chemical heat release rate HRR_t was 46.91kW

Figure 23. HRRt curve



Measured total heat release THR through the test was 19.814 MJ

Figure 24. THR curve



3.8 Convective heat release rate measurement

The convective heat release rate was measured using thermopile, a velocity probe, and a Type K thermocouple, located in the exhaust system of the exhaust duct.

The convective heat release rate was calculated at each of the flows as follows:

$$HRR_c = V_e A \frac{353.22}{T_e} \int_{T_o}^{T} C_p dT$$

Where:

HRR_c = *The convective heat release rate (kW)*

V_e = *The exhaust velocity (m/s)*

A = *The exhaust duct cross sectional area (m^2)*

T_e = *The temperature at the location where exhaust velocity is measured (K)*

$353.22/T_e$ = *The density of air at the velocity measurement location (kg/m^3)*

T_o = *The ambient temperature (K) in the test room*

T = *The thermopile temperature (K)*

$$\int_{T_o}^{T} C_p dT = A_0(T - T_o) + A_1/2(T^2 - T_o^2) + A_2/3(T^3 - T_o^3) + A_3/4(T^4 - T_o^4)$$

Cp = Specific heat of air (kJ/kg-K), given as $\boldsymbol{C_p = A_0 + A_1 T + A_2 T^2 + A_3 T^3}$, where:

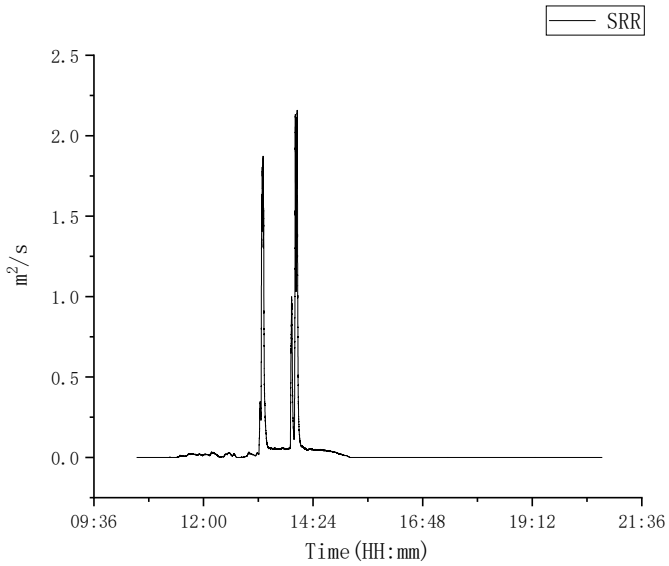
A_0 = *0.9950*

A_1 = *-5.29933E-05*

A_2 = *3.21022E-07*

A_3 = *-1.22004E-10*

Figure 25. Peak smoke release rate SRR: 2.16 m2/s



3.9 Gas generation measurement

The composition, velocity and temperature of the vent gases were measured within the calorimeter's exhaust duct.

Gas compositions were measured using a Fourier-Transform Infrared Spectrometer with a resolution of 1 cm^{-1} and a path length of 4.2 m within the calorimeter's exhaust duct.

The total hydrocarbon content of the vent gas was measured using flame ionization detection.

Hydrogen gas was measured with electrochemical method.

Composition, velocity and temperature measurement instrumentation were collocated with heat release rate calorimetry instrumentation.

3.9.1 Total gas release

The flow rates of various gases were integrated over the test duration and the total cumulative volume of gas calculated for the total test duration (10:32 ~ 20:43) was presented in the below table.

The total cumulative volume of gases before cell venting (10:21 ~ 12:46) was also presented in the table for reference. Which may be considered as ambient gases background before the test.

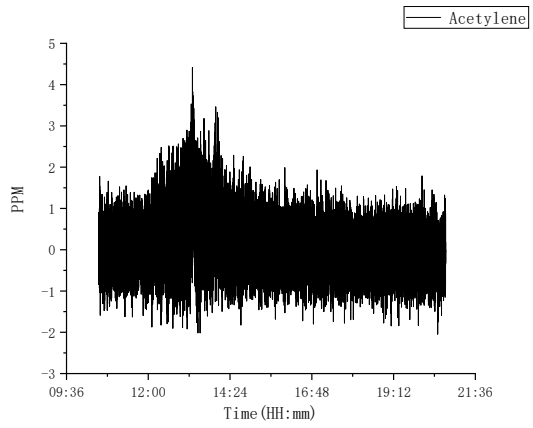
Gas type	Gas components		Total volume of gas (L)	
			Before cell venting	Throughout the test
Hydrocarbon species	Methane	CH4	0	45.5
	Acetylene	C2H2	0.1	6.4
	Ethylene	C2H4	0	35.4
	Ethane	C2H6	0	14.8
	Propylene	C3H6	0	71.6
	Propane	C3H8	0.1	25.5
Hydrogen halide species	Hydrogen Fluoride	HF	0	61.1
Nitrogen containing species	Nitrogen Monoxide	NO	0.1	29.1
Others	Carbon Monoxide	CO	0	152.3
	Carbon Dioxide	CO2	23096.8	80258.1
	Hydrogen	H2	0	466.9
	Oil as octane	--	0	25.3
	Methanol	CH4O	0	69.5
	Diethyl carbonate	C5H10O3	0	5.8
	Ethylmethyl carbonate	C4H8O	0	73.7
	Dimethyl carbonate	C3H6O3	0	362.1
Total Hydrocarbons				363.9

Note:
1) The collection time is from 10:32 to 20:43;
2) The carbon dioxide in the air during this period1) was also counted;
3) Total hydrocarbon gas volume was measured by flame ionization detection (FID);
4) Total volume of carbon monoxide (CO) and carbon dioxide (CO2) was measured using nondispersive infrared spectroscopy (NDIR);
5) The volume of hydrogen (H2) was measured using electrochemical with MODEL5000 sensor.

3.9.2 Gas components

Concentrations of the gases were scaled based on the measured flow rate of the exhaust system and were presented in the standard volume flow rate of gas ventilated in below figures.

Figure 26. Hydrocarbon species



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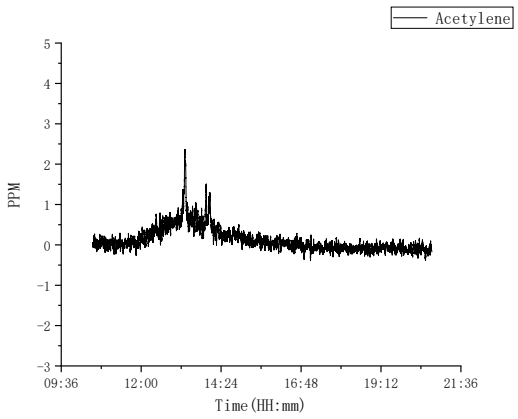
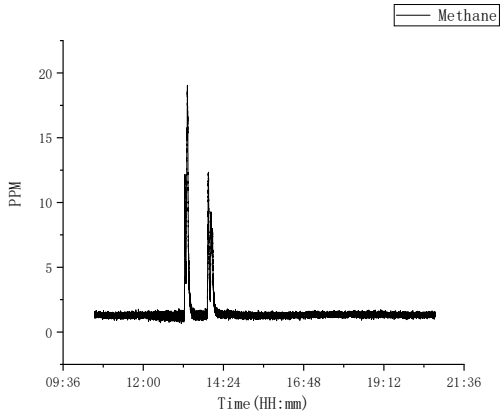


Savitzky-Golay filtered data



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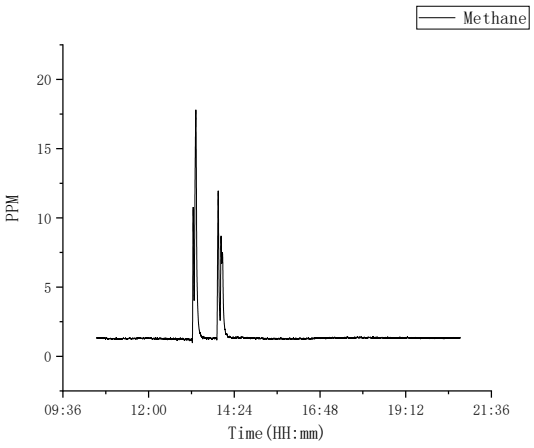

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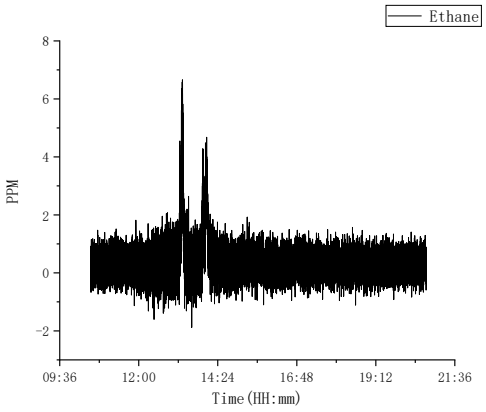

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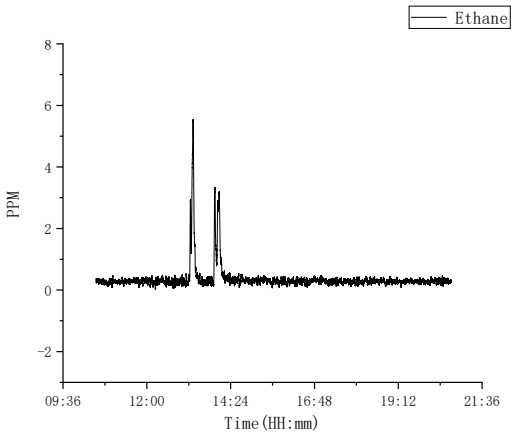

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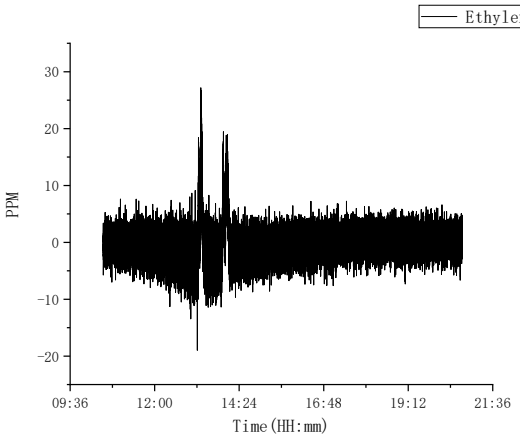

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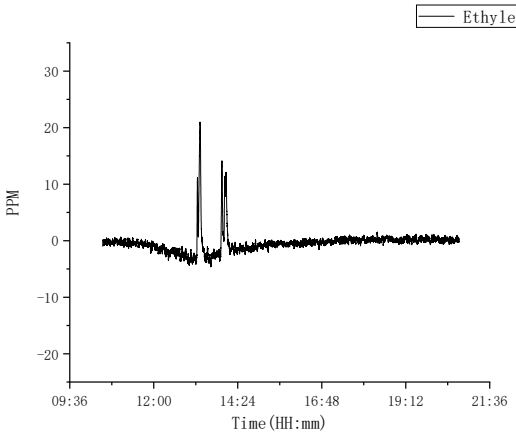

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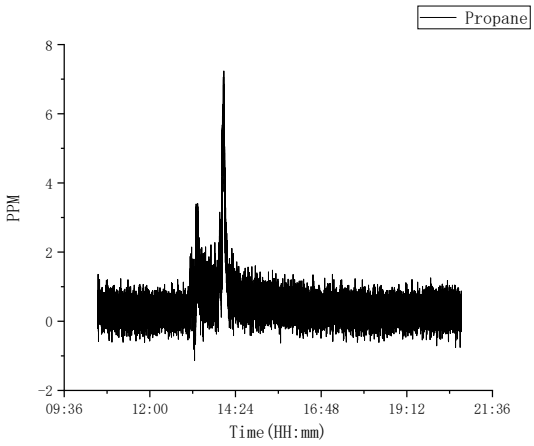

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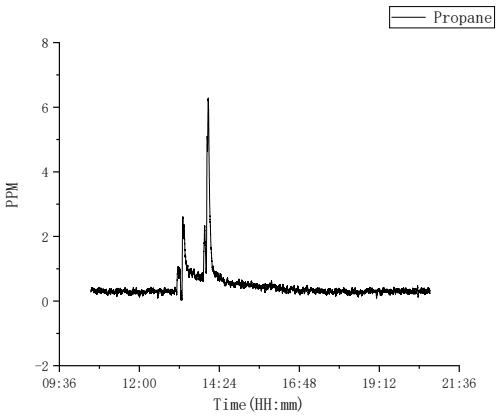

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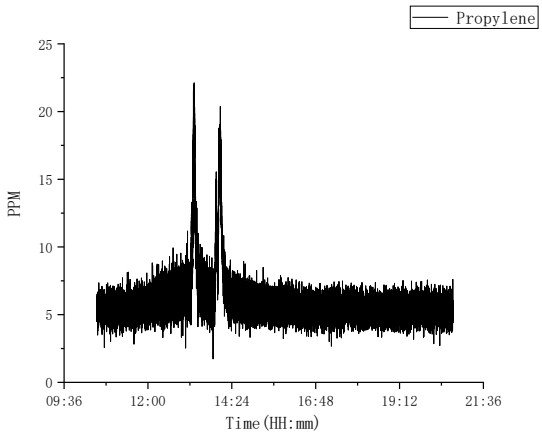

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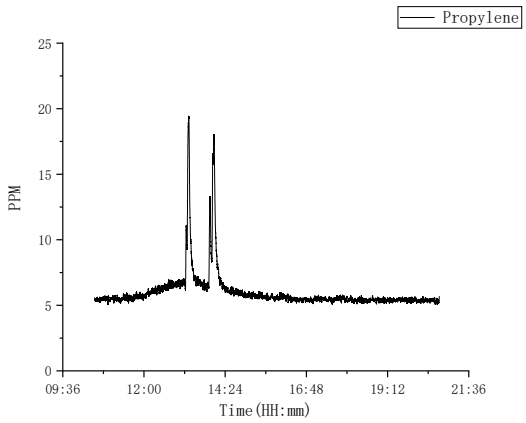
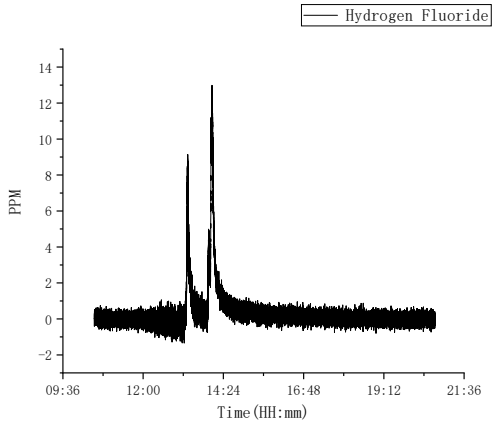


Savitzky-Golay filtered data

Figure 27. Hydrogen halide species



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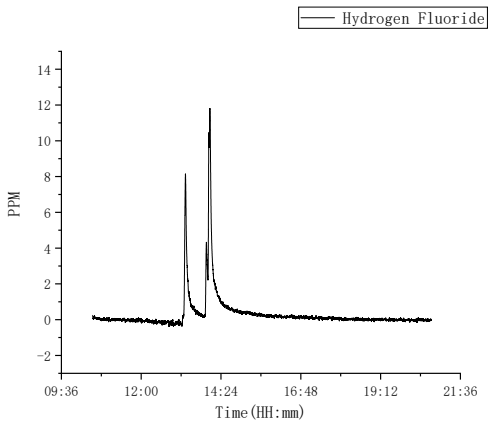
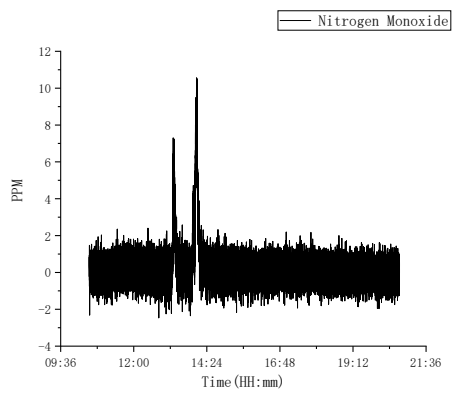


Savitzky-Golay filtered data

Figure 28. Nitrogen containing species



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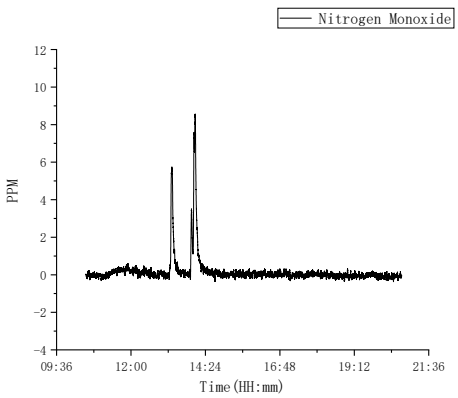


Savitzky-Golay filtered data

Figure 29. H_2 containing species

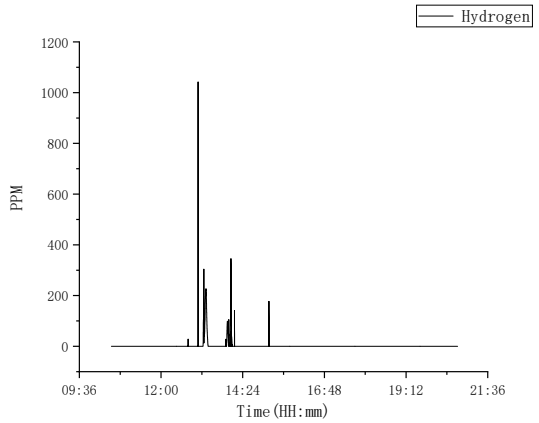
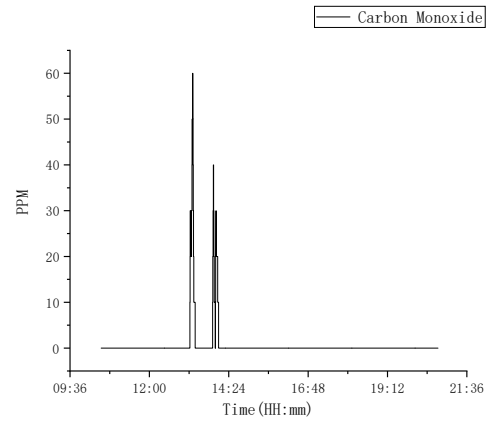
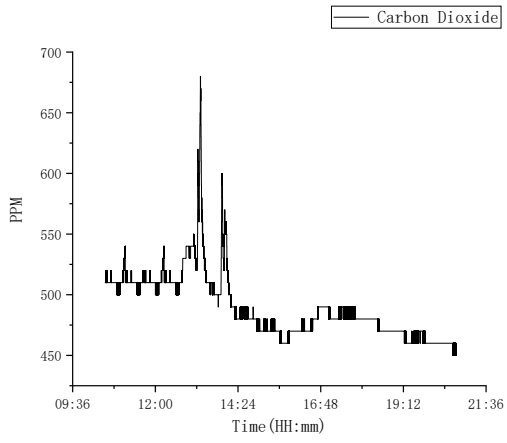


Figure 30. CO, CO_2 containing species

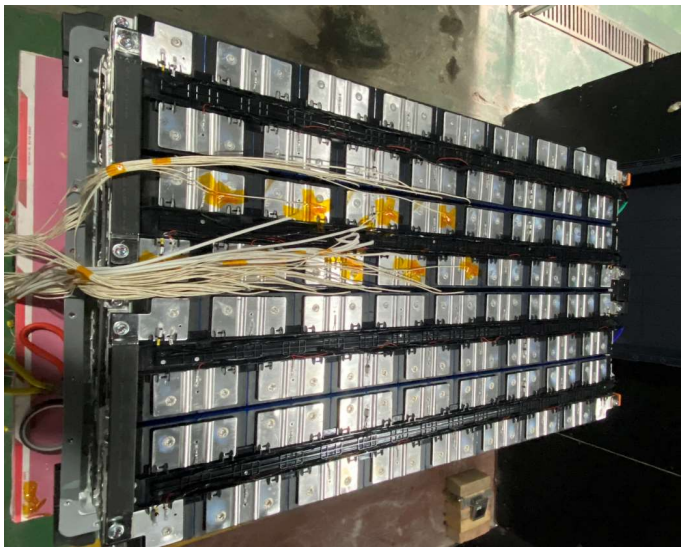




Note: Since raw original data is hard to interpret. Savitzky-Golay filtered data is also provided as this smooths the data and increases the precision of the data without distorting the signal tendency.

3.10 Photos

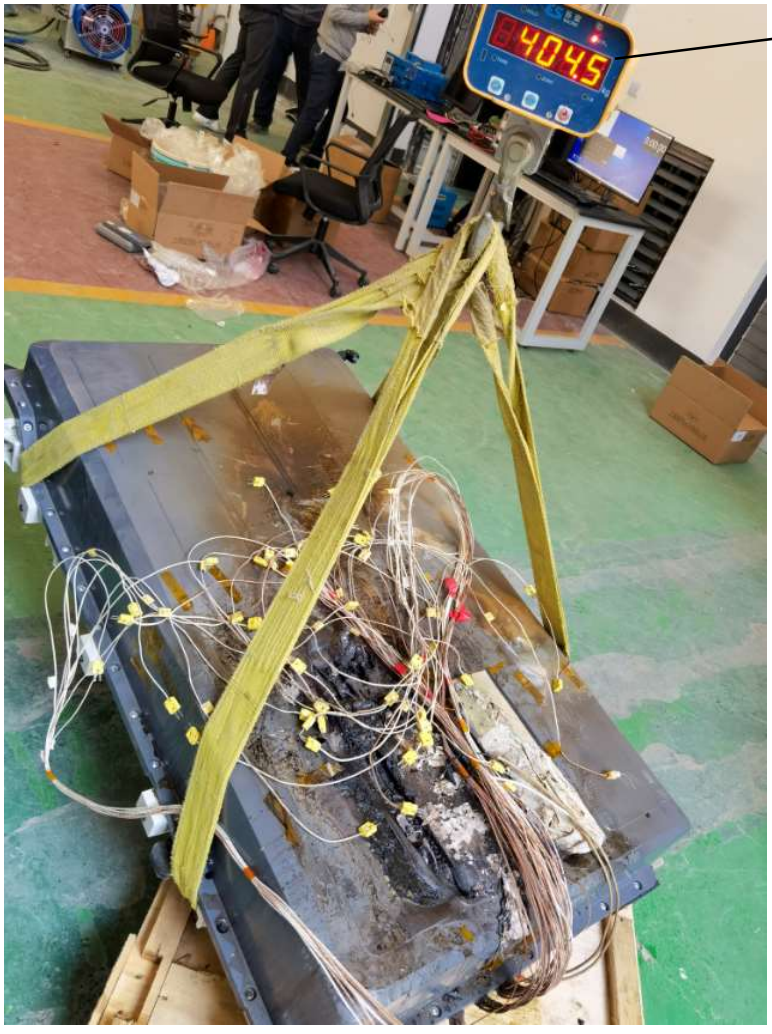
Initial module



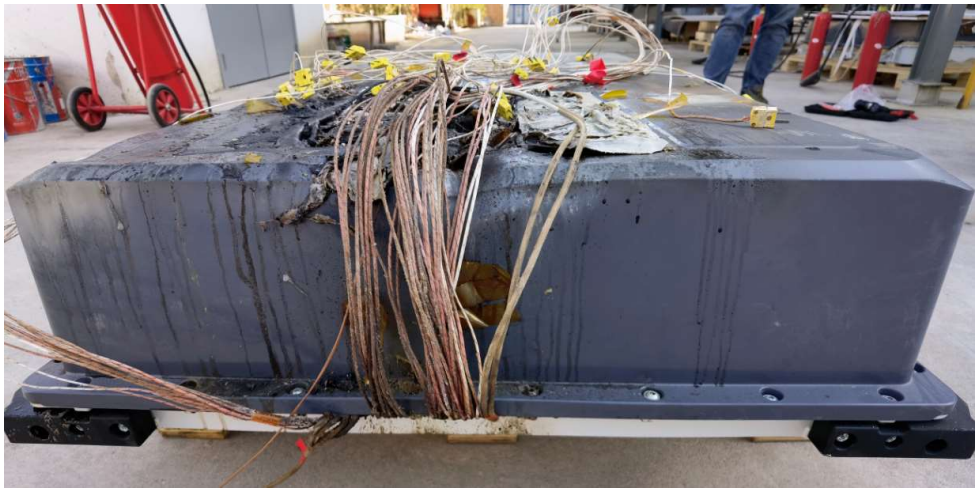
Test setup

Smoke release during the test

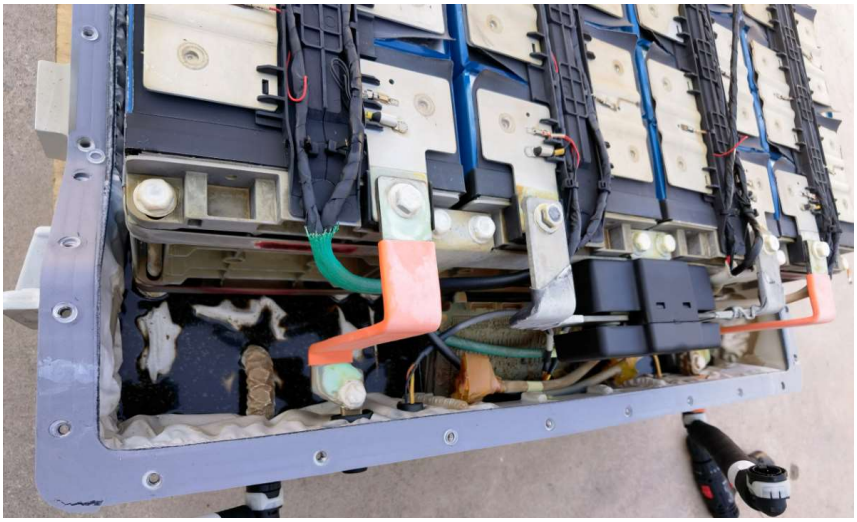
Photos after the test



BAT-
COMM2
IN
COMM1
BAT+
OUT



Initial module after test



4 List of Test and Measurement Instruments

No.	Equipment		Model	Rating	Inventory no.	Last Cal. date
1	Ambient monitor		WSB-2-H1	0-40°C，10-90%RH	T-125	2021.07.24
2	Ambient monitor		WSB-2-H1	0-40°C，10-90%RH	S-050	2021.05.31
3	Data acquisition equipment		DTM	0-1000°C	S-029	2021.04.19
4	Data acquisition equipment		ADAM-4117 ADAM-4118 MT4W DTB4824	0-10V 0-1000°C 0-100V 0-1000°C	S-028-3 S-028-4 S-030-(5~8) S-046-2	2021.04.19 2021.05.06 2021.07.19 2021.07.20
5	Digital multi-meter		FLUKE101	0-600V	S-038	2021.04.22
6	Tape		1000mm 5000mm	0-1000mm 0-5000mm	S-040 S-042	2021.04.22 2021.04.22
7	Electronic scale		TCS-500	0-500kg	S-039	2021.04.19
8	Oxygen consumption calorimeter measurement system	Paramagnetic oxygen analyzer	SERVOMEX MultiExact 4100	O_2: 0-21% CO_2: 0-10% CO: 0-1%	S-024	2021.03.20
		CO and CO2 sensor				
		Velocity probe	WIKA	0~0.4MPa	S-024-5	2021.03.08
		Photo detector	DP101MD	-100~100Pa	S-024-4	2021.03.08
		Light filter	——	25%、50、75%	S-024-6 S-024-7 S-024-8	2021.03.12
9	Palladium-nickel thin-film solid state sensor		H2scan 740B MODEL5000 OMD-650	500ppm-100% 0-4% <20%	S-023-1 S-023-2 S-023-3	2021.03.20
10	Fourier-Transform Infrared Spectrometer		MG6000	0.01ppm-100%	S-019	2021.03.20
11	Flame Ionization Detector		ABB AO2000	0-3000ppm	S-025	2021.03.20
12	Thermopile		OMEGA TT-K-24	0-260℃	S-026	2021.04.01

13	Heat flux measurement equipment	Schmidt-Boelter, 64-5-20	0-50kW	S-031 S-032 S-033 S-034 S-035 S-036 S-037 S-065	2021.06.21

End of Test Report